
Report No: 98/055 CP-RLC
Date: 2 September 1998

AMAZON REGION

**FISHERIES AND AQUATIC BIODIVERSITY
MANAGEMENT IN THE AMAZON**

DESK STUDY

**FOOD AND AGRICULTURE ORGANIZATION OF THE
UNITED NATIONS, ROME**



**INVESTMENT CENTRE DIVISION
FAO/WORLD BANK COOPERATIVE PROGRAMME
IN COLLABORATION WITH THE FISHERIES DEPARTMENT**

AMAZON: FISHERIES AND AQUATIC BIODIVERSITY MANAGEMENT

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ABBREVIATIONS

CONAMAZ	National Council for Legal Amazon, Brazil (Conselho Nacional da Amazônia Legal)
COPESCAL	Commission for Inland Fisheries in Latin America (Comisión para la Pesca Continental Amazónica)
CNPq	National Research Council, Brazil (Conselho Nacional de Pesquisas)
DFID	Department for International Development (United Kingdom)
EDIEN	Environment Unit of the World Bank's Economic Development Institute
ESA	Endangered Species Act, USA
GEF	Global Environmental Facility
IBAMA	Brazilian Institute for the Environment and Renewable Natural Resources (Instituto Brasileiro para o Meio Ambiente e Recursos Naturais)
IIAP	National Institute of Amazon Studies, Peru (Instituto Nacional de Investigaciones de la Amazonia, Iquitos)
INPA	National Institute of Amazon Studies, Brazil (Instituto Nacional de Pesquisas Amazônicas)
IPAAM	Amazon State Environmental Protection Institute, Brazil
MMA	Ministry of the Environment, Water Resources and the Legal Amazonia, Brazil (Ministério do Meio Ambiente, dos Recursos Hídricos e da Amazônia Legal)
MPEG	Emilio Goeldi Museum, Belém (Museu Paraense Emílio Goeldi)
ORSTOM	Institut français de recherche scientifique pour le développement et la cooperation
PPG7	Pilot Program for the Protection of the Brazilian Rain Forest
SAP	Strategic Action Programme
SECTAM	Pará State Environmental Protection Secretariat
TCA	Amazon Cooperation Treaty (Tratado de Cooperación Amazônica)

SUMMARY AND CONCLUSIONS

(i) *The Amazon basin lies within the territories of eight countries. The river system is the largest and most complex on the planet. The extent of its lowland plains means that large areas are subject to flooding for up to eight months, at least once during the year. Two major types of flooded area exist, the varzea of the rich, sediment laden white-water rivers, and the igapo of the nutrient and sediment poor black and clear water rivers.*

(ii) *Fisheries research has been unable to cover the basin fully, either in space or in time. Data collection has concentrated on a few urban centres in Brazil, Bolivia, Colombia and Peru and ignored the large rural market and subsistence sectors. It has also been carried out irregularly, and consistent time series are therefore not available.*

(iii) *The river supports rich and varied fish faunas with an estimate of up to 3,000 species for the basin as a whole. However, many of these remain undescribed. The fish show a series of life strategies related to flooding and essentially comprise three groups: large and long-distance migratory catfish, migratory characins, and species that do not regularly migrate along rivers. Each of these groups requires a different approach in terms of fisheries management and conservation.*

(iv) *Complex fish faunas, such as those of the Amazon, respond to fishing and other environmental pressures by a progressive loss from the fishery of larger, high value species. Smaller, less valuable species then dominate the fishery until, with excessive fishing, the catch is composed of juveniles of only the smaller species.*

(v) *Three main types of fishery exist in the Amazon: food fisheries, fisheries for ornamental species and recreational fisheries. In addition, aquaculture has been studied as an alternative source of supply of valuable species.*

(vi) *The food fishery has three major components: local market and subsistence fisheries mainly for small, less valuable species; urban-based fisheries for larger, more valuable fish; and an industrial fishery in the delta for one species of migratory catfish. The food fishery supplies annually some 420,000 t of fish both for consumption within the basin and for export (1991).*

(vii) *The fishery for ornamental species exports about 30 million fish a year from major centres in Belem, Manaus and Iquitos. This fishery is important economically in localities where few other possibilities for income exist.*

(viii) *The recreational fishery is locally important but still small. It targets large, valuable species at exploitation levels that are unlikely to affect abundance in white waters, although some black-water population might be impacted. Expansion of sport fishing in the future is to satisfy local demand. There are also possibilities for sport fishing associated with tourism.*

(ix) *No fish species appears to be in danger of extinction at present levels of effort. Multi-species yield is well below expected maximum levels. There is an ample supply of animal protein, except possibly in some rural areas distant from varzea floodplains. Nevertheless, there*

are indications that yields of the largest, most valuable species have decreased near urban centres and that the overall production is dominated by smaller, cheaper species. Larger species are still economically significant in floodplain areas far removed from the cities. At the present level of effort, catches still consist of few species and relatively large fish. Most of the smaller species in the basin are still unexploited.

(x) The ability to monitor changes in fish stocks through fisheries data is severely hampered by institutional and resources limitations. Proper mechanisms are needed to monitor annual catch and fishing effort data by species sold in major markets as well as per capita consumption by urban and rural households.

(xi) Existing regulatory systems throughout the basin are inadequate. They are applicable to fishery management for single species stocks that are found elsewhere, but not to multi-species stocks and varied multi-gear fisheries such as those that exist in the Amazon. Costs of monitoring, surveillance and enforcement of existing regulations are prohibitively expensive and impracticable.

(xii) There is no optimum strategy to exploit a multi-species fishery in such a diverse system. Probably only the piramutaba catfish that dominates in the estuarine fishery lends itself to a traditional single species approach using existing models. In other areas a mixed scheme that maintains economic returns from valuable species, yet also caters to the urban markets for less valuable species is essential. A graded exploitation system extending from the cities to large Parks and Reserves is one possible approach to better management.

(xiii) Most full and part-time fishermen do not have the education, job opportunities, or capital to switch or diversify sources of income. Therefore, the main issue among fishermen's groups is how to control the economically valuable stocks, rather than adhere to formal regulations. The corresponding issue for aquatic biodiversity is how to rein in economic and political power exercised by that fishing interests, in order to sustain the appropriate ecosystem services.

(xiv) At present levels of effort the major threats to the aquatic biodiversity of the Amazon system do not come from the fishery but from other, non-fishery activities in the basin. Conservation of biodiversity should not be limited to the fisheries sector but should be aimed at through an integrated approach involving all activities impacting on the aquatic ecosystem. Solutions may lie in systems of transferable fishing rights for stocks of valuable species, involving urban and/or rural-based organizations, and of co-management for the less valuable fish exploited by rural communities.

(xv) The potential of parks and reserves to protect higher vegetation, local catchments, sedentary fish, and some life-history stages of migratory fish should not be underestimated. In the case of migratory species, however, there is a need to protect the habitats at the downstream and upstream ends of the migration as well as the migratory path in between. This tends to be a much greater undertaking involving a wider commitment, and it would be unrealistic to depend on Parks and Reserves alone to protect hydrological regimes and migratory fish stocks.

(xvi) *Policies for the protection of aquatic biodiversity and management of fisheries in the Amazon should draw upon experiences and lessons from other flood plain rivers. Generally the rivers in the temperate zones have been managed in favour of non-fisheries interests and have become degraded. Such errors should be avoided in the tropics although the same developmental pressures are apparent and temptations are strong to follow similar developmental pathways. Some tropical systems, such as the Ganges floodplain in Bangladesh, are experiencing similar problems in developing the fishery while protecting biodiversity. Here a consultative approach, using experiences of similar social and economic nature, would be appropriate.*

(xvii) *The major threats to Amazonian aquatic biodiversity are:*

- *the conversion of varzea floodplain to pasture and crop agriculture;*
- *changes in flood regimes and system connectivity through hydropower dams and navigation channels ('hidrovias'); and*
- *deterioration of water quality through mercury used in gold mining, petrochemical effluents, drug processing wastes and sewage discharges.*

Varzea conversion is the greatest short-term threat, while the most fundamental long-term threat is water-use, principally navigation and dam construction, that reduces biological productivity by altering the floodplain inundation regime and curtails longitudinal and lateral connectivity.

(xviii) *There should be greater emphasis on natural resource management, particularly of water and forests. Fisheries management is important to the extent that the need for continued supplies of fish, particularly high value species, and the economic interests of stakeholders, will influence water- and land-use decisions. It is also vital that urban and rural sectors reach a consensus on the management of the riverine ecosystem in order to integrate the interests of all possible water uses and stakeholders.*

(xix) *A number of measures are advocated to improve fisheries management and aquatic biodiversity conservation in the Amazon:*

- *Institution of exclusive rights to fishing resources – exclusive rights can be designed for different species and regions, especially for stocks of valuable, large species that do not undertake long distance migrations.*
- *Improved fishery management – if exclusive rights are accepted as a basis for management, government agencies should evolve into arbitrators and data management organisations that act as a resource to provide reliable information to all sides in fishing planning and marketing strategies.*
- *Varzea forest protection – major threats to the varzea are intensive ranching and the potential for converting varzea to intensive, single crop agriculture. Possible alternatives that need field experimentation include floodplain farming of native fruits and seeds, the development of plantations to provide high quality food for *Colossoma* in intensive aquaculture units and extensive aquaculture of *Colossoma* in varzea lakes through stock enhancement.*

- *Improved or new fish products – development of techniques to improve the quality of fish and fishery products for sale locally or for export.*
- *Awareness education – any improvements to management and conservation in the basin rest on raising local peoples' awareness of the issues.*
- *Water quality control – better control of water quality is essential to prevent health problems among consumers of fish and to conserve healthy environments.*
- *Economic evaluation – current data limitations point to the need for a systematic and comprehensive effort at data collection and analysis that is required to arrive at an adequate evaluation of current and potential ecosystem services, taking into account the various competing uses of the water and floodplains in the basin.*

(xx) A series of actions are proposed to provide follow-up to this study in the short, medium and long term. These include: dissemination of this report; preparation of a block grant proposal to develop a GEF project; implementation of an eventual GEF project and the formulation and implementation of a Strategic Action Programme (SAP).

(xxi) The report includes tables and an appendix in support of its conclusions. Two further appendices accompany the report, one setting out guidelines for monitoring fish yield, the other describing two opportunities for bilateral collaboration.

(xxii) Basic data used for the study are available in FAO, Rome.

I. INTRODUCTION

1. The following paper presents a general overview of the status of fisheries in the Amazon basin and its relationship to present and future threats to critical habitat in the region. The underlying purpose of this study is to improve the understanding of land-aquatic interactions in the Amazon basin and the effects of current land-use practices have on the long-term sustainability of fresh water biodiversity and fisheries in the regions. This desk study¹ is based on a literature review and also incorporates unpublished communications from several professionals working in the basin. The study was prepared in collaboration by FAO and will serve as an input in a meeting of stakeholders tentatively scheduled for November 1998 to begin discussions an integrated approach to the long-term sustainable development within the River Basin. This is turn may lead to a development programme focusing on sustainable land uses, including subsistence and commercial fisheries, in the floodplain forests along the Amazon River.

2. This study highlights major fishery issues in the basin. Urban-based, rural-based, and export fisheries in the basin are dominated by Brazil and Peru. Due to this factor, and time limitations, and information available, local aspects of fisheries in other Amazon countries are not covered in detail.

3. Also, this paper deals primarily with technical issues. Nevertheless, it does indicate some key policy, institutional, regulatory, economic and social issues related to fisheries and aquatic biodiversity. Non-technical issues of particular concern are highlighted in the text.

4. Following a brief description of the basin environment and the ecology of Amazonian species, the institutional framework for administration and research is described in Chapter II. Current fisheries, with an update on total fishery yields, are presented in Chapter III. A brief overview of existing fishery regulations, their enforcement and relevance (Chapter IV), is followed by a discussion of the relationship of fisheries to aquatic biodiversity in the context of current management and conservation programmes (Chapter V). Major issues and threats affecting aquatic biodiversity are described in Chapter VI. Finally, a set of recommendations, in the context of experiences in other systems and constraints within the system, is combined in a proposed outline for a future action plan (Chapter VII).

A. Description of the basin

5. The Amazon basin, including the R. Tocantins, covers close to 7×10^6 km², of which about 58% lies in Brazil, 16% in Peru, 10% in Bolivia, and the remaining 16% in Colombia, Ecuador and Venezuela (**Map 1**). Most of the basin is flat, forming a Tertiary peneplain above maximum flood levels lying between granitic shields to the north and south, and the Andes to the west. The bulk of nutrients and recent sediments are derived from the large, turbid, white-water

¹ The desk study was prepared by the FAO Consultant Dr. Peter Bayley (Oregon State University). A FAO team comprised of Mmes/Messrs. Katia Medeiros, Devin Bartley, Random DuBois, James Kapetsky and Loretta Sonn also contributed. Stefano Moretti provided assistance in literature review and summary. Finally, Dr. Robin Welcomme (FAO Consultant) reviewed and edited the document.

rivers rising in the Andes. These include the 4,000 km long Ucayali/Marañon-Amazonas-Solimões-Amazonas mainstem, and the Beni/Mamore, Madeira, Purus, Juruá, and Putumayo-Içá rivers, which contain the richest floodplains (várzea)¹. Other large black or clear water tributaries, including the R. Negro, Tapajós, Xingu, and Tocantins are low in nutrients and are associated with diverse forested floodplains (igapó)².

6. The basin discharge contributes 20% of the world's river flow. It results from high precipitation ranging from 1.6 m.yr⁻¹ in the eastern basin to several meters per year near the lower Andes. Discharges are seasonal with a pronounced flood that lasts for several months. The flood is maximal in May at Obidos (Brazil) and somewhat earlier at sites upstream. This flood pulse is the major conditioning factor for the biology and ecology of the Amazon system as it spills over from the main channel to inundate adjacent low-lying areas. Areas of regularly flooded floodplains are moderately large in the central basin and very large in geosynclinal regions in Bolivia and Peru. Goulding and Ferreira (in press) suggested that some 300,000 km² of floodplain are associated with the larger rivers. A conservative, 180,000 km² estimate of várzea floodplain (Bayley 1989) excludes the significant low-nutrient swamps dominated by the *Mauritia flexuosa* palm, that occupy, for example, a third of the total floodplain area in the Peruvian Amazon (Bayley 1981a).

7. The human population associated with Amazon fish consumption and fisheries was estimated at 12.1 million³ for 1991 (other estimates, based on different criteria and including large populations near the basin periphery, range up to twice this estimate). The basin supports a diffuse rural population, which includes indigenous peoples (numbering some 326,000 persons, distributed among 215 ethnic groups in Brazil alone), recent immigrants, a large mestizo population resulting from earlier immigrants, and former riverine native groups. Several major urban centres exist in the basin, particularly Belem (1,300,000 inhabitants) near the mouth, Manaus in the centre of the basin, and Iquitos (350,000 inhabitants) in Peru (large urban várzea). Migration to the cities is increasing. For example, the population of Manaus was estimated at 1.5 million inhabitants in 1996 (Araujo-Lima and Goulding 1997) which is equivalent to a mean 8.7% annual increase since 1991. A number of smaller urban centres are distributed along the river particularly in Brazil and Peru (small urban varzea). Products of the fishery also reach areas of the countries lying outside the Amazon basin (non-várzea) through export.

B. General principles

8. Certain basic principles, derived from studies on the Amazon itself, and on other rivers throughout the world are important in understanding fisheries and aquatic biodiversity management in the Amazon.

¹ Várzea is a regional term synonymous with floodplain for productive, turbid, white water rivers .

² Igapó is a regional term synonymous with floodplain for black and clear water rivers; clear water rivers carry little sediment and are poor in nutrients. The igapo has soils that consist basically of quartz sand (low erosion) together with partially decomposed organic matter from forests that dyes the water to produce the classic black water rivers.

³ See Table 6 in Chapter III.

Structure of the river

9. The Amazon River, in common with most lowland rivers around the world, consists of two components, the river channels and the floodplain. The channels are the main conduit for river discharge and retain water throughout the year. The floodplain, including most islands, is a complex of seasonally inundated land forms containing numerous seasonal lakes and connecting channels, many of which retain water in the dry season.

Biology of fish species

10. The combination of tropical latitude, rain forests, and a variety of water/land interfaces results in an unparalleled biodiversity, much of which is associated with floodplain forests (Goulding and Ferreira in press). Because of the complexity, extent and inaccessibility of the region, much of the biodiversity remains undescribed. Fish taxonomy is incomplete although the current consensus suggests between 2-3,000 species may exist in the basin, most of which are endemic.

11. The biology and ecology of the fish species depend on the flood cycle. Most fish move to the floodplain during the floods to benefit from the abundant living space, shelter and food. Reproduction is highly seasonal and aims to place the young fish on the floodplain at the beginning of the floods. Fish move off the plain or to permanent floodplain waterbodies during low water to shelter from the often hostile conditions over much of the system. In general, the 2000 or more species from the Amazon fall into three general classes with regard to life styles (**Appendix 1**):

- large and long-distance migratory catfish;
- migratory characins; and
- species that do not regularly migrate along rivers

12. Each of these categories relates to broad types of fisheries operating in different habitats and/or markets, and hence require differences in management approach. Specific management and conservation needs for species or groups of special importance would fall within the respective approach.

Fish assemblage response to fishing and other environmental stress

13. Multi-species fisheries, such as those of the Amazon, respond to increasing fishing pressure and other environmental stresses in a characteristic manner. As pressure on the assemblage of fishes increases, the larger species tend to disappear from the catch and be replaced by smaller faster growing ones (**Figure 1**). This process continues with increasing pressure until in heavily exploited fisheries, such as those of Bangladesh, the catch is drawn almost wholly from young-of-the-year of the smallest species.

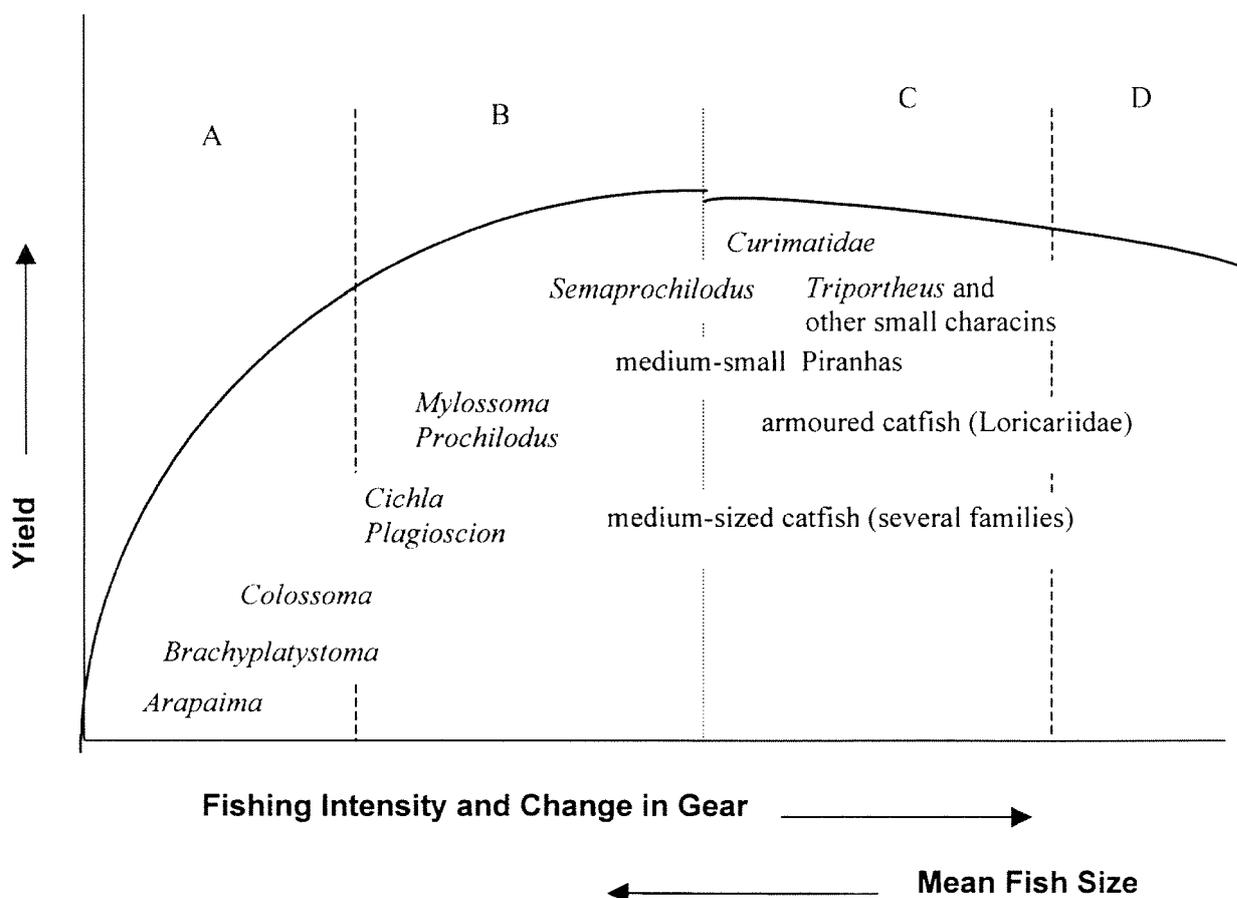


Figure 1. The fishing-down process in multi-species food fishery, with some dominant species or groups from the Amazon fisheries (see Appendix 1 and para. 55)

14. Classical concepts of overfishing, derived from single species fisheries, are difficult to apply in multi-species assemblages of this type. Individual species may become overfished and disappear from the catch according to classical population dynamics models, but the yield from the assemblage as a whole tends to remain the same. The concept of community overfishing is used to describe situations where the total off-take from the fishery falls below the level of sustained catch or where the assemblage becomes non-functional due to the loss of important elements. As river fisheries are extremely resilient, provided the natural flood regime is maintained, cases of community overfishing world-wide are extremely rare.

II. ADMINISTRATION AND RESEARCH

15. The Amazon basin lies within the jurisdictions of eight South American countries. Each country has different mechanisms to deal with the region. Initially the various countries adopted independent approaches to the management of their common resource but in 1978 they signed a treaty for co-operation in all major sectors including natural resource management and conservation. Until recently there has been a policy among all countries of the basin to designate one organisation to promoting the development of fisheries while at the same time taking responsibility for monitoring, control and enforcement of fisheries regulations. Experience over

much of the world has shown this to be ineffective as the fishermen come to view such agencies as organs of repression and do not collaborate in the vital task of information gathering.

16. Documentation on the complete administrative and research structure is not available for all countries so the following section describes the situation in Brazil as an example of the complexities throughout the basin. The lack of a compendium of detailed information on institutions and programmes from all countries of the Amazon basin should be rectified through a further study.

A. Administration

Regional organisations

17. Two regional organisations have some responsibility for the Amazon basin.

i) The principal organisation is the Amazon Co-operation Treaty (TCA). Brazil, Colombia, Ecuador, Bolivia, Peru, Surinam, Guyana and Venezuela signed the TCA in 1978 as a response of the special needs of the basin including common or transboundary fisheries and environmental problems.

ii) The Commission for Inland Fisheries in Latin America (COPESCAL) was founded by FAO in 1979 in response to the need of the countries of South and Central America for a forum in which to discuss common problems on inland fisheries. The Commission has two regional sub-commissions, one on the la Plata basin the other on the Amazon.

18. In addition to the two regional organisations that have international legal status, a number of programmes and non-governmental institutions with regional scope have been created in the last few years. These include the Association of Amazonian Universities (UNAMAZ) and the Forum Belém, both relevant to improve co-operation on research, technical assistance and training within the Amazon region.

National organisations

19. The major agencies responsible for fisheries development and management in the various countries are shown in **Table 1** (provisional list).

Fish and fisheries administration in Brazil

20. The Government of Brazil's (GOB's) approach to environmental protection and fisheries management has been mainly to share responsibilities between central and state governments. Nevertheless, since the 1988 Federal Constitution, these responsibilities were also given to the municipal governments. As a result, a number of municipalities, including some in the Amazon region, have assumed responsibility for environmental protection and fisheries, and incorporated them in their 1990 Municipal Constitutions (MCs). Regarding fisheries in the Amazon, some of these MCs are particularly focused on issuing or endorsing fishing agreements and on controlling access to fishing resources in the floodplain lakes by assigning exclusive

exploitation rights to rural communities (local market /subsistence), excluding the urban-based fisherman¹.

21. At central government level, the primary responsibility for environmental and fisheries matters rests with the Ministry of Environment, Water Resources and the Legal Amazonia (MMA). The Autonomous Institute for the Environment and Renewable Natural Resources (IBAMA) is the national body, within the MMA, that is responsible for assessment, monitoring and control of aquatic biodiversity and fisheries, as well as for promoting the development of fisheries.

22. Brief descriptions of the major institutions that are responsible for fisheries and environmental management in the Brazilian Amazon are presented in **Table 1**. A provisional list of main fisheries institutions for all the other Amazon countries is also presented in this table.

23. In addition to the existing Brazilian executive institutions a new national body, the National Council for Legal Amazonia (CONAMAZ), was created to play a central role in policy planning and serve as the major focus for the implementation of Agenda 21 in the region. This body groups the entire senior hierarchy of the federal and state governments of Amazonia, as well as the President of Brazil. The major policy statement approved by CONAMAZ is the 1995 Integrated National Policy for the Legal Amazon.

Major related projects in the Brazilian Amazon

24. A number of programmes and projects that contribute either directly or indirectly to the improvement of fisheries management and/or conservation of aquatic biodiversity are currently being implemented by the MMA, IBAMA, state environmental agencies, NGO's, private sector and grass-root organisations of Brazil. The results of a survey carried out in 1995 indicate that there are a large number of projects on environment (with some specific to fisheries) in the Brazilian Amazon (**Table 2**). A list of relevant past, on-going and planned projects on natural resources management financed by the World Bank and/or other development agencies is presented in **Table 3**. Some of these projects have been rather successful and have provided lessons on best practices for World Bank assistance in environmental matters.

Pollution and environment

25. The federal government of Brazil has stressed decentralisation of government services in a number of areas (health, sanitation, education, etc.). However, the 1988 Federal Constitution mandates federal-state and federal-municipal revenue transfers without requiring States and Municipalities to assume clear and detailed responsibilities for delivery of services. This is also true in the environmental field.

¹ **Institutional and legal issues.** The fishing agreements in the Brazilian Amazon, although already in place, are not automatically endorsed by the federal government (IBAMA), who questions not only their principles (e.g. exclusive exploitation rights to rural fisheries) but also the agreements' legality. Nevertheless, IBAMA's current approach to this problem seems to consist in the analysis of existing agreements followed by a possible endorsement that would include certain requirements to be complied by the fishery communities, e.g. the need for systems of transferable fishing rights for urban fish and co-management for rural ones.

26. Until about 1994 federal environmental strategies focused largely on green issues and were largely reactive to external pressures, which at that time became increasingly oriented to issues of domestic and especially urban pollution. The GOB has now officially adopted a policy of sustainable natural resource development and decentralisation of environmental management. Since the 1992 UNCED Conference, progress has been achieved in managing pollution in selected watersheds, strengthening the management of conservation units, sharing responsibility with State environmental agencies, improving dialogue with the private sector on environmental management, and stimulating greater interest in the use of economic instruments for environmental protection. Regarding pollution and aquatic resources management in the Amazon, this policy has yet to be translated into action.

B. Research and related issues

27. Research on the fish and fisheries of the Amazon basin has been very patchy and discontinuous. The major centre for biological investigation has always been at and around the Instituto Nacional de Pesquisas Amazonicas (INPA) in Manaus (Brazil) with lesser investigations on the Amazon and Negro rivers branching out from there. Considerable work, particularly on the piramutaba and other major catfishes as well as on fish systematics has been based at the Museo Paraense Emilio Goeldi in Belém (Brazil) and local research on biological, social and economic issues is now being carried out from Santarém (Brazil).

28. In Peru almost all research has been based in the Instituto Nacional de Investigaciones de la Amazonia in Iquitos (IIAP). This programme was initially supported by the FAO and UNDP field programme but has since become a national institute. Some work has also been carried out on parts of the Colombian Amazon by INPA (Colombia) and on the Mamore in Bolivia from Trinidad. French bilateral aid through Institut Francais de Recherche Scientifique pour Le Developpement et la Cooperation (ORSTOM), and United Kingdom bilateral assistance, through the Department for International Development (DFID), supported much of the work on the Bolivian Amazon. Specific studies have also been carried out in various countries as impact assessments during the planning phases and after the construction of dams. Examples of the range of projects currently being implemented are given in **Table 3**.

C. Data collection and information gaps

29. Statistical data collection has been limited to the major urban fish landings in Brazil and Peru and has on occasions been interrupted for financial and organisational reasons. Gross landing statistics are reasonably continuous at several sites in the two countries as well as overall estimates from Bolivia but detailed breakdowns of catch by species are less complete. Data collection in the other countries of the basin has not been systematic although some figures are available for Leticia in Colombia. Given the size of the basin, its diversity and the numbers of rivers involved the research effort has been small. Furthermore, given the international character of the basin, international collaboration in research and data exchange has been slight and limited mainly to mechanisms such as the FAO COPESCAL and, more recently the Pro Tempore

Secretariat of the “Tratado de Cooperacion Amazonica”. As a result of this lack of international focus common approaches to management among basin states has been totally absent.

III. CURRENT STATUS OF AMAZON FISHERIES

30. Three major fisheries are carried out in the Amazon:

- A) food fisheries;
- B) fisheries for ornamental species and
- C) recreational fisheries.

31. In addition to these capture based activities, research and development in aquaculture indicate that this activity might be of paramount importance as a possible means of increasing production of some commercially valuable species in the long term.

A. Food fisheries

32. Three major categories of food fishery can be distinguished:

(1) Local market/subsistence¹: small, usually individual rural-based units that fish for what they can sell and for family consumption using gillnets, cast nets, hook and line, and many other single-person methods from canoes. Some live around urban centres and some sell to ice boats, often under an informal contract. Fishing by indigenous peoples falls into this category

(2) Urban-based units¹: mostly boats with ice boxes (significant salted-dried fish are prepared and traded in Peru) and several canoes for fishing, that sell cheap and expensive fish in large urban centres, and small quantities to refrigeration units for export from the basin. Methods, usually operated from larger canoes, include large lampara seines and very large beach seines, gillnets, and deepwater drifting gillnets or longlines for large catfish in main channels.

(3) Industrial¹: large ice boats and pair trawls used in estuary for large catfish (see first group, **Appendix 1**) for urban consumption and export from the basin. The influence of the Amazonian plume is felt for several hundred kilometres around the estuary and freshwater species are found in what would otherwise be a marine environment. However one fishery, that for the migratory catfish *Brachyplatystoma vaillantii* (piramutaba) is so important as to justify a classification of its own.

¹ Artisanal is an adjective frequently used to describe fisheries based on canoes and simple fishing gear. In Amazonian fisheries the term is not useful to distinguish among fisheries, because artisanal techniques are used throughout the basin for subsistence, to supply local markets (1) and large boats with ice-boxes bound for cities or refrigeration units (2). An exception is in the estuary where the fishery involves large pair trawls (3). The term ‘commercial’ is absent from the above classification. Among food fisheries, it would be misleading to omit the adjective from (1) because there are few fisherman who are not interested in selling or bartering at least some of their catch, while there are a few urban-based fishermen (2) who do not also fish for family needs. In addition to (3), the term ‘commercial’ is often used for urban-based fishermen (2) who have larger fishing gear and depend more on selling their catch ‘Commercial’, therefore, should be regarded as a relative term.

33. These three types of fishery tend to exploit different elements of the fish population but act together on the total stock. The recreational and ornamental fisheries do not remove sufficient fish overall to affect the total statistics.

Estimation of yields

34. Available landing statistics from the various countries (Barthem, Guerra and Valderrama, 1995) indicate catches as follows: Brazil – 139,342t (1987, Amazonas and Para only); Peru – 13,993t (1992); Bolivia – 2,729 (1992); and Colombia – 4,087t (1992). The total yield from the basin can not be accurately derived from these figures. Data is only collected episodically from the major urban centres (particularly for Type 2 and Type 3 fisheries) and omits the numerous small markets and the widely practised subsistence fishing in the basin (Bayley and Petrere 1989). The significance of under-reporting from rural areas appears to have continued despite recent trends in urban in-migration, in part, due to the greater *per capita* fish consumption in rural populations, particularly in the várzea (**Table 4**).¹ Difficulties in deriving accurate yield estimates are further exacerbated by inefficient monitoring systems particularly when faced with the increasingly complex marketing systems characteristic of rapid urban growth in the region. As a result, an arguably more reliable approach was adopted to estimating total yield based on aggregating consumption and export data (**Tables 5 and 6**).² Applying this methodology to the three types of food fish, Type 1 and most of Type 2 fisheries are included in the consumption-based estimate, while exports consist of a small percentage of Type 2 and all of Type 3 fisheries.

35. Because recent estimates of population and export yields have not been compiled, the yield was estimated on the basis of Brazilian and Peruvian 1991 census data (Bayley et al. 1992). Data for estimated *per capita* consumption were subsequently stratified by várzea city size. **Table 4** shows estimates of annual yields by population class in Brazil.

36. Exports (**Table 6**) from the basin are dominated by large, migratory catfish which have been averaging 20,000 t/year since the early 1990s. This figure is based on the Belem piramutaba fishery (10,000 t year⁻¹); exports from Amazonas State (5,400 t year⁻¹; Barthem and Goulding 1997) and upper Brazil (4,000 t year⁻¹); Leticia, (Colombia); Iquitos and Pucallpa (Peru) and some 600 t year⁻¹ from Trinidad (Bolivia). In addition, small but unknown quantities of *Colossoma* are exported to cities in southern Brazil.

37. The increase in yield from the 200,000 t estimated for 1980 by Bayley and Petrere (1989) to the 420,000 t for 1991 in **Table 6** is not as dramatic as it may appear. Although human population has increased over this period, the earlier estimate lacked the high consumption rates that have since been estimated for Brazil's rural varzea (**Table 4**).

38. Given the conservative estimate of total várzea area of 180,000 km² (Bayley and Petrere 1989), the average yield is only 24 kg/ha/year. This is much below typical yields for

¹ One can note an inverse correlation between size of urban population and fish consumption (see Table 4). This can be partly explained by a decrease in fish consumption among the urban population due to the increased availability of chicken that competes with intermediate valued fish.

² For the purposes of the present paper, yield estimates were based on consumption rates estimated from various sites in the basin (Table 4). Populations inhabiting the periphery of the basin (e.g. La Paz, Santa Cruz) where local production from Amazon tributaries is negligible and the consumption of fish low were excluded from the analysis (see **Appendix 2** for more detail).

African and Asian floodplain rivers (Welcomme 1985). It is also below the projected maximum of 125 kg/ha/ year for tropical river-floodplains (Bayley 1988a) which approaches the 180 kg/ha/ year being reported in Bangladesh floodplains (Ian Payne, MRAG, pers. communication). Locally, yields near major Amazon cities are higher. For example an estimate for catch rates in the Manaus area, based on the data used to compile **Table 4**, was about 80 kg/ha/y. This estimate presumes that the approximately 6,000 km² of maximum várzea floodplain of the R. Solimoes between Ilha do Careiro and R. Purus mouths provided the total landings for Manaus city and adjacent areas. This indicates that increased fishing pressure may not result in greatly increased yields.

High-value species

39. Monitoring of landings of high-priced species in major urban markets¹, albeit intermittent because of budgetary constraints, provides a rough resource indicator of fisheries status. It also acts as a check on the results obtained from the application of multi-species models to calculate total yield. Although only 30% of the total Brazilian yield consumed in the basin comes from major cities and their associated rural districts (**Table 5**), yields from Type 2 and 3 fisheries, along with exports, contain a number of large, high-priced (US\$2-4/kg retail) species. These include *Arapaima gigas*, *Colossoma macropomum*, *Brachyplatystoma flavicans*, *B. vaillantii*, that are uncommon in small markets (**Appendix 1**). While the results obtained from the multi-species model adopted above appears to indicate that yields are well below sustainable maxima, available data for a few selected high-value species suggest only partial support for this conclusion.

40. *Arapaima gigas* (pirarucu/paiche) has been the most sought after species since before the rubber boom (Verissimo 1895), and continues to fetch the highest prices of all Amazonian species. However, actual or perceived enforcement of regulations on *Arapaima gigas* in Brazil and Peru has led fishermen to under-report its yields in recent decades. An analysis of *Arapaima gigas* data from Peru (Bayley et al. 1992) indicated a remarkable consistency in mean individual weight, which showed no trend to increase or decrease, between 61 and 82 kg over five decades. Apparent reduction of known catches is partly due to under-reporting, and was assumed to be partly due to growth overfishing² of this very fecund fish (Bayley et al. 1992). However, adults rear a limited number of young, are easily harpooned and are very large top predators (50% maturity at 180 cm, maximum lengths ca. 275 cm). As a result the species has disappeared from individual lakes and may become locally rare. However, dispersal migrations among lakes and along rivers are frequently reported. This factor, plus the maintenance of the floodplain and its

¹ For example, Petrere 1978b; Petrere 1978a; Hanek 1982; Petrere 1983; Tello 1995; Isaac and Ruffino 1996; and Barthem and Goulding 1997.

² 'Growth overfishing' occurs when a stock is exploited such that yield in weight is below the maximum due to exploitation of the stock before its optimum net weight is realised. Recruitment of new fish into the exploited ages groups is unaffected. Correction to increase the yield can be obtained quickly by reducing effort and/or increasing minimum age or size exploited. 'Recruitment overfishing' occurs when exploitation reduces the spawning stock of adults to a level when the average number of recruits entering the fishery is reduced. Failure in recruitment from overfishing or other causes can result in a population 'crash', from which it takes a long period to return to normal biomass levels. Growth overfishing can develop into recruitment overfishing, especially with intense fisheries on stocks of limited fecundity or nursery production.

higher vegetation and high growth rate, probably account for the remarkable persistence of this species that still provides major urban markets with 1-3% of its landings.

41. Large migratory, piscivorous catfish live almost exclusively in the turbid river channels, several species of which are known to extend from the estuary to Peru, Bolivia, and Colombia (Barthem and Goulding 1997). Since the 1970s the advent of deepwater drifting gillnets in main channels and pair trawls in the estuary, and the opening up of markets in Para, southern Brazil, and Colombia, resulted in significant increases in catch. These have since decreased over the last ten years (Barthem and Goulding 1997).

42. The fruit-eating tambaqui (Brazil) or gamitana (Peru), *Colossoma macropomum*, is the largest non-piscivorous Amazon fish. It has been the most sought after species during the past three decades since lampara and gill nets have been employed in the river and várzea respectively (Araujo-Lima and Goulding 1997). During the late 1970s it formed 44% of Manaus fleet landings by weight (Petrere 1978a). During the 1980s and 1990s its total yields became depressed and the stock showed all the signs of growth overfishing (Isaac and Ruffino 1996) with market dominance by immature individuals. The detritivore, jaraqui (*Semaprochilodus spp.*), became the dominant genus (Merona and Bittencourt 1988) in the Manaus landings by the mid 1980s.

43. Type (2), urban-based fisheries have now become dominated by a suite of detritivores (mainly *Prochilodus*, *Semaprochilodus*, and *Curimata spp.*) and several omnivorous characins (**Appendix 2**), that are also still a staple of local markets and subsistence (type (1)) fisheries. Like tambaqui, these species are highly fecund, fast-growing, migratory characins, but depend on a more widely available floodplain food source. There are signs that the largest detritivore, *Prochilodus nigricans*, is close to a state of growth overfishing in the Ucayali R., Peru (Tello and Montreuil 1991).

Economic Value

44. Fish prices vary enormously by species, individual size, market, and season. For example mid-1990s retail prices of *Colossoma* varied from US\$0.5-4.32/kg for juveniles and US\$1.05-6.08/kg for adults in Manaus, values which encompassed those from markets in Colombia, Peru, NE Brazil, and Rio de Janeiro (Araujo-Lima and Goulding 1997). In 1991, the moderately priced, ubiquitous detritivore, *Prochilodus nigricans* was retailing for US\$0.5-1.5/kg under ice in Iquitos, Peru, depending on water level and short-term supply/demand (Bayley et al. 1992).

45. Insufficient data on either prices of most species or the proportions of the more valuable species throughout the basin preclude a definitive analysis. A rough value corresponding to an average estimated retail price of US\$2/kg for all Manaus market fish in 1995 (Goulding and Ferreira in press) was used for major cities and exports, and a range of US\$0.5-1.0/kg for other fish under the subsistence “component” (Petrere, 1992, in (Goulding and Ferreira in press)). Total annual market value applied to the yield data in **Table 5** would be of the order of US\$380-540 million, not including secondary effects from other related economic activity that could double this estimate.

46. In economic terms, the cost of alternative animal protein supplies would be a better indicator of the value of fish, e.g. to estimate losses in fish supply due to environmental alteration.

Based on an average price of chicken at about US\$2 per kg, the economic value of fish produced annually in the Amazon basin would be some US\$850 million.

47. Obviously, a systematic and comprehensive effort at data collection and analysis is required to arrive at an adequate evaluation of current and potential ecosystem services, taking into account the various competing uses of the water and floodplains in the basin (see paras. 128-129 in Chapter VII (A)).

B. Fisheries for ornamental species

48. Fishing for ornamental species is a highly important economic activity in areas where alternatives for income are few. It is correctly characterised as one of the last strongholds of the traditional indentured labour system in the basin (Goulding and Smith 1997). Barthem, Guerra and Valderrama (1995) quote the following figures in millions of fish exported annually:

Brazilian Amazon	17 millions fish of 177 species (1988)	worth \$ 1,500,000 approx.
Peru	8.3 million fish of 107 species (1992)	worth \$ 1,117,347
Colombia	3 million fish	worth \$ 600,000

49. Apart from locally intense fisheries for “cardinal tetras” and “discus” in Brazil, and young aruana (*Osteoglossum bicirrhosum*) in Colombia and Peru, ornamental fisheries remain at an apparently modest level. At current intensities, ornamental fisheries are considered unlikely to affect or be affected by food fisheries, even when young of food fish species, such as *Osteoglossum*, *Phractocephalus*, or *Arapaima*, are involved (**Appendix 1**). Discus (*Symphysodon sp.*), in its various local forms, represents the only species that has some chance of being locally eliminated due to heavy fishing pressure. This is because of the unusual combination of a dependence on specific seasonally stable environments in varzea lakes, its limited fecundity, and its unusual vulnerability to being observed and captured (Crampton 1996).

C. Recreational fisheries

50. Sportfishing has increased rapidly during the past two decades, and is now estimated, when all associated costs are included (Brazil Ministry of Environment, IBAMA, in (Goulding and Smith 1997)), to be worth about US\$ 400 million. Apart from headwater camps established by outfitters, most sportfishing is operated from tour boats in the Central Amazon. Some diversification from the most popular species, tucunare, (*Cichla spp*) has occurred, and larger characins and catfish are now sought (Goulding and Smith 1997). There is more emphasis on non-turbid rivers and associated igapo-forest floodplains because there are fewer mosquitoes and fewer conflicts with food fishing than in the várzea.

51. Yields from the sport fishery are not available but are probably insignificant at present levels of effort. Recreational fisheries are highly selective in terms of species and they also prefer large individuals. Even light fishing pressure, especially in the low production (but high pristine biomass) black and clear waters, can quickly reduce the catch-per-effort of large fish to levels unacceptable to sport fishermen. There can, therefore be potential interactions between the food and recreational fishing interests that can lead to conflict. More important is the high degree of political pressure that can be brought to bear by the sport fishing lobbies which has

already caused Brazil to abandon food fisheries in favour of recreational ones in several states, especially in the potentially productive Pantanal.

D. Aquaculture

52. Aquaculture may pose problems for biodiversity protection particularly when non-native species or hybrids of local species are cultured. Even when local species are cultured some problems of genetic contamination can arise if proper broodstock management practices are not observed. Aquaculture is currently in its infancy in the Amazon but significant advances have been made in the components needed for profitable, intensive culture of *Colossoma macropomum* (Araujo-Lima and Goulding 1997). The earlier technical bottlenecks of producing fry for stocking from very small eggs has been overcome, and private sources are now producing more fry for stocking than government agencies (Araujo-Lima and Goulding 1997). Those authors estimated that pond raised monoculture of *Colossoma* with supplemental feeding could provide a profit/operating cost of 54% from a total cost of US\$ 58,200 and a 1995 retail price of US\$ 2.6/kg. during two years, with a break-even price of US\$ 1.69. Cage and more intensive pond monoculture and polyculture estimates were less profitable (10-20%).

53. A widespread boom in intensive culture based on raceways could have negative water quality effects (McGinn 1998a; McGinn 1998b). These are liable to be minimal in the case of the type of still water ponds preferred for rearing this species. Naturally functioning várzea floodplains could provide a service that can maintain good water quality up to some limit, while most várzea lakes and channels themselves are typically not physically suitable for intensive pond or cage culture. The economic effects of a boom in aquaculture on wild fisheries producing the same species could be more significant. Current interest and momentum in aquaculture in all major Amazon countries is considerable and production from this source is growing. At the same time, potential effects of indigenous and imported diseases or parasites (Araujo-Lima and Goulding 1997), competition from other countries and depressed prices are potential long-term moderating factors. A potential positive effect of intensive culture is a demand for várzea tree fruits for high quality *Colossoma*. The concept of 'fish orchards' (Araujo-Lima and Goulding 1997) provides an attractive alternative land-use to intensive ranching or agriculture in the várzea. There may also be extensive várzea tree opportunities, because regrowth várzea forest contains a large proportion of fruits favoured by fish species (Goulding and Ferreira in press).

54. Extensive aquaculture, including stock enhancement, is an untried experiment in the basin, although it has been tried successfully in countries such as Bangladesh where much more intensive human population and fishing pressure exists. One promising possibility is the stocking of várzea lakes with juvenile *Colossoma*, and harvesting pre-adult fish three years later, because, unlike many other migratory characins, this species remains in the várzea floodplain until exiting to the river for first spawning at about 6 kg (Araujo-Lima and Goulding 1997). It was estimated using 1995 prices that a profit of US\$ 6.65 million could be made from a total investment of US \$1.2 million by stocking 5 million juvenile, 100-g *Colossoma*, in várzea lakes and harvesting 1 million, 3-kg fish three years later (Araujo-Lima and Goulding 1997). However, this calculation assumed an accumulative "survival rate to capture" of 20% (this includes the proportion of survivors that can be captured), which is equivalent to an average of 59% per year, in an environment with about 35% piscivores by weight, excluding piscivorous birds, caimans, and mammals (Bayle 1988b). The mean annual "survival" rate for their economic scenario to break-

even is 31% per year. Therefore, the onus is to prove that very high survival rates to capture are possible for this species before making a significant investment in stock enhancement.

E. Conclusions

55. No fish species appears to be in danger of extinction at present levels of effort. Multi-species yield is mostly well below expected maximum levels, but approaches them near to major cities. There is an ample supply of animal protein, except possibly in some rural areas distant from varzea floodplains. This is remarkable considering the state of fisheries management (Chapter IV), and attests to the high productivity of a river-floodplain system supported by a near-natural hydrological regime (Junk et al. 1989). Nevertheless, some geographical patterns can be discerned that are representative of species assemblage progression when subject to increasing fishing pressure. Parts of the Amazon basin farthest from urban areas are in the first stages of a progression (A in **Figure 1**), in which yields of the largest, most valuable species have decreased but still are of economic significance, while at the same time supporting fisheries for smaller species. The progression is more advanced in those areas relatively closer to urban centres, where the yield is dominated by smaller, cheaper species dominated by detritivores, but including omnivores and some piscivores (B in **Figure 1**), which support the bulk of urban consumption (**Appendix 1**). Despite variable levels and types of effort in food fisheries, the overall catch is still dominated by few species although better data in small-market and subsistence fisheries will reveal many more species. Most of the smaller species in the basin remain under- or unexploited (stages C and D in **Figure 1**), although level C may already have been reached close to Manaus, Belem, and Iquitos. Stage D, which has not been reached, may or may not decrease in total yield depending on markets and efficiency of catching very small fish.

56. The ability to monitor changes in fish stocks through fisheries data continues to be severely hampered by inadequate investment. Systems are needed to (1) obtain catch and effort data by species in major markets annually, and (2) obtain *per capita* consumption estimates from urban and rural households according to a stratified sampling programme about every five years (**Appendix 2**).

IV. FISHERY MANAGEMENT ISSUES

A. Existing regulations

57. Inland fisheries throughout the world are conditioned by factors external to the fishery and those within the fishery itself. General environmental and wildlife conservation law is also increasingly impacting on the freedom of fishery managers to regulate their own sector. On the whole, regulations throughout the Amazon basin have followed traditional techniques used by fishery management for single species stocks elsewhere. These rely on centralised control and blanket laws that apply over large areas and a diversity of fish species. An exhaustive treatment of all such regulations on fishing would not be useful, because most regulations cannot be or are not enforced. However, the existence of such regulations and the policy attitudes underlying them stands in the way of the adoption and testing of possibly more realistic alternatives (Isaac et al. 1993). The following paragraphs outlines the types of regulations in existence and examines their relevance.

58. Current regulations in Brazil, Peru and Bolivia are designed to manage species or species groups individually through minimum individual lengths of fish in possession, restricted mesh sizes and restricted gear. The minimum lengths are based on estimates of sizes at first maturity and mesh sizes are fixed accordingly. In addition, closed seasons are specified for individual species. For example, fisheries for *Arapaima* was closed from the beginning of December to the end of May in Brazil¹, and from the beginning of October to the end of March in Peru to cover the spawning seasons. Fisheries for migratory characins such as *Colossoma*, *Piaractus*, *Mylossoma spp.* and *Prochilodus*, are closed for the spawning migrations during the rising water period (often December through March in Brazil) (e.g. **Appendix 1**). Gears may be prohibited seasonally, as in the case of the cast nets, or totally, particularly in the case damaging fishing methods such as poisons or explosives.

59. Different regulations exist between countries and among neighbouring states of the same country that have fish stocks and species in common. For instance, seine nets have been banned in Para State but not in Amazonas State, Brazil (Isaac et al. 1997). There are also local restrictions on gear dimensions, such as a minimum 70 mm stretched mesh for gillnets in Para (Ruffino and Isaac 1994).

60. So-called subsistence fishing and sport fishing are exempted from most regulations. The application of this reasonable rule, however, is made difficult considering that the most rural and some sport fishermen try to sell some of their catch if they can.

61. Amazonian fisheries are open access, common resources in rivers and floodplains that are not privately owned. Although land titles are granted to communities in the Peruvian varzea, fishing rights continue to be common when and where boats can physically access waters. Current opinion on the management of multi-species fisheries in rivers as elsewhere, is that regulation of access through some system of long-term licensing or public recognition of ownership is preferable to attempts at regulation of gear. Adoption of such policies in the Amazon would require a political and legal realignment of the open access, common resource principle.

B. Regulations enforcement

62. Fishing regulations are not enforced throughout the basin. In part this is due to the perception by the fishermen that existing regulations are inappropriate and in part due to the need on the part of the fishermen to make a living from stocks whose mean size is declining. For example the legal 70mm minimum gillnet mesh will capture and kill *Colossoma* below its legal size limit in floodplain lakes, while failing to capture many species that are of potential value to the Type 1 fisheries (Petreere 1978b; Isaac et al. 1993). At the same time some fisheries are independent and can be regulated separately. Fisheries for large river catfish do not catch other species (Barthem and Goulding 1997) and fishermen following upstream migrations of characins can recognise the species group and often the approximate size of individuals before deciding whether to launch their lampara net or beach seine (Ribeiro 1983).

¹ Fishing for *Arapaima* (pirarucu) has been totally prohibited in Brazil for the past 2 years. The fact that this species still appears for sale in the better restaurants and markets illustrates the difficulties in enforcing such legislation under existing management regimes.

63. It can be argued that some minimum size and gear regulations could work in principal for valuable fish, providing that fishing is allowed in some areas to cater for urban-based and subsistence fisheries for smaller, cheaper species. However, the ability to circumvent regulations by selling in unsupervised markets or using illegal gear that is easily hidden in field locations, makes enforcement from a centralised agency prohibitively costly. Indeed the frequent complaints that agencies are not enforcing regulations do not take into account the huge government subsidy that would be required for their monitoring, surveillance and enforcement.

64. Were management to be subsidised to the extent that enforcement was applied universally with effective penalties, the fear of catching immature fish would result in a near-optimal fishery for a few, very large species, mainly *Colossoma*, *Brachyplatystoma spp*, *Arapaima*. The total yield, adding the maximum (probably unsustainable) yields for each species, would amount to a small fraction of current yield which includes many smaller species. This would result in a profitable industry for a few entrepreneurs but a serious animal protein shortage in the urban centres, the resolution of which would require yet more subsidies.

65. Education of fishermen is a viable tool in the process of fisheries management but is only of value where the regulations can be demonstrated to be sound. For example it is difficult to convince fishermen that prohibiting fishing during the upstream spawning migrations of highly fecund characins, when the water level is rising, dispersal is occurring, and vulnerability of fish is lower, makes more sense than trying to restrict harvest when natural mortalities are at their highest during low water (Isaac et al. 1993).

66. Some of the most effective, but not necessarily advisable, regulations are unofficial. Some fishermen groups clear vegetation at low water from strategic areas where migrations pass at higher water, so that beach and lampara seines can be employed (Ribeiro 1983). Preparation of these fishing stations requires a significant investment, and is therefore defended from use by other fishermen. Many floodplain areas have been unilaterally closed to outsiders in Brazil and Peru.

67. This crisis of management is common to all fisheries at present and the most frequently advocated solutions are exclusive exploitation rights and co-management. This social, economic and policy tool needs careful appraisal as it involves fundamental changes to the relationship between government and the fishery. These are discussed in Chapter V and expanded to other actors in Chapter VII.

C. Rural community development

68. In recent decades there has been an accelerating trend in Brazil and Peru to establish zones from which non-resident fishermen are excluded. Most such zones arise from unilateral declarations of rights of access to the fishery by residents, which result from conflicts with urban-based fishing units who had previously fished in those areas. Establishment of zones such as these, where control is invested in local communities is the first step in setting-up co-management systems.

69. Several of these zones are supported by NGOs and external funding (e.g. McGrath et al. 1993) and have evolved into integrated conservation and development projects. Exclusion zones of this type are included in the two large (> 20,000 km²) floodplain reserves, Pacaya-

Samiria in Peru (COREPASA 1986; Bayley et al. 1992) and Mamirauá in Brazil (Menz et al. 1995). They are also included in the IARA project in the Santarém region (IBAMA 1995). The long-term success of externally supported projects depends on the setting up of self-sufficient communities that derive part of their income from natural resource exploitation. In this way they have a strong incentive to protect their production and the natural processes that support it (Bayley et al. 1992).

70. Naturally, conflicts have resulted when urban-based fishing units have attempted to fish in many of these areas. The income to be derived from the sale of the valuable fish species involved is considerable and both sides continue to try to exercise their right of access to the fishery.

71. Except for some rare, truly indigenous groups, riverine residents in Brazil and Peru are part of a society that retains elements of the patron/indentured labour system. Hence, the strongest social unit is the family. Some communities have become divided due to different religious affiliations in addition to the urban/rural estrangement (personal observations in Peru and Brazil).

72. Individual economic pressures are always present. Many residents hire themselves out to visiting commercial interests that sometimes lend gear, when it is not profitable for them to catch and sell independently. Groups will pressure for government assistance in giving them rights to manage their fishery and expel outsiders, while group members will fish illegally within their reserve. This indicates what residents feel they need to do in order to support their families, an obligation that supersedes community obligation.

73. Part of the solution may be some form of property right that is sufficient to oblige controlling interests to limit their level of exploitation. There are economic and ecological elements in this that relate to spatial scale and human geography. For example, when the issue is the control of stocks of local migrant and floodplain resident species local community control may suffice. However, single communities cannot manage efficiently stocks whose migration patterns extend beyond their jurisdiction. The concept of joint exclusive rights to such stocks is discussed in Chapter VII.

74. In conclusion, rural projects such as these, if successful, would provide a partial solution to effective management of fisheries and other resources where alternatives are hard to find. Therefore, despite the list of doubts expressed above, current ventures should be supported at their current, modest levels for about 15 years or until evaluations indicate that they are either self-supporting or unlikely to succeed.

D. Conclusions

75. There is no single optimum strategy to exploit a multi-species fishery in such a diverse system. A mixed scheme that maintains economic returns from valuable species, yet also caters for the urban markets for less-valuable species is essential. One possibility is a graded system extending from the cities to large Parks and Reserves (Bayley 1995a). Greater exploitation for cheap fish would be possible near to the major urban centres where it is most economically feasible. Progressively more valuable species that can be profitably exploited at greater distances would be managed between cities and in Parks and Reserves, where a high degree of control

would be attempted (Bayley 1995a). This process is evolving in spite of current regulations (Bayley and Petrere 1989), but cannot be stabilised without an effective management process (Chapter VII(A)).

76. Regulations have followed traditional techniques used by fishery management for single species stocks elsewhere. Probably only one species, the piramutaba catfish that dominates in the estuarine fishery, lends itself to a traditional single species approach using existing models. Considering the significance of gear and ecological interactions among species and the extensive nature of the resource, one cannot blame management agencies for failing under their current paradigm. However, even though current financial and human resources are limited, they are not well used. There is room for improvement in approaches to fishery management to benefit long-term profitability (Chapter VII(A)) and to promote unified support to fishermen's organisations to counter the real, irreversible threats to the resource. These need resource management approaches on a large scale, and outside the traditional boundaries of fishery management.

77. Most full and part-time fishermen do not have the education, job opportunities, or capital to switch or diversify sources of income when profit margins become too thin. Therefore, the main, but usually unstated, issue among fishermen's groups is control of the economically valuable stocks, rather than adherence to formal regulations. The corresponding issue for aquatic biodiversity is controlling the amount of economic and political power that fishing interests can apply while at the same time to sustaining the appropriate ecosystem services. Solutions to this may lie in systems of transferable fishing rights for urban fisheries and of co-management for rural ones.

V. BIODIVERSITY AND FISHERIES

A. Relation between fisheries, the aquatic environment and biodiversity

78. International concern about diminishing biodiversity led to the signing of the Convention on Biological Diversity in 1992. This Convention defines biodiversity as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (UNEP 1994). Signatories to this Convention undertake to protect their biodiversity and to ensure that any benefits accruing from it are distributed equitably among stakeholders¹.

79. This definition of biodiversity should be used in Amazon aquatic environments as a broad, conceptual goal rather than as a tool to prescribe the process of measurement and evaluation. Knowledge of this extraordinarily complex system is not only incomplete now but will be so long after the time frame in which the system could be destroyed. Traditional measures of biodiversity use some index based at least partly on numbers of native species but these would be difficult to apply in the Amazon where many species have not been described. In the U.S. concerns about species conservation led to the Endangered Species Act (ESA) which has resulted in notable victories and distortions (Rohlf 1991; Walters 1997), and economic ramifications (Niemi et al. 1994).

¹ All the Amazonian countries are signatories to the Convention on Biodiversity.

80. **Constraints.** Turbid and black-water systems in the Amazon have distinct and highly diverse biota, most of which is associated with floodplain forests (Goulding 1980; Salo et al. 1986; Goulding et al. 1988; Junk et al. 1989; Goulding and Ferreira in press). Keeping track of the welfare of most individual species or species-based biodiversity is currently impossible because of:

- (a) an inadequate taxonomic knowledge of the species present;
- (b) lack of keys that can be practically used for identification of fish in the field; and
- (c) scarcity of experts who have the necessary taxonomic and sampling skills.

81. Therefore, effective species protection by enforcing laws equivalent to the ESA is impractical for all but a few key species.

82. The ability to set standards for biodiversity conservation and monitor the changing status of aquatic biodiversity on the basis of surveys for full sets of species is almost impossible in most habitats. Surveys based on subsets of known commercial fish species are more feasible, because post-larval through adult stages of most medium and large-sized species can be distinguished. (see **Appendix 2**). As this problem applies particularly to fish and invertebrates, the use of avifauna associated with aquatic systems may present an alternative as a biodiversity indicator, but parallel problems of availability of experts and distinction of species in the field exist (S. K. Robinson, Illinois Natural History Survey, Pers. comm.)

83. It is now generally accepted that the conservation of most species in the aquatic system, as well as biodiversity in its broader sense, depends on the maintenance of the flood pulse (Junk et al. 1989; Junk and Furch 1991; Bayley 1995b). It also depends on the maintenance of connectivity, both longitudinally within the river channels and laterally between the main river and the floodplains. Longitudinal connectivity is necessary to keep migratory pathways open for the long and medium distance migrants. Lateral connectivity is necessary so that the floodplain environments including the associated higher vegetation are sustained (Junk 1986; Goulding and Ferreira in press) and fish can move from their dry season habitats to the wet season spawning and feeding areas. This affects even large catfish and mammals that live in the main river channels, because they depend on migrating fish reared in the floodplain (Barthem and Goulding 1997). A further factor that needs to be controlled is water quality because pollutants can kill fish in floodplain water bodies and can act as chemical barriers to migration. The basic assumption is that if some degree of system integrity is maintained with respect to hydrological regime, higher vegetation, connectivity and water quality, this will suffice to maintain a level of biodiversity that will not accelerate extinction levels above natural rates.

84. Generally the effects of excessive fishing are insignificant relative to the damage that can be caused by changes in connectivity, and water quantity, quality and timing. It is thought to be practically impossible to cause fish extinctions by exploitation alone because mistakes in fishery management are reversible and response times are short. Nevertheless, there are few grounds for complacency in this regard because species have disappeared and species composition has been drastically altered in some very heavily fished systems such as the Oueme in West Africa (Welcomme, 1995). Environmental degradation brought about by other human interventions in river systems has, however, proved much more damaging. This means that the protection of aquatic biodiversity is a challenge facing all of society and not just the fisheries sector.

B. Parks and Reserves protecting aquatic environments

85. The two principal Amazonian reserves which are dominated by floodplains and large rivers are the Pacaya-Samiria (20,800 km²) between the lower Ucayali and Marañón rivers in Peru (Bayley et al. 1992) and the Mamirauá (11,200 km²) between the lower Japurá and middle Solimões rivers in Brazil (Ayres 1993). Logging has impacted both reserves and, although this continues to some extent, they are now reasonably well protected under their Reserve status. Their sizes seem impressive, but while Pacaya-Samiria includes 18% of the Peruvian floodplain area (Bayley 1981a; Bayley et al. 1992), the reserves together only protect a total of about 350 km of the 8,000 km on either side of the mainstem (Goulding and Smith 1997).

86. The aquatic areas included in other nominally protected areas in the basin are much smaller. Few of these are worthy of note. The well-managed Manu Park in Peru contains significant Andean piedmont stream environments and a limited floodplain on the R. Manu. A small várzea floodplain is protected on the R. Cuni tributary to the R. Madeira. In black-water systems, the Anavilhanas Reserve preserves a unique biotope of about 300 islands in the R. Negro. Significant parts of terrestrially dominated parks are aquatic, such as the well-protected Noel Kempff Mercado National Park in Bolivia and other reserves along the Guapore R. (**Appendix 3**).

87. The main distinction between riverine-aquatic parks and terrestrial ones is that the former can be impacted by water development projects upstream. Because of the strong links between flood regime and the biotic integrity of floodplains, any project having adverse effects on water quantity, quality and timing can affect the viability of downstream reserves. However, the potential of such reserves to protect higher vegetation, local catchments, sedentary fish, and some life-history stages of migratory fish should not be underestimated. In the case of migratory species there is a need to protect the habitats at the downstream and upstream ends of the migration as well as the migratory path in between. This tends to be a much greater undertaking involving a wider commitment and it is unrealistic to depend on Parks and Reserves alone to protect hydrological regimes and migratory fish stocks.

VI. MAJOR ISSUES AFFECTING BIODIVERSITY

A. Aquatic resources in the Amazon: parallels with other large rivers

88. The prospects for conservation of aquatic biodiversity in large tropical rivers are not good, as many systems including the Amazon, Parana and Orinoco in Latin America are candidates for rapid development. The situation in the Amazon has strong analogies with the situation in most large temperate rivers at the turn of the century. Taking the Mississippi and Illinois Rivers in the USA as typical (Forbes 1895; Forbes 1925; Bayley 1991), both the Amazon and Mississippi systems have, or had, important commercial fisheries and incipient sport fisheries. In the Upper Mississippi and Illinois River, pressure first from transport and large-scale agriculture and later from flood control and hydropower generation, resulted in the construction of dams, levees and revetments along much of the channel. These transformed the system into strongly regulated channels for water traffic and dry floodplains for industrial agriculture and incurred a high cost in loss of biodiversity and ecosystem service (Sparks et al. 1990; Sparks 1992; Sparks 1995). Efforts are now being made to rehabilitate parts of most temperate river systems at high cost to society.

89. Why did the massive degradation of such systems occur, and on such a massive scale? Firstly the European colonisers of the Mississippi were culturally not adapted to natural flooding and were mostly ignorant of the effects of land-use on increased frequency and intensity of floods (Bayley 1991). As the basin developed under the European agricultural paradigm, commercial fishermen protested but were not organised. Sport fishermen were few, but later increased in number and political power and fought over a diminished resource to win concessions from the commercial fishermen. Large government subsidies to the transport and farming interests, with the support of a democratic system, produced a magnitude and rate of change that would have been impossible on a free market basis. Brazil already has experienced federal government subsidies that prompted clearing of rainforest in excess of that justified economically. Fortunately these have now been discontinued. Secondly ecological knowledge of the Mississippi system was far more rudimentary at that time than what is known about the Amazon now, especially the principal driving forces that maintain the system and provide the signals for migration among what migratory fish species existed. Lastly, there was no widely held concept of the economic and environmental consequences of ecosystem services at the turn of the century.

90. We should learn from these experiences in order to formulate development policies that conserve rather than destroy these valuable environments. The essential difference between the Amazon now and Mississippi a century ago is that the Amazon basin has a large rural and urban human population depending on floodplain ecosystem services. While many parts of the Amazon are functioning close to natural conditions, we have already reached the stage where more expensive restoration alternatives are being considered in the Amazon várzea floodplains downstream of the R.Negro confluence (Isaac et al. 1997; Goulding and Ferreira in press).

B. Major issues and threats affecting aquatic biodiversity

91. **Extra-sectoral linkages and policy issues.** Critical issues and constraints related to other sectors represent a major threat to the conservation of aquatic biodiversity. The key issues identified are described below.

Land use

92. The most dangerous trend at present is the large-scale conversion of várzea floodplain to pasture for ranching of cattle and water buffalo (Goulding and Smith 1997; Isaac et al. 1997; Goulding and Ferreira in press). Apart from social conflicts arising from direct incursions into traditional small-scale agricultural plots, emergent aquatic macrophytes, including 'floating meadows', are being decimated, along with the water quality of the littoral zone that spreads over the floodplain as the flood pulse advances. These habitats, which are dominated by seasonal aquatic and terrestrial macrophytes, are as important as the flooded forest for maintaining biodiversity (Goulding and Ferreira in press) and productivity in the varzea (Bayley 1989). Losses in these environments can affect the whole system.

93. The most dangerous potential use of the várzea is intensive, single-crop agriculture, which in addition to the ranching effects noted above, will almost certainly need pesticides because of the large number of potential pests in that system. These real and potential land-uses will not only sharply reduce biodiversity and the economic value of the fishery, but may also

compromise total fishery yield, upon which the residents depend for 70-80% of their animal protein needs (Shrimpton et al. 1979).

Water use

94. The largest dam in the basin, Tucuruí (Brazil), has been shown to have significant negative effects on fisheries downstream by affecting hydrology and preventing upstream spawning migrations (Merona et al. 1987; Ribeiro et al. 1995). Fortunately, high turbidity has prevented plans to construct further dams on white water rivers because of the risks of rapid sediment accumulation. However, the same impediment does not exist on major black or clear-water tributaries such as the R. Negro, which supplies about 40% of the water to the central Amazon. In such rivers damaging hydrological changes could result as well as massive hydrological deterioration in the reservoirs themselves due to the decay of trees flooded by the impoundment.

95. Water navigation systems are at least as threatening as major dams. The 'hidrovia' currently being developed in the Madeira R. extends from Porto Velho to Itacoatiara on the R. Amazonas. What the ultimate plans for this hidrovia are is unclear. It is suspected that an attempt will be made to provide a navigable channel at the Teotônio and other falls or cascades between Porto Velho and the Bolivian border (Goulding, M. pers. comm.). If plans proceed along that line, instead of road transport from Porto Velho south, then it can only mean that the R. Guaporé will be part of a system connecting with the Pantanal. This will certainly compromise the currently productive, unregulated hydrological system in that region (**Appendix 3**) and damage biodiversity by allowing access to species currently denied by the falls and invasion by species from the Parana basin via the Pantanal.

Water quality

96. Mining activities have decreased by about 30% from the peak (Malm et al. 1997) but thousands of gold mining sites still remain active. For example, in the Brazilian State of Pará, 45,000 gold miners were recorded in 1997 (Ambrozio Ichihara, DNPM/PA, pers. communication). The Madeira, Tocantins and Tapajós rivers appear to be most affected by severe mercury pollution from extensive, small-scale mines leading to contamination of fish and potential poisoning of the water. Malm et al. (1997) estimated that gold mining released around 2,000 tons of mercury into the soil, water and atmosphere of the Brazilian Amazon during the past 20 years.

97. The direct problem is one of human welfare rather than one of biodiversity. In the R. Tapajós, half of 24 fish samples exceeded the 0.5 ppm total mercury concentration level considered a maximum safe level in Brazil (Akagi et al. 1995). Levels in two large, piscivorous piraíba catfish near upstream mining centres in a tributary were 3.82 and 2.85 ppm, but two other piscivores near the mouth of the river were 0.39 and 0.08 ppm (Akagi et al. 1995).

98. Petroleum mining, which is predominant in Ecuador and Peru, can be locally damaging, but the effects of releases of brine and hydrocarbon spills are less long lasting than those of mercury. Published scientific material on these operations could not be located. While not an immediate problem, surface water pollution associated with (i) untreated sewerage in urban areas and (ii) a few industrial hot spots, is also a point of concern (FAO 1998). Finally, another

concern has been expressed about contamination arising from drug processing, especially in Peru and Bolivia.

99. Mining activities, while posing serious threats locally, are considered minor compared to the major ongoing and potential water- and land-use activities. Nevertheless, there is a need to regulate gold mining activities and to increase awareness among the riverine populations that depend on fish as their main source of protein (see further recommendations in Chapter VII).

Demographic considerations

100. Success of rural community sustainable development projects (Chapter IV (C)) depends on retaining profitable communities in rural areas. This in turn depends on maintaining or restoring biodiversity, defending their interests against the large-scale hydrological changes (which would result from hydrovia, upstream hydropower dams and water diversion), local land encroachment (ranching, single crop farming), and competing fishermen. Rural community development has also to be achieved in the face of the draw of ever-larger cities with better schools and health facilities.

101. Currently more people live in large urban centres in the basin (e.g., **Table 5**), with more access to information, markets, and decision-makers. They also have an interest, currently taken for granted, in the natural productive processes in the várzea that provide more than half of their animal protein in the form of fish. For most inhabitants, the alternatives to fish are too expensive, although chicken is becoming competitive with intermediate valued fish.

102. For this reason urban inhabitants have a stake in the discussion on Amazonian natural resources. Their support is also necessary to counter the changes supported by external interests that ignore these ecosystem services. Unfortunately, some of the current support given rural fishermen, while important to give them a sense of ownership and control, tends to exacerbate their antipathy towards urban-based fishermen. This in turn increases conflict between urban and rural interests and serves the external interests who want to transform the system at the cost of current ecosystem services.

C. Conclusions

103. There should be greater emphasis on natural resource management, particularly of water and forests. Fisheries management is important to the extent that the need for continued supplies of fish, particularly high-valued species, and the economic interests of stakeholders will influence water- and land-use decisions. In this context it is vital that urban and rural sectors reach a consensus on the management of the riverine ecosystem, as without it any policies are doomed through internal conflict.

VII. RECOMMENDATIONS AND FOLLOW-UP

A. Recommendations

104. The development of systematic approaches to the management of large rivers is fairly recent. New programmes should draw on experiences from other large river-floodplain systems around the world such as the North temperate rivers, and the floodplain rivers of Bangladesh and Indonesia (MRAG, 1998). At present no one model has emerged as a universal solution although parallel approaches are proposed in a number of systems. The lack of precedent requires strategies for biodiversity protection to be experimental and sufficiently flexible as to be able to adapt to differing political, social and economic conditions. Programmes should rest on information systems that present the risks and economic implications of development alternatives to decision-makers and stakeholders.

105. An experimental approach, following as much as possible the principles of Adaptive Environmental Assessment and Management (Holling 1978; Walters 1986) is advocated. This approach should not be restricted to the planning and evaluation of new projects aimed at the conservation of biodiversity, but should also apply to existing projects or development activities that affect the aquatic environment. Monitoring and evaluation of existing projects should not only include those aimed at rural development as outlined in Chapter IV(C), but any development programme that has already been approved.

106. Many localised rural projects at present have a poor success rate because they are based on one paradigm and one social group. To reduce the risk of failure, knowledge should be gathered on the other social and economic groups involved in the fishery and programmes should diversify their approaches and their target groups accordingly.

107. The lack of a compendium of detailed information on institutions and programmes from all countries of the Amazon basin should be rectified through a further study.

Exclusive rights to fishing resources

108. Exclusive exploitation rights to the most valuable fishery resources are as essential to urban-based fishing organisations as rural ones. This is a complex issue, especially for migratory fish, yet no government agency can be expected to provide all the resources for effective management and enforcement as a subsidy to any Amazon fishery, as attempts in all countries have demonstrated.

109. An understanding should be obtained of the trade-off between the number of groups capable of sharing a resource of one or more species, the market value of that resource, how much of the estimated resource can be included, and the mechanisms and cost of exercising exploitation rights. First attempts should concentrate on valuable, localised fish stocks that do not undertake obligatory migrations. An example of these is *Arapaima*, whose management according to exclusive fishing rights is already being tried in the Mamiraura reserve¹ (Tim Bostock, Pers.

¹ Mamirauá Project (Brazil). CNPq, DFID (ODA).

comm.)(Bostock 1998) and is being planned in Pacaya-Samiria Reserve (Peru) at the rural community level. Later research should be directed at the migratory catfishes.

110. The type of exclusive right should be defined for the species and region involved on the basis of appropriate economic, scientific, and legal inputs. Fishing organisations, including urban-based organisations, would then be invited to bid for the exclusive rights thus established.

111. Exclusive rights could lie anywhere on a spectrum from an annual right to licensed individual fishermen, through a franchise granted to an organisation or a consortium, to outright ownership. Experience in other systems (Southeast Asia) has shown that license times that are too short (annual or bi-annual) lead to excessive fishing, which tends to liquidate the stock and erode the biological capital. Longer license times (five or more years) provide an incentive for good management and stock conservation.

112. Near the licensed individual end of the spectrum, government agency involvement will still be high and possibly too expensive. Near the ownership end, co-management would be more cost-effective, and government enforcement may only need to be concerned with preventing overfishing. Exclusive rights shared within a consortium of organisations with different long-term interests, as would be expected between urban and rural-based groups exploiting some migratory species, would provide an internal check against this strategy.

113. Exploitation rights could be tradable and license holders should not be required to allocate yield according to a general model imposed from outside. Some flexibility in the way that the exploitation rights are defined is desirable to encourage efficiency and profitability as well as to be able to adjust to new information as it becomes available. The concept of *varzea* community rights to resources in a fixed geographic area has already been accepted by IBAMA in Brazil. However, important stocks, such as those of *Colossoma*, cannot be managed when only part of their life cycle is effectively owned, while the remainder is open to unlimited entry of fishermen.

114. Species that currently have low-value do not provide good candidates for exclusive access rights and are generally better managed at community level under some form of co-management. Low value species may, however, be found in the same area and vulnerable to the same gear as valuable species under joint ownership. Although such low-value species are unlikely to provoke conflict under existing patterns of exploitation, decisions on rights to unavoidable by-catches should be made in a manner that minimises conflict and provides incentives to develop new value-added products.

115. An exclusive rights system should not be expected to be perfect, but has only to be good enough to provide sufficient incentives for license holders to make a realistic profit after management costs. License holders should not depend on what government assistance may be available, although the role of government assistance should not disappear, but evolve as described below.

Improved fisheries management

116. If exclusive exploitation rights are adopted as the basis for management, government and international agencies should take an active role in the transition to the new regime. Government agencies should evolve more into arbitrator and data management organisations that

act as a resource to provide reliable information to all sides when joint owners plan fishing and marketing strategies. They should also settle disputes, negotiate with other license holders to avoid conflicts and ensure the protection of the fishery from damage by other, non-fishing interests in the basin. The agency should also be associated with fish biodiversity monitoring (**Appendix 2**) and participate in an international dialogue to address issues of common stocks (e.g. migratory catfish)¹.

117. To be an efficient and respected arbitrator and ultimate protector of the environment, the government agency needs to be impartial. It also needs good data and scientific advice that is respected by the fishermen's organisations, whether they operate through licenses or are exploiting open access resources for cheap fish. The inability of agencies to make the connection between reliable data and effective management is the principal reason for their current ineffectiveness.

118. Reliable and sustained collection of data from major markets is critical. These should be supplemented by per-capita consumption surveys at about 5-year intervals (**Appendix 2**). Data collection should be contracted to independent, scientific research organisations who are not seen by the fishing groups as responsible for enforcement and who have the statistical and ecological expertise.

119. Details on catch quotas, sizes at capture and gear characteristics for the most valuable stocks subject to exclusive exploitation rights, would be up to the licensee exploiting that resource. An overall catch limit may be imposed by the government agency to guard against overfishing.

120. In the absence of an exclusive exploitation scheme, government would remain the effective owner and would probably need the help of outside donors to shoulder the recurring cost of effective management and enforcement. Failure to establish a satisfactory alternative to existing approaches to management means that the supply of fish to urban centres, and efforts to retain ecosystem services and conservation of the environment, would depend on a considerable and permanent national and international subsidy.

Varzea forest protection

121. Although hydrological change remains the principal long-term threat, the most critical change that currently threatens biodiversity is the conversion of varzea forest and floodplain macrophytes. The major threat here is intensive ranching of cattle, water buffalo, and smaller livestock (Isaac et al. 1997; Goulding and Ferreira in press). This activity is estimated to have a lower potential retail value than fisheries currently do (Chapter IV). An equally dangerous

¹ Scientific knowledge has been recently synthesised on the migratory catfishes. Thus, it is timely to take the first steps towards basin-wide management. As a first step, it is recommended that an international workshop be organised to bring together in one setting the perspectives on management of catfish fisheries of all of the basin countries. The national perspectives would be based on background papers that lay out the issues and suggested remedies from the viewpoint of the catfish industry (fishers, transporters, processors and marketers, boat and gear suppliers) as well as from the position of local, state and national government authorities with responsibilities for fisheries and biodiversity conservation. The underlying objective would be to identify common management objectives and to define the kinds of international co-operation that could be marshalled to attain them.

development is the potential of converting varzea to intensive, single crop agriculture such as rice (Goulding and Smith 1997) or soybean. This would not only reduce employment, animal protein production, and biodiversity, but would require the large scale use of pesticides and fertilisers (Goulding and Ferreira in press).

122. The concept of floodplain farming of native fruits and seeds (Goulding and Ferreira in press) is worth pursuing for several reasons. The potential seed production from natural floodplain forests was conservatively estimated at 9-37 million t/yr. Even at a conservative conversion rate, this would be capable of producing 80,000-370,000 t/yr of fish (Goulding and Ferreira in press). Considering that secondary growth varzea forest is dominated by fast-growing fruit trees favoured by fish (Silva et al (1977) in (Goulding and Ferreira in press)), there are several possibilities that should be tested.

123. The development of plantations to provide high quality food for *Colossoma* in intensive aquaculture units relatively close to urban centres is one example of such an initiative. Such a scheme would provide rural and urban income, and would encourage restoration and protection of varzea forest surrounding natural rearing areas.

124. A third possibility is the extensive aquaculture of *Colossoma* in varzea lakes through stock enhancement. Provided a variety of native trees were used and a natural flooding regime were permitted, this would provide a low-capital, potentially profitable land-use that would maintain biodiversity, support and protect capture fisheries of several valuable species, and on a large scale protect the natural flooding and sediment transport processes. It would not be compatible with intensive ranching or row-crop agriculture, which should be seen as an additional advantage. Constraints are technological and possibly economic. For example, proof of high survival rates of stocked fish to capture (Chapter III(C)) before field testing would be needed.

Improved or new fish products and marketing

125. The poor quality of fish products reaching urban markets in the basin, and the low market value of less desirable species impose limitations on income.

126. Improved techniques for ice production, which are economically appropriate for urban or rural situations (Bostock 1998) are one avenue for adding value. Pilot experiments and extension of the improved technology are required. Improvement of salted-dried products, still important in Peru or remote areas of Brazil for specific species, can permit preservation for 3-4 months using cheap, low technology processes. This allows cheaper transport from greater distances and the storage of fish until market prices rise, such as during the rising water season. Iquitos market 1991 retail prices per kilogram of salted-dried *Prochilodus nigricans* were US\$0.8-1.5 at low water and US\$1.5-2.0 at high water (Bayley et al. 1992). The corresponding fresh fish (under ice) equivalents for this medium-priced fish were US\$0.5-1.0 at low water and US\$1.0-1.5 at high water. About 2.5kg of fresh fish produces 1kg of the salted-dried product. No estimates are available of the potential quantity of this product that could be processed.

127. Markets and techniques should be developed for other products such as smoked fish for restaurants or export, to increase the value of currently cheap species. Improved market value of products will strengthen the interest and power of fishing organisations with respect to

maintaining a productive natural environment. Constraints are technological. Projects could start now.

Economic evaluation

128. The ad hoc valuation exercises in Chapter III underline the need to properly evaluate the ecosystem services that the river-floodplain system provides in the form of marketable and subsistence products to each country. In addition, a proper assessment of the economic benefits to be derived from maintaining or protecting aquatic-related biodiversity in the region would necessitate a better knowledge, *inter alia*, of the effects of water navigation systems on the natural hydrological regime and of the possible impacts that conversion of várzea forest to pasture and/or single crop agriculture is having on fish supply.

129. Ideally an analysis should be made at two levels:

(i) micro (financial analysis), at the level of the fisherman and/or economic actor in each of the 3 groups described in Chapter III, which should establish the benefits and losses incurred by these groups. This would require data or estimates of: (a) the major types of fish, the proportion of each caught and sold distinguishing, where applicable, between domestic sales and exports; (b) local market and export (where applicable) prices of each type or main category of fish; c) production and processing costs; and d) beneficial changes, if any, in a) and possibly c) in the second scenario. Given the geographical scope and the range of possible actions to conserve aquatic-related biodiversity in the basin, the analysis would be based on representative "farm models" incorporating the characteristics of the different situations;

(ii) macro (economic analysis), if not of the whole Amazon basin, at least in the individual countries and more particularly Brazil and Peru. This analysis would evaluate, in economic terms, the ecosystem services currently provided by the floodplains (and their eventual reduction caused by resource degradation or lack of protection of the biodiversity), be they economic, social or environmental goods and services. It would also assess the overall effect of water navigation systems, livestock raising and crop agriculture as well as, data permitting, other projects and programmes that impact on the economy and environment of the region.

Awareness education

130. Effective management of assigned fishing rights through licenses or co-management systems assumes a level of knowledge on the part of the participants over and above that required of simple open access fishermen. This means that training schemes should be set up to inform participants in the revised management systems as to their rights and responsibilities as well as to the implications of their activities for fisheries and biodiversity.

131. Awareness programmes designed to inform urban residents about the importance of floodplain habitats, hydrology, and fisheries for their well-being is also essential. A multiplicative approach through the training secondary schoolteachers is recommended, along with provisions for college/university students that include field visits. Programmes should include meetings with

local representatives, including rural teachers. Information should include rural and urban perspectives and economic information, so that a more objective understanding of the reasons for conflicts and alternative uses or replacement of natural resources can be realised. The only perceived constraint is the need to synthesise information and courses, which could be initiated now.

Recreational fisheries

132. Recreational fisheries should be allowed to develop in black and clear water rivers and associated floodplains. These fisheries are evolving in this direction (Chapter. III), and are, for the most part, interested in low exploitation rates and in environmental protection. Sport fishermen and tour operators should be encouraged to contribute to the raising of awareness of the value of the environment in general and the large migratory catfishes in particular. Sport fishing licenses should also contain provisions obliging the fishermen to contribute information on fish catches and returns.

133. Government authorities of the Brazilian States (particularly Amazon and Pará) should consider the implementation of programmes on recreational fisheries as a high priority. A clear definition of institutional responsibilities at federal, state, and local levels is needed before the implementation of such programmes. Programmes for the development of sport fisheries should attempt to reach accommodation with existing food fisheries.

Stakeholder's conservation lobby

134. At present there is no effective lobby whose resource interests coincide with needs to conserve biodiversity. Most food fishermen are preoccupied with conflicts over valuable fish species resources. Therefore, allocation of the resource is necessary before an effective lobby can function. Such a lobby would group those benefiting from the food fishery, those with interests in recreational fishing and varzea forest protection/plantations, as well as those motivated by awareness education programmes. With such disparate groups from rural, urban, and educational backgrounds, social constraints are expected to slow its development. This type of interest group will be very dependent on good leadership.

Water Quality Control

135. Mercury pollution and consequent fish contamination from wildcat gold mining are widespread problems in the region. Although gold mining activities have decreased significantly in the last few years, there still remain literally thousands of active gold mining sites (45,000 gold miners are active in Pará. Moreover, as mercury is persistent and bio-accumulative, existing environmental contamination will persist and is likely to become even more pervasive in the future.

136. Results of past and on-going monitoring programmes provide strong evidence for the need for urgent action (FAO, 1998). In addition, data on mercury contamination are not readily available to the public. Information dissemination campaigns should be implemented throughout

the whole Amazon region to increase awareness of the main human exposed groups, i.e. the gold dealers and the riverine populations that depend on fish as their main source of protein.

137. Most state government authorities do not seem to consider this a priority issue since the boom in gold mining is past. There nevertheless, appears to be an urgent need to dispel this view and regulate gold mining activities and provide cleaner technological alternatives (which are already available) and make local people aware of the problem (FAO, 1998).

138. Gold mining is not the only source of pollution in the basin and concern has been expressed about contamination arising from drug processing, especially in Peru and Bolivia. While not an immediate problem, population growth in the area and possible industrial development could lead in the future to pollution for urban sewage and industrial effluents. Careful monitoring is needed to prevent these potential sources from becoming a problem.

General approach

139. Given the vast scale and complexity of the basin there is a need for a large scale effort to be addressed through a regionally co-ordinated approach by the riparian governments, possibly in the form of a politically-accepted regional action plan. The development of such plan should be pursued initially on a country-level basis, probably in one or two countries at most (such as Brazil and Peru), in order to build on the body of knowledge and other initiatives already existing in the country. Such an approach is also needed in view of the complex administrative situation within the basin and the need to obtain functional consensus from all stakeholders. The Brazilian experience could then be readily transferred to the other countries of the basin. The initial country-based experience could then be readily applied to initiatives in the other countries of the basin.

140. There is an urgent need to seek funding in support of the activities outlined in this document. In view of the initiatives that already exist in the Brazilian Amazon, such as the Pilot Program for the Conservation of the Brazilian Rainforest (PPPG7) - especially the Floodplain Natural Resources Management Project - and EDIEN's forthcoming workshop on economic development and conservation of water and aquatic resources in the Amazon estuary, it would be sensible to choose Brazil for an initial activity to improve the overall knowledge of the status and uses of aquatic resources in the Amazon basin. Along those lines, it is proposed that the Global Environment Facility be approached to complement the already existing initiatives through a project focused on the clear and blackwater river systems in the Brazilian Amazon, which are as yet unprovided for in existing programmes. Such a project should also support the development and negotiation of a strategic action programme (SAP) for the whole basin, possibly using Brazilian experience as an example.

B. Follow-up Actions

141. This study concludes that:

(i) fisheries research has been unable to cover the basin fully, either in space or in time. The ability to monitor changes in fish stocks through fisheries data is severely hampered by institutional and resources limitations. In addition, knowledge of the biology and ecology of many of the key species is lacking;

(ii) at present levels of effort the major threats to the aquatic biodiversity of the Amazon system do not come from the fishery but from other, non-fishery activities in the basin. The major threats to Amazonian aquatic biodiversity are: the conversion of varzea floodplain to pasture and crop agriculture; changes in flood regimes and system connectivity through hydropower dams and navigation channels ('hidrovias'); and deterioration of water quality through mercury used in gold mining, petrochemical effluents, drug processing wastes and sewage discharges;

(iii) notwithstanding the low level of risk from the fishery at current levels of effort, a consistent approach to fisheries management is central to any rational approach to the conservation of aquatic biodiversity in the basin. A number of measures are advocated to improve fisheries management and aquatic biodiversity conservation including: institution of exclusive rights to fishing resources; improved fishery management; economic evaluation of the fishery; awareness education; varzea forest protection water quality control and development of improved or new fish products

142. Based on these findings a strategy is proposed which complements and builds upon that of the World Bank, and includes:

- Improving knowledge of the fishery and fish resources of the basin
- Contributing to improved management through the reinforcement or creation of networks of stakeholders
- Raising awareness of aquatic resource issues at local, state, federal and international levels

143. The following steps are proposed for the development and implementation of a work programme in support of the Fisheries and Aquatic Biodiversity Management Initiative in the Amazon.

Short Term (coming 12 months - FY99)

Actions regarding this report

- Finalisation of the draft desk study after Bank review. The executive summary (and perhaps the full document) should be translated into Portuguese and Spanish for future distribution among stakeholders.

- Presentation of this study to the COPESCAL meeting scheduled for 11 to 14 August, 1998 (Belém, Brazil) in order to discuss and secure approval of its ideas.
- Presentation and distribution of the desk study during the EDIEN¹ workshop scheduled for November, 1998. This document would be used to get feedback from the attendees and, in turn, serve as major input (together with EDIEN study) into the development of a 'Block B' GEF grant proposal and other subsequent steps under the Amazon initiative.

Project activities

- Presentation to this report to the GEF Secretariat together with a concept note for a GEF project to secure their interest in funding activities in the basin.
- Brazil could be the focus of the first GEF activity in order to build on the body of knowledge that already exists in that country. Such an approach is also needed in view of the complex administrative situation within the basin and the need to obtain functional consensus from all stakeholders. The Brazilian experience could then be readily transferred to the other countries of the basin.
- Preparation of a Block B grant proposal for the Brazilian Amazon in collaboration with the Brazilian Government and with the assistance of FAO using FAO-CP resources to develop a GEF project to promote the conservation of freshwater biodiversity in the Amazon basin. The proposed project would cover freshwater ecosystems not included in the PPG7 Floodplain Natural Resources Management Project, such as clearwater rivers and streams, and white (muddy) water affluents to the Amazon River. The GEF proposal, would provide the following outputs:
 - (i) a general strategic framework² for living aquatic resources management and conservation based on the ideas presented in **Chapter VII** and **Appendix 3** and on new material as it arises. This should serve as a starting point for negotiation and formulation of a Strategic Action Programme in the medium term.
 - (ii) activities which would a) complement the activities of the on-going Pilot Programme for the Protection of the Brazilian Rain Forest (particularly the Floodplain Natural Resources Management Project (Varzea Project), as well as other relevant interventions (e.g. the Brazil National Biodiversity Project (PROBIO) and the Brazilian Biodiversity Fund (FUNBIO)); and b) expand the Várzea Project effort to the clear and black water rivers of the Brazilian Amazon.

¹ EDIEN: the Environment Unit of the World Bank's Economic Development Institute.

² This general strategic framework would explain how the Brazilian proposal, followed in the medium term by other Amazon countries, would be an initial step towards the ultimate goal of conservation of aquatic biodiversity and to sustained fisheries management for the whole basin.

Medium Term (from year 2 - 5: FY2000 to 2003)

- Implementation of the GEF grant project proposal.
- Transformation of the generalised framework into a government-approved action programme, through a number of initiatives such as:
 - Discussions in each of the concerned countries and with regional organisations that might be in charge of regional co-ordination of future initiatives on behalf of the concerned governments (e.g. Amazon Co-operation Treaty, FAO COPESCAL) to agree on broad priorities (see section below);
 - A series of activities (studies and eventually pilot projects, agreed among stakeholders) that would build up consensus amongst interested stakeholders and help to identify:
 - (a) national issues and transboundary problems of the basin related to aquatic biodiversity and fisheries;
 - (b) data and information needs;
 - (c) root causes of the problems and potential opportunities for their resolution; and
 - (d) preliminary indications of priority interventions which could be part of a future strategic action programme for the basin.

These activities, which should be initially implemented at national level, should gradually lead to an overall framework for a global basin wide strategy. A focused integrated management study and economic valuation (recommended in para. 129) should be part of the studies. National and inter-sector workshops should be held concurrently to discuss major issues and potential opportunities, as well as priority actions. Participation of the business community in those workshops should be encouraged. EDIEN is already planning a series of activities along those lines, starting with the November 98 workshop on the Amazon estuary, and it is envisioned that EDIEN would continue to play a major role in conducting these types of activities in the basin for the next three years.

- Promotion of national and regional collaborative mechanisms to ensure participation of all stakeholders concerned with the Amazon aquatic resources throughout the entire process leading to the development of the action programme;
- Preparation of detailed project proposals (based on pilot projects) for financial support by international agencies to the above process;
- As a result of the above, negotiation and formulation of an overall Strategic Action Programme (SAP) based on the activities outlined for the development of responsible and sustained fisheries and conservation of aquatic biodiversity in the Amazon basin. The

process by which the SAP is to be developed is as important as the eventual SAP itself and must be country-driven, action-oriented and flexible. It must be country-driven, involving the wide range of stakeholders concerned with the aquatic environment, to incorporate lessons learned¹ and avoid some of the pitfalls of other SAPs, to ensure national and regional ownership of the SAP, as well as to enhance the possibilities for its success. This process should be undertaken in parallel with the formulation of national SAPs by each of the concerned countries.

Long Term (from year 6 on)

- Implementation of the Strategic Action Programme.

¹ It should be pointed out that, among the lessons learned from other SAPs supported actions, a critical factor is the need for strong and sustained commitment during project preparation and implementation. For example, in the case of the Baltic Sea Environment Programme, political commitment at the national and local level has been the key factor to progress in project preparation and implementation; public support has been critical to sustaining political commitment; access to project information has facilitated support; and international partners also need long term commitment (Linter, Stephen F. n.d. "Baltic Sea Environment Programme: lessons learned from project preparation and implementation. The World Bank. presentation outline and personal comm.)

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Table 1. Environmental and Fisheries Institutions and Tasks

COUNTRY Name of the Organisation	Major Tasks in Environment & Fisheries
BRAZIL	
Ministerio do Meio Ambiente, dos Recursos Hidricos e da Amazonia Legal (MMA): Secretaria de Meio Ambiente Secretaria de Coordenação da Amazonia Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA)	<ul style="list-style-type: none"> - develop and promote implementation of environmental and fisheries policies; - focal point for COPESCAL; - co-ordinate, supervise and promote the implementation of the Integrated National Policy for the Legal Amazon; - monitoring, control and enforcement of environmental and fisheries regulations; - promote the development of fisheries.
Ministerio da Agricultura e do Abastecimento (Nucleo de Pescado do Forum Nacional de Agricultura)	<ul style="list-style-type: none"> - promote the development of fisheries (proposed by the GOB, yet to be approved by the National Congress).
Órgaos Estaduais de Meio Ambiente (OEMAs): IPAAM (Amazonas), SECTAM (Pará), SEMA (Amapá), SEPLAN (Roraima), NATURANTINS (Tocantins)	<ul style="list-style-type: none"> - monitoring, control and enforcement of environmental and fisheries regulations; - co-ordinate the implementation of state environmental policies.
COLOMBIA	
Instituto Nacional de Pesca y Acuicultura (INPA), autonomous, under the Ministry of Agriculture	<ul style="list-style-type: none"> - develop and promote implementation of fisheries policies; - monitoring, control and enforcement of fisheries regulations.
PERU	
Ministerio de Pesquería	<ul style="list-style-type: none"> - develop and promote implementation of fisheries policies; - monitoring, control and enforcement of fisheries regulations.

COUNTRY Name of the Organisation	Major Tasks in Environment & Fisheries
ECUADOR	
Subsecretaría de Recursos Pesqueros, Ministerio de Industrias, Comercio, Integración y Pesca	<ul style="list-style-type: none"> - develop and promote implementation of fisheries policies; - monitoring, control and enforcement of fisheries regulations.
VENEZUELA	
Servicio Autonomo de Pesca y Agricultura (SARPA), under the Ministerio de Agricultura y Cría	<ul style="list-style-type: none"> - develop and promote implementation of environmental and fisheries policies; - monitoring, control and enforcement of fisheries regulations.
BOLIVIA	
Centro de Desarrollo Pesquero, under the Ministerio de Asuntos Campesinos y Agropecuarios	<ul style="list-style-type: none"> - develop and promote implementation of environmental and fisheries policies; - monitoring, control and enforcement of fisheries regulations.
GUYANA	
Fishery Department, Ministry of Agriculture	<ul style="list-style-type: none"> - develop and promote implementation of environmental and fisheries policies; - monitoring, control and enforcement of fisheries regulations
SURINAME	
Animal Husbandry and Fishery Department, Ministry of Agriculture.	<ul style="list-style-type: none"> - develop and promote implementation of environmental and fisheries policies; - monitoring, control and enforcement of fisheries regulations

Table 2. Number of related projects in the Brazilian Amazon

Field	Governmental projects (*)	Non-Governmental projects				
		Grass-root	Indigenous	Religious	Private Sector	NGO
Fisheries	36	0	0	2	1	3
Protection of water resources	55	1	0	4	1	15
Flora & fauna management	76	1	1	7	2	25
Pollution abatement	20	0	0	3	0	5
Strengthening community organisations	44	5	1	4	2	21

(*) some 66% of the projects are under the sponsorship of the federal government, 23% of state government and 11% of municipalities.

Source: UFPA. Desenvolvimento e conservação na Amazonia brasileira: inventario e análise de projects; Série POEMA 3. TCA, Secretaria Pro-tempore. 1995.

Table 3. Brazilian Amazon: major related projects financed by the World Bank and/or other development agencies (completed, ongoing and planned)

Sector issue	Project
<u>World Bank-financed (or co-financed with other development agencies)</u>	
<ul style="list-style-type: none"> Promoting the generation and evaluation of information and knowledge on the natural resources as well as human impacts on the várzea/floodplain of the Amazon river, through strategic studies (does not include tributaries) Promoting experimental NRM pilot projects in the várzea (fisheries, aquaculture, small farming systems and conservation) Monitoring and evaluation of the status of ongoing natural resources uses in the varzea and of human impacts upon the ecosystem 	Brazil - Floodplain Natural Resources Management Project, Projeto Várzea (PPG7) ¹
<ul style="list-style-type: none"> Strengthening of main environmental institutions, and development of legal and regulatory framework 	Brazil - National Environmental Project
<ul style="list-style-type: none"> Establishment of ecological corridors in the central Amazon region and in the Atlantic Forest region, respectively Support the implementation of conservation units in priority biodiversity conservation areas Establishment of a basis for planning in other corridors, for future implementation 	Brazil - Parks and Reserves Project (PPG7) ¹
<ul style="list-style-type: none"> Environmental institutional strengthening and capacity building 	Brazil - Rondonia NRM Project (PLANAFLORO)
<ul style="list-style-type: none"> Strengthening community organisations and promoting the management and conservation of the Amazon Rain Forest 	Brazil - Extrative Reserves Project, RESEX, (PPG7) ¹
<ul style="list-style-type: none"> Promoting and disseminating sustainable NRM and conservation systems modelled by local communities in the Amazon 	Brazil - Demonstrative Projects, PDA (PPG7) ¹
<ul style="list-style-type: none"> Strengthening policy analysis, regulatory and implementation capacity of state level Amazonian environmental agencies 	Brazil - Natural Resources Policy Project, NRPP (PPG7) ¹
<ul style="list-style-type: none"> Promoting partnership among government, non-profit organisations, academic institutions and the private sector in support of efforts to improve conservation and sustainable use of biodiversity 	Brazil - National Biodiversity Project (GEF-PROBIO) and the Brazilian Biodiversity Fund (GEF-FUNBIO)
<u>Other development agencies</u>	
<ul style="list-style-type: none"> Promoting the conservation and sustainable use of the Amazon Floodplain 	Project IARA (IBAMA/GTZ)
<ul style="list-style-type: none"> Promoting the conservation and sustainable use of the Amazon Floodplain 	Mamirauá Project (CNPq, ODA/DFID)
<ul style="list-style-type: none"> Strengthening the Pro-Tempore Secretariat for the Amazon Co-operation Treaty² 	FAO Technical Co-operation Project (GCP/RLA/118/NET)
<ul style="list-style-type: none"> Strengthening civil society 	Brazil National Environmental Fund (IDB)

¹ PPG7 - Pilot Program for the Protection of the Brazilian Rain Forest, supported by the Group of Seven (G-7), with funds administered by the World Bank.

² Although this is project to support a regional organization (TCA Secretariat) and not the government of Brazil, it has been included in the list above for its relevance to fisheries in Brazil, since it supported a study on the evaluation of fisheries in the Amazon Basin, involving each of the TCA countries.

**Table 4: Fish consumption per capita rate estimates based on household surveys
(see Appendix 2 for sampling design guidelines)**

Location (period)	Consumption of fresh, whole fish g.(capita)⁻¹(d)⁻¹	CV ^{1/} (%)	SE ^{1/} of mean consumption	Source (interviews)
Rural, várzea:				
. L. Grande de Monte Alegre, PA (1993/95)	369	75	11 (3%)	<i>(Cerdeira et al. 1997)(3918)</i>
. Várzea near Manaus (approx. 1994)	500			<i>Batista, Univ. Amazonas (pers comm.)</i>
. Várzea in Peruvian Amazon (several sources) (1980)	277			<i>(Hanek 1982)</i>
Rural/urban, in várzea:				
. Itacoatiara - AM plus rural area within 60km mid 1970's	194			<i>(Smith 1979)</i>
Small urban, in varzea:				
. Nauta, Perú (8,548 hab.) (1993/4)	327	10	2 (0.6%)	<i>(Tello 1995) (333)</i>
. Requena, Perú (14,690 hab.) (1993/4)	215	12	1.4 (0.7%)	<i>(Tello 1995) (318)</i>
Large urban, in/adjacent to várzea:				
. Manaus - AM (mid 1970's)	117-167			<i>(Shrimpton et al. 1979)</i>
. Iquitos & Pucallpa, Perú (1980)	99			<i>(Hanek 1982)</i>
In basin, outside varzea:				
. Several estimates from Perú, Brazil & Bolivia	11-39			<i>(Bayley and Petrere 1989)</i>

^{1/}: CV: Coefficient of Variation (standard deviation) (mean value); SE: Standard Error; both approximate estimates from cited publications.

Table 5: Annual fishery yields, excluding exports from basin (see Table 6), from Brazilian Amazon States only, based on 1991 census and fish consumption per capita rate assumptions (see Table 4)

Location	Population totals	Urban			Urban catchment and Rural			Total yields (t)
		Human population	Mean per capita rate (g/day)	Yield (t)	Human population	Mean per capita rate (g/day)	Yield (t)	
<u>City</u>					<u>Urban catchment</u>			
Manaus	989,123	984,505	100	35,934	4,619	200	337	36,272
Santarem	264,407	179,499	100	6,552	84,908	200	6,198	12,750
Belem ^{1/}	1,239,564	845,448	100	15,429	394,116	200	14,385	29,815
Abaetetuba ^{1/}	99,803	56,236	100	1,026	43,567	200	1,590	2,617
Ananindeua ^{1/}	87,746	73,746	100	1,346	14,000	200	511	1,857
Macapa ^{1/}	289,397	179,777	100	3,281	109,620 ^{2/}	370	7,402	10,683
All 6 cities above	2,970,040	2,319,211	100	63,569	650,829	200	30,424	93,704
		<u>Urban</u>			<u>Rural</u>			
Várzea districts with Urban populations 10-50,000 (24 districts):	1,009,884	528,738	200	36,376	481,146	370	62,328	98,704
Varzea districts with Urban populations <10,000 (54 districts):	789,935	237,031	370	29,453	552,904	370	66,948	96,401
All non-várzea districts in Amazon basin:	5,260,697	2,783,240	20	16,427	2,477,457	20	13,579	30,005
Totals	10,030,556	5,868,220		145,824	4,052,716		173,279	319,103

^{1/}: Diet of communities bordering the river Tocantins downstream from Abaetetuba to the salt water zone were assumed to include 50% of Amazon freshwater fish.

^{2/}: Remainder of Amapa State population without Macapa urban population.

Table 6: Fishery yield estimates (t) of fresh fish equivalent for 1991 from all major sources in Amazon basin ^{1/}

Country	Human Pop. basis (x10 ³)	Fish consumed within basin (t) ^{1/}	Fish "exports" from basin (t) ^{1/}	
			Piramutaba	Other species
Brazil (for states in Table 5)	10,031	319,100	10,000	5,400
Peruvian Amazon (Bayley et. al. 1992)	1,752	80,000		4,000
Colombia (Amazonas) ^{2/}	36	3,400		
Bolivia (Beni) ^{3/}	321	1,300		600
Totals	12,140	403,800	20,000	
Total 1991 yield (t)	423,800			

^{1/}: "Basin" defined by Brazilian states (Table 5) and named departments for other nations in "Country" column. Total human population of 12.1 million associated with Amazon fish consumption. Exports explained in text (para. 22).

^{2/}: Based on 200 g/p/d for Leticia (popn. 22,980), 370 g/p/d for remaining 13,100 people in Amazonas Dep., Colombia.

^{3/}: Based on M.J. Harvey (pers. comm.) in (Bayley and Petrere 1989), with an update estimate of population of 321,000 and consumptions of 11 g/p/d "exports" mostly to La Paz.

APPENDIX 1: Key species and species groups
Principal species and species groups of marketed fish, within three broad life history categories

Species (group)	Most common local name in Brazil (Peru)	Max. fork length (cm)	High or Medium Value ^{1/}	Comments ^{2/}
1. Large, long-distance migratory catfish ^{3/}				
<i>Brachyplatystoma flavicans</i>	dourada (zungaro dourado)	192	H	migrates from estuary to Peru, Bolivia dominant export in estuary fishery
<i>Brachyplatystoma vaillantii</i>	piramutaba (manitoa)	105	H	
<i>Brachyplatystoma vaillantii</i>				
<i>Pseudoplatystoma tigrinum</i>	piraíba (zúngaro saltón)	280	H	
<i>Pseudoplatystoma fasciatum</i>	caparari (tigre zúngaro)	125	H	
<i>Phractocephalus hemiliopterus</i>	surubim (zúngaro doncella) pirarara (pez torre)	105 110	H H	
2. Migratory characins (Characoidae)				
<i>Colossoma macropomum</i>	tambaquí (gamitana)	100	H	largest fruit-eater
<i>Piaractus brachypomus</i>	pirapitinga (pacu)	60	M	omnivore
<i>Mylossoma duriventis</i>	pacu comun (palometa)	25	M	omnivore
<i>Prochilodus nigricans</i>	curimatã (boquichico)	45	M	detritivore
<i>Semaprochilodus</i> spp.	jaraquí (yaraquí)	30	M	detritivore
<i>Brycon</i> spp.	matrinchão (sábalo)	60	M	omnivore
<i>Anastomidae</i> spp.	aracú (lisa)	43	M	omnivore
<i>Triportheus</i> spp.	sardinha (sardina)	30	L	omnivore
<i>Curimatidae</i> spp.	branquinha (yahuarachi, llambina, ractacara)	32	L	detritivore
3. Various species that do not regularly migrate along rivers				
<i>Arapaima gigas</i>	pirarucu (paiche)	275	H	piscivore
<i>Osteoglossum bicirrhosum</i>	aruaná (arauana)	90	M	carnivore
<i>Cichla</i> spp.	tucunaré (tucunaré)	60	H	piscivores
<i>Astronotus ocellatus</i>	acará-açú (acarahuaquí)	37	H	carnivore
<i>Plagioscion</i> spp.	pescada (corvina)	40	H	piscivores
<i>Piranhas (serrasalminidae)</i>	piranha (piraña)	40	M	omnivores

^{1/}: Ranked by retail price per unit weight; rank can vary with individual size. Several low-and medium value species not listed.

^{2/}: Most piscivores also consume decapods, and omnivores include fruits or seeds in their diet.

^{3/}: All piscivores; data from (Barthem and Goulding 1997).

APPENDIX 2. Guidelines and recommendations for monitoring yields and fish species

Actions for monitoring yields and fish species

1. Three critical areas need to be addressed:
 - (1) Major city markets. Data are incomplete on yields and associated values for fishing effort of major species and species groups (Appendix 1) with distinct prices, markets, and life history patterns. These data are needed for continued stock assessment of major species, to provide economic valuation of the different fisheries (e.g., Isaac and Ruffino 1996), and valuation of the fish production component of ecosystem services for the basin and political/geographic parts thereof:
 - (2) Per capita fish consumption. There is a need for estimates with better precision and timing than those attempted in Chapter III to compare trends in total yields for estimating changes in animal protein supply to different localities and to detect long-term changes in overall fishery yield, and those of dominant, cheaper species groups; and
 - (3) Biodiversity monitoring. A controlled sampling system of young fish to assess trends in species composition is needed in the most critical system: varzea floodplain.

These are discussed in turn, followed by four specific recommendations for action.

(1) Major city markets

2. Because most species commanding higher retail prices (>US\$2/kg) are almost exclusively traded in major cities or exported from the region, direct measurements of fish in markets by well-established processes (Petrere 1978a; Petrere 1978b) is recommended. Data have been collected for limited periods for Manaus (Petrere 1978b; Merona and Bittencourt 1988), Santarem (Isaac and Ruffino 1996), Iquitos (Tello 1995; Tello 1998), Porto Velho (Goulding 1981; Boischio 1992), Tefe, (Barthem 1996), and the Estuary (Barthem and Goulding 1997).
3. These efforts have given some insight into local trends in catch of valuable species over short periods since the mid 1970s. They have documented, for instance, the general decline in *Colossoma* yields (Isaac and Ruffino 1996; Araujo-Lima and Goulding 1997). However, regular, synoptic sampling across markets in the basin is needed to reliably assess regional and total trends in all valuable stocks. This is particularly important for migratory fish species (Appendix 1), because they are widespread, and their stock or metapopulation structures is unknown, and will be for a long time.
4. As cities become larger, trading systems become more complex. Most fish were traded through a single market in Manaus during the 1970s, but there are now about 80 markets spread around the city of 1.5 million inhabitants (Vandick Batista, Universidade de Amazonas, Manaus, pers. comm.). Data and syntheses will soon become available that assesses recent trends in Manaus and Central Amazonia (Vandick Batista, doctoral thesis), which has suffered a long hiatus in fisheries data collection since the mid 1980s.
5. Recommended actions are outlined below in para. 14 (a) and (b) below.

(2) Per capita fish consumption

6. Major market data, excludes the larger portion of the catch that passes through from smaller markets and subsistence pathways. They do not typically include all landings in urban centres. Therefore, surveys of per capita fish consumption are best designed to estimate total yields and broad species composition of fish consumed in the area concerned, of which major market data is a subset containing more detailed information on more valuable species. Fish for export and for restaurants would not be included in per capita fish consumption data, and fish destined for markets outside the region (exports) would not normally be included in either major market data or per capita fish consumption data. A recommended action is outlined in para. 14 (c) below.

7. The traditional approach to yield estimation in small markets is to sample fishermen for their daily catch and effort, and multiply estimates of mean catch per effort by an independent estimate of total fishing effort to estimate total yield. An alternative approach, described here in detail, is to estimate per-capita consumption at the household level. These data are then scaled to estimate total yield using human demographic data, which, if interpreted and projected carefully, is sufficiently accurate. Bias due to unused fish is typically small with locally based artisanal fisheries. The survey design needs to establish boundaries within which total yield estimates are based on per-capita consumption, and exports passing that boundary are estimated independently. This was the procedure used in Chapter III and in earlier studies (Bayley 1981b; Bayley and Petrere 1989).

8. Coefficients of variation from the per capita method in Peru, Paraguay, and Panama ranged from 33-99% (see also Table 6) compared to 190-270% from traditional surveys in Peru (Bayley and Petrere 1989), with all survey designs being stratified as much as possible. The cost and convenience of obtaining a similar number of samples (counted as completed boat trips versus household interviews) was superior with the per-capita method. The precision and cost advantage of per-capita surveys increases as the fisheries become more dispersed, serving small markets or subsistence needs outside Amazon urban centres.

9. A viable alternative to household interviews using trained, locally acceptable personnel, is to train residents to weigh and record their own consumption (Cerqueira et al. 1997). In this case, a system to check for possible non-response bias due to unreturned forms is important. Interview processes also work well in urban centres, where effective stratified designs have been utilised (Shrimpton et al. 1979; Tello 1995).

10. Direct information on the fishery, such as catch-per-effort, size structure and verified species content of fish caught, is usually not possible with household surveys. Supplementary information using less frequent samples of fishermen when landing fish and/or direct sampling of fish populations may be considered. However, appropriately designed strata and interview methods can be used to obtain information on species or groups of similar species consumed, and on fishing effort (time and gear used) from households with fishermen (Tello 1995).

11. Each interview needs to account for how many previous days the person preparing the food (usually the mother) can remember (a maximum between 2 to 6 days is usual). It also needs to allow for different ways of how quantities of fish are conceptualised, which often depends on how the fish were acquired. Some remember weights, others numbers with estimated lengths, from which weights can be estimated later. Species or taxa through local names are usually remembered. The most convenient basis is the total household occupants who share the food, so a per capita estimate is derived from each sample. There are ways to adjust for differing age structures, but the bias correction is small compared with the between-household variance.

12. Precision of yield estimates increases with the number of samples. Sample size largely determines the cost of the survey. However, thoughtful stratification along temporal (e.g., fishing season) and spatial axes (e.g., communities, socio-economic groups within communities, closeness to fishing activity or transport routes) can increase precision markedly. An appropriate precision to aim for in a survey undertaken every 5 years would be $\pm 10\%$ of the sample mean with 95% confidence. Assuming a typical within-stratum CV (Coefficient of variation) was 50% among households, such a precision would be obtained by interviewing about 100 households randomly sampled per stratum. Optimal sampling for the whole survey area is approached if sampling intensity across strata is appropriately weighted according to areas and seasons where fish consumption is highest. Because first attempts at stratification and weighting would be sub-optimal, initial attempts would result in a lower precision unless additional random samples were taken.

(3) Biodiversity monitoring

13. The várzea floodplain is the most critical, threatened system in the basin (Fig. 1) (Junk et al. 1989; Goulding and Ferreira in press). A controlled sampling system of young fish in periodically inundated habitats in the floodplain and permanent floodplain lakes is needed to assess trends in species composition in relation to environmental changes, and to provide early warnings with respect to any collapses in recruitment to fished populations. A calibrated net-seining process that captured over 325 species has been developed and executed in the central Amazon varzea during the late 1970s (Bayley 1983; Bayley 1988b), and continued during the mid 1980s (P. Petry, INPA, doctoral dissertation). Therefore, standardised baseline data exist, but in an area that had already been altered. A second, complementary method using a standardised gillnet fleet (Barthem 1981; Barthem 1984) has also been used in the central várzea. Both methods are effective, cheap, convenient, and technologically simple. Details of a recommended action are under para. 14(d), below.

Recommended actions

14. Actions, as components of "Improved fisheries management, Chapter VII(A), are needed to:
- (a) Derive approximate estimates of yields and market prices of fish species of distinct values to place value on ecosystem services;
 - (b) design and implement a common, ongoing system for collecting city market statistics for use by fisheries management agencies (Chapter VII(A));
 - (c) design and execute a stratified, per capita fish consumption sampling programme to detect trends in medium and low-value species groups and the whole exploited resource (multi-species yield) for use by fisheries management agencies and monitor human diet; and
 - (d) design and execute a fish species monitoring programme in the varzea floodplain.
15. Action (a) is for immediate implementation. The objective is not to obtain detailed valuations for each city, which would be impossible, but rather to collect existing data and collate them so that an economist can broadly estimate fishery ecosystem services in Peru (Loreto), Bolivia (Beni), and Brazil (Amazonas, Para, Rondonia). Fisheries and market price data are scattered among several laboratories and in several formats, so direct visits with personnel who have collected the data or who are responsible for its storage are necessary. Available per capita fish consumption data for smaller

markets and subsistence and updated human population estimates should also be utilised. Input from a resource economist and fishery scientist is necessary prior to on-site visits.

16. Action (b) would follow from (a), and build on relationships developed during that project. A fisheries scientist experienced with statistical design and riverine market sampling should visit and work with existing programmes or agencies in at least the following urban centers: Belem, Santarem, Manaus, Porto Velho, Trinidad, Tefe, Leticia, Iquitos, and Pucallpa, to design a long-term market sampling programme from which data can be interchanged and combined. This does not mean the same computers and software are needed, but rather the sampling protocol, including species groups and fishing effort, can be made sufficiently consistent so data can be combined and compared. Some existing programmes, such as those by I.A.R.A. in Santarem (IBAMA 1995), and I.I.A.P. in Iquitos (Tello 1995), and Mamirauá Ecological Station, Tefe, (Ayres 1993; Barthem 1996) already have a large number of procedures in common¹. COPESCAL² (FAO) could have a role in this process.

17. Action (c) should be designed to cover representative regions in the basin every five years. Major strata should be political: Peru (Loreto), Bolivia (Beni), and Brazil (Amazonas, Para, Rondonia, Amapa). Within those boundaries, strata corresponding to contrasting per-capita consumption (**Table 4**) would be: rural areas in várzea floodplain, rural areas outside várzea floodplain (a secondary stratum could be defined by riparian settlements on black or clear water rivers), cities in or near várzea at 10-50,000 and cities >50,000 population sizes. Although seasonal differences can be slight in productive várzea areas (Cerdeira et al. 1997), seasonal stratification is advisable: one rising-water and one falling-water period per year. Interviews in eastern Para and Amapa states should be particularly careful when distinguishing species consumed, so that marine-derived fish can be discounted. Cities distant from major rivers and floodplains (e.g. La Paz, Santa Cruz) have low fish consumption rates, depend on fish transported from large river fishing centres, and are best estimated in the export category through contacts with traders.

18. Action (d) should employ a 25-m-long by 6 m-max-depth seine net with 5-mm diagonal mesh, and a graded gillnet fleet with stretched meshes of close to 4, 5, 6, 7.5, 9.5, 12 cm (Barthem 1984). The seine is to be used in and around herbaceous macrophyte beds (inc. floating meadows) and open water up to 3-m deep, using three distinct methods depending on minimum and maximum water depths. The gillnet fleet should be set overnight (under vigilance) among original and regenerated várzea forest as well as deeper, open water areas and areas adjacent to floating meadows. Fishermen experienced with these gears should be hired. Sampling should at least include a heavily altered várzea region (e.g., areas near Santarem), the deteriorating central várzea region between Manaus and Purus R. mouth, and an unspoiled várzea region farther upstream in the Solimoes-Amazonas R. The design should be based on best available aerial photographs or images, so that site selection can be randomised within depth- and vegetation-dependent habitats at rising and low water levels. The regions should be sampled every three years. An attempt should be made to measure vertical profiles of dissolved oxygen. Recording of catches should be species, length, and quantity for large species, including all fish associated with fisheries. Distinct, known smaller species should be similarly recorded, but most small species (especially Tetragonopterinae and piranhas) should be counted en masse and sub-samples preserved for future identification.

¹ In addition, the recently appraised Varzea Project (PPG-7) will finance integration of existing statistical survey systems along the various landings of the Amazon river within Brazil.

² COPESCAL: Commission for Inland Fisheries of Latin America

APPENDIX 3. Two specific opportunities for bilateral co-operation

Introduction

1. Bolivia and Brazil share a remote river basin (Guapore) which is rapidly becoming less remote from the Brazilian side. The proposed project focuses on conservation, with minimal resource exploitation, to take advantage of significant protected riparian and floodplain areas on both sides. In contrast, Peru and Brazil share upstream and downstream parts of the extensive várzea-flanked Amazon which, with the exception of a large Reserve in each country, has undergone significant alteration in higher vegetation, but whose hydrological system has so far indicated natural behaviour. Both systems offer several avenues in which a third party and appropriate funding can assist in securing or improving system function and biodiversity by species, with some economic support generated in the process.

Bolivia-Brazil: R. Guapore basin

Description of the area

2. Most of the R. Guapore forms the border between Rondonia and Mato Grosso States in Brazil and Bolivia. There are several protected areas totalling 11 million ha (1,100 km²) in Bolivia and 4 million ha (3.3 proposed) in Brazil that were primarily set up for terrestrial biodiversity protection or indigenous peoples reserves. Most of the Bolivian riparian zone and associated floodplain is, in principle, protected, and includes the Noel Kempff Mercado national park. Despite increasing human immigration to Rondonia and Mato Grosso, there are also two proposed protected areas in Brazil that include the upper catchment of the river, and two existing areas (Corumbiara State Park and the biological Reserve, Rebio de Guapore) in Rondonia. All have extensive naturally functioning floodplains. Representatives from both countries have already met to discuss ecological and legal issues for future management (Anon 1997).

3. There is one major question mark: What are the plans for the hidrovía that currently extends from Porto Velho to Itacoatiara on the R. Amazonas? It has been implied that an attempt will be made to provide for navigation past the Teotónio and other falls or cascades between Port Velho and the Bolivian border. If plans proceed along that line, instead of road transport from Port Velho south, then it can only mean that the R. Guapore will be part of a system connecting with the Pantanal. This will certainly compromise conditions for a natural hydrological system.

4. The river-floodplain system is not well characterised ecologically, but the Guapore is a low-gradient river that falls somewhere between a clear and turbid water classification, and receives higher-gradient clear water tributaries from the granitic shield on both sides. Although the floodplain is expected to function in a similar manner to its mainstem counterparts in Brazil and Peru, the biota are almost certainly different in many respects due to its distance, southerly location (12-16° S), and high water connection to the Parana system via the Pantanal. Strong circumstantial evidence (Barthem and Goulding 1997) indicates that the large catfish, that support commercial fisheries as they migrate through the cascades in the upper Madeira (Goulding 1981), spawn upstream. The Guapore river itself supports moderate fisheries for catfish and large migratory characins, mostly exported to Sao Paulo (personal observation, 1992).

Fisheries

5. This area should be maintained at high levels of fish biomass and close to natural community composition. This means restricting commercial fisheries to a limited off-take of large catfish in specified reaches at road-access points that can be policed. The expected demand for local, subsistence fisheries is limited.

6. This is a good area for both countries to invest in development of quality sport fishing, particularly by wealthy foreign tourists. This is a natural extension of park-oriented tourism development already being initiated on the Bolivian side.

7. Each country, and possibly each reserve, should be responsible for local management for sport and commercial fishing, and for awarding franchises and/or permits for tour operators. They should operate within an overall, bilateral management commission that also directs a system of collecting data on catch, species, effort, and fish sizes. The system should be financed as much as possible from local sources, such as a levy on tour operators.

Conclusion

8. The future, in terms of conservation of biodiversity and self-sustaining ecological processes lies in economic independence through income from tourism, sport fishing and limited commercial fishing. This depends on sustaining the hydrological regime, protecting forests, and maintaining aquatic and terrestrial corridors. The key potential constraint, as mentioned, is the possibility of the river forming part of a hidrovia.

Peru-Brazil: Amazonas-Solimoes-Amazonas

9. With minor exceptions (e.g. Barthem et al. 1995) there has been limited joint work from the two major riparian countries in the basin, although some interchanges of individual scientists have taken place. There are a considerable number of ecological and socio-economic features and problems that are shared between the two countries. As development proceeds, the sharing of experiences in managing these features would be of mutual benefit. Failing the adoption of such a common approach, disputes between the two countries are more likely.

10. Both countries have ideas about development in the floodplain and currently differ in policies regarding varzea ownership. The following highlights themes that, if brokered by a neutral party, will (i) assist in projects/policy development that will maintain or restore biodiversity and natural processes; (ii) reduce the likelihood of conflicts; and (iii) explore avenues that will provide a long-term economic incentive to maintain these two processes.

Downstream and Upstream Effects

11. Typically, a downstream country suffers from water abstraction or hydrological alteration through upstream damming if this takes place on a sufficiently large scale. While such an alteration is a potentially serious problem among the two countries, it would have equal or greater repercussions on the várzea and natural productive systems in Peru.

12. An understanding of processes following damming requires a hydrological model that will predict effects on natural flooding downstream on the basis of the characteristics of the proposed projects hydropower dams, especially with regard to deforestation in the Peruvian uplands.

13. Potential upstream (or downstream) problems may result from competition for upstream migrating piscivorous catfish (especially dourada, *Brachyplatysoma flavicans*) that support high-value commercial fisheries in both countries. Current evidence points towards spawning and early life history upstream of the border and subsequent growth through to adult size downstream as far downstream as the estuary (Barthem and Goulding 1997).

14. The foregoing issues point to a bilateral programme that should include the following components:

1. Fish yields and needs for urban and rural communities

- (a) Design and carry out long-term, periodic (approx. 5 year interval) monitoring of per-capita fish consumption in varzea-rural, várzea-city, and non-varzea-rural parts of the basin, to estimate total yield and species composition trends in combination with commercial yield information. The monitoring system should be complementary to annual commercial fisheries data collection (“Várzea project” proposals have already been forwarded for commercial fishery monitoring in Brazil);
- (b) estimate current and future yield requirements of urban centres for low-cost fish species; and
- (c) estimate quantities and locations of varzea floodplain needed for seasonal access (direct exploitation or negotiated) by urban-based fishermen, in addition to river channel fishing.

2. Fisheries management/legislation

Review current fisheries legislation in Brazil and Peru regarding its utility, futility, and ecological relevance. Recommend reforms to account for:

- (a) local community management that limits effort and total yield in order to to increase yield of high-value species,
- (b) high yield from low-value species for urban-based fisheries,
- (c) reserves and parks, and
- (d) high-value stocks crossing national boundaries (large catfish).

Reforms should retain the facility for national agencies to co-ordinate with local management units to conserve fish stocks that cross boundaries.

3. Hydrological modelling/prediction

Develop an hydrological model of Amazon R. and major tributary influences that facilitates estimates of changes in magnitude and timing of várzea flooding in both countries in response to

- (a) hypothetical hydropower facilities in the Peruvian Andes,
- (b) upstream deforestation/ranch conversion of varzea, and
- (c) deforestation in terra firme catchments.

15. Most full and part-time fishermen do not have the education, job opportunities, or capital to switch or diversify sources of income when profit margins become too thin. Therefore, the main, but usually unstated, issue among fishermen's groups (the urban-based 'colonias' or the new rural-based groups) is control of the economically valuable stocks. The corresponding issue for aquatic biodiversity is the amount of economic and political power that fishing interests can apply that focus on sustaining the appropriate ecosystem services. These are discussed in Chapter V.