WCMC Biodiversity Series No. 8

Freshwater Biodiversity: a preliminary global assessment

UNEP

WORLD CONSERVATION MONITORING CENTRE

17443

WCMC Biodiversity Series No. 8

Freshwater Biodiversity: a preliminary global assessment

World Conservation Monitoring Centre
Brian Groombridge and Martin Jenkins

WORLD CONSERVATION MONITORING CENTRE

UNEP

WCMC – World Conservation Press

1998

The World Conservation Monitoring Centre, based in Cambridge, UK, is a joint venture between three partners in the World Conservation Strategy and its successor Caring for the Earth: IUCN – The World Conservation Union, UNEP – United Nations Environment Programme, and WWF – World Wide Fund for Nature. The Centre provides information services on the conservation and sustainable use of species and ecosystems and supports others in the development of their own information systems.

UNEP – The United Nations Environment Programme is a secretariat within the United Nations which has been charged with the responsibility of working with governments to promote environmentally sound forms of development, and to coordinate global action for development without destruction of the environment.

UNEP has as its mission "to promote leadership and encourage partnerships in caring for the environment by inspiring, informing and enabling nations and people to improve their qualify of life without compromising that of future generations".

WORLD CONSERVATION MONITORING CENTRE

UNEP

Published by: WCMC – World Conservation Press, Cambridge, UK.

ISBN: 1 899628 12 6

Citation: World Conservation Monitoring Centre. 1998. *Freshwater Biodiversity: a preliminary global assessment.* By Brian Groombridge and Martin Jenkins. WCMC – World Conservation Press, Cambridge, UK. vii + 104 pp + 14 Maps.

Cover design by: Michael Edwards

Printed by: Unwin Brothers, Martins Printing Group, Old Woking, Surrey

Available from: World Conservation Monitoring Centre
219 Huntingdon Road, Cambridge, CB3 0DL, UK
Tel: +44 1223 277314; Fax: +44 1223 277136
Email: info@wcmc.org.uk: http://www.wcmc.org.uk/

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

PREFACE

PURPOSE

This document has been prepared on behalf of the United Nations Environment Programme (UNEP) by the World Conservation Monitoring Centre (WCMC). Its purpose is to provide useful information on inland waters and their biodiversity to a wide audience, ranging from those interested in the state of the world environment generally, to those needing an overview of the global and regional context in order to improve planning, management and investment decisions.

This report is explicitly preliminary in approach, largely because of the enormous scope of the issues involved, but by striving to be geographically comprehensive and to use existing data and expertise to best advantage, we aim to provide a firm foundation for subsequent more detailed assessment of freshwater biodiversity.

Within this general context, the project has three principal objectives:

- to present a global overview of freshwater biodiversity, covering notable aspects of distribution, use, status and trends: *see chapters 1, 2 and 3*;
- to produce a preliminary global assessment of areas of special importance (hotspots) for freshwater biodiversity: *see chapter 4*;
- to develop a framework for comparative analysis of major river basins, using indicators of biodiversity, the condition of catchment basins and pressures on water resources, in order to generate indices of importance and risk: *see chapter 5.*

The 'hotspots' assessment is based on a compilation of expert knowledge. A number of leading specialists on the systematics and biology of four better-known animal groups kindly agreed to provide documented information on areas of special importance within each continent, 'importance' here being defined in terms of high species number or high endemism, or both, relative to other parts of the continent. The areas are mapped in this report and the supporting data summarised in table format. Information on these four groups was synthesised to arrive at a preliminary global list of key areas for freshwater biodiversity. This list is far from definitive, but will be of great value for many immediate purposes, while more detailed and quantified analysis will perforce await more prolonged research.

Similarly, a main aim of the comparative catchment basin analysis was to explore the extent to which sets of global data (either readily available or possible to generate within a reasonable period) could be analysed in order to derive meaningful indices of the status of drainage basins. The results appear promising enough to consider extending the analysis using fine-scale data, and make it possible to suggest a potential scheme for prioritising river basins with a view to biodiversity maintenance.

No attempt has been made to address directly the issue of water availability and quality for human use; this complex area has been comprehensively analysed in an overview document (UN [CSD], 1997) and a series of supplementary reports published by the Stockholm Environment Institute.

Whilst this document addresses various aspects of the biodiversity of inland waters in general, emphasis is given to large rivers and lakes as opposed to the variety of shallow, often well-vegetated systems (bogs, marshes, mires, swamps and coastal lagoons) traditionally referred to as *wetlands.*

WCMC TEAM

Text, analysis: Brian Groombridge, Martin Jenkins. GIS analysis: Jonathan Rhind. Research: Neil Cox, Janina Jakubowska. Final document production: Julie Reay. Other assistance: Igor Lysenko (GIS services), Mary Cordiner (information services).

CONTRIBUTORS TO 'HOTSPOTS' COMPILATION

Gerald R Allen (Western Australian Museum); Philippe Bouchet (Laboratoire de Biologie des invertébrés marins et malacologie, Muséum National d'Histoire Naturelle, Paris); Keith Crandall (Dept. of Zoology, Brigham Young University); Neil Cumberlidge (Department of Biology, Northern Michigan University); Olivier Gargominy (Laboratoire de Biologie des invertébrés marins et malacologie, Muséum National d'Histoire Naturelle, Paris); Maurice Kottelat (Cornol, Switzerland); Sven O Kullander (Dept. of Vertebrate Zoology, Swedish Museum of Natural History, Stockholm); Robert Lesslie (Dept. of Geography, Australian National University, Canberra); Christian Lévêque (ORSTOM, Paris); R von Sternberg (Centre for Intelligent Systems, State University of New York at Binghamton); Guy Teugels (Lab. Ichthyologie, Musée Royal de l'Afrique Centrale, Tervuren).

OTHER CONTRIBUTORS

Angelo Antonio Agostinho; Tadeusz Backiel; Nixon Bahamon, Fernando Gertum Becker; Jonathan Benstead; Arthur Bogan, Jianbo Chang; Brian Coad; Salvador Contreras-Balderas; Adele Crispoldi (FAO); Mike Dadswell; Volodymyr Domashlinets; Benigno Elvira; Jens Floeter; Raghavendra Gadakar; Lance Grande; Tong Haowen; Charles Hocutt; Erling Holm; Bernard Hugueny; K. C. Jayaram; Erkki Jokikokko; Pulsri Kanjanamyoon; Chen Kelin; Kip Keller; Stefan Kuhardt; Sakari Kuikka; Guo-Qing Li; Paul Loiselle; Ricardo Moran Lopez; Massimo Lorenzoni; John Lundberg; G. Maiorana; Mearelli Mario; Petr Mashkin; Jascha Minnow; Rolando Muñoz; Daniel Paz; Tadeusz Penczak; Winston Ponder, Didier Pont; King Yue Poon; Asad Rahmani; T. V. Ramachandra; Patrick de Rham; Jon Paul Rodriguez; Richard Ruggiero; Tyson Roberts; Vladimir Sal'nikov; Scott Schaefer; Guiseppe Notarbartolo di Sciara; Melanie Stiassny; Glenn Switkes; Henne Ticheler; Cor de Van; Richard Vari; Lorenzo Vilizzi; Mauricio Zárate Villareal; Asbjørn Vøllestad; Lee White; Rick Winterbottom; Christian Wolter; Ted Zimmerman

ACKNOWLEDGEMENTS

WCMC is particularly grateful to numerous colleagues (see above) who have kindly provided information used in this report. Not all have had the opportunity to review our use of information provided; any errors, omissions or inconsistencies are the responsibility of WCMC. Special thanks are due to Rob Lesslie (ANU), for providing data resulting from his global wilderness analysis, and to a number of field and museum colleagues working on freshwater biodiversity.

Many thanks also to Pat Foster-Turley (formerly coordinator, IUCN-SSC Freshwater Biodiversity Initiative) for facilitating involvement of the SSC Specialist Groups on Molluscs and Inland Water Crustaceans.

Part of the data compilation on fish diversity at catchment level was first carried out for the World Resources Institute (WRI), who kindly allowed further use of the data here. We also are indebted to the many people who made time to provide data on fish diversity in major rivers, or advice on data sources. We are especially grateful to Dr Hamdallah Zedan (UNEP, Nairobi) for his interest in this study and for providing support. Thanks also to Paul Akiwumi (Water Branch, UNEP) for providing pertinent review comments. Part of this document is based on material first collated in a discussion paper on freshwater biodiversity prepared by WCMC for the CBD Secretariat in 1996.

1. FRESHWATER SYSTEMS

THE IMPORTANCE OF WATER

Water has the central role in mediating global-scale ecosystem processes, linking atmosphere, lithosphere and biosphere by moving substances between them and enabling chemical reactions to occur. Natural waters are never pure H_2O but a complex and ever-changing mixture of dissolved inorganic and organic molecules and suspended particles.

Water is by far the most abundant single substance in the biosphere. It is unique or extreme in most of its physical properties and these are the basis of its biological importance. Living cells are around 75% water; liquid water is essential for life processes and organisms must obtain water, in amounts broadly proportional to size, from their environment. Spatial and temporal differences in the availability of water and its solutes are important determinants of ecosystem richness

At the Earth's surface, freshwater forms the habitat of large numbers of species. These aquatic organisms and the ecosystems in which they participate represent a substantial sector of the Earth's biological diversity.

Water as a resource has two key features:

- it is absolutely essential for human survival,
- the amount of water in the world is constant, so that although it is used, the stock is not globally diminished but nor can it be increased.

At below global level, water is often not available where and when needed, nor in the appropriate amounts, nor with the necessary quality. The two last are particularly important to the maintenance of freshwater biodiversity.

The finite supply of freshwater on the Earth is now being used by a human population that has grown exponentially in the past few hundred years, and continues to grow, and which demands increasing volumes of water to service agricultural and industrial processes on which economic development depends. Freshwater systems are under growing pressure, as flow patterns are disrupted and the load of waste substances increases. Inevitably *per capita* shares of water for human use are decreasing and water stress is becoming more widespread (UN, 1997).

Agriculture consumes around 70% of all water withdrawn from the world's rivers, lakes and groundwater (FAO, 1996b). In places, more than half the water diverted or pumped for irrigation does not actually reach the crop, and problems of waterlogging and salinisation (deposition in soil of salts left by evaporation of pumped groundwater) are increasing. However, irrigated agriculture produces nearly 40% of world food and other agricultural commodities on only 17% of the total agricultural land area, and is thus disproportionately important to global food security (FAO, 1996b).

THE WORLD WATER RESOURCE

The total volume of water on Earth has been estimated at around 1,500,000,000 km^3. Salt water in the world's oceans and seas accounts for almost all, perhaps 97%, of the total volume. Freshwaters make up most of the remaining 3%; this component consists largely of water in the form of polar ice (mostly Antarctica) and groundwater. See Table 1.

Table 1. The world water resource

	Area million km^2	**% total area**	**Volume million km^3**	**% total water**	**% fresh water**
Earth surface	510				
land	149	29			
world ocean	361	71	1338	96.5	
fresh water:	-	-	35	2.5	
ice	16	-	24	1.75	69
ground water	-	-	10.5	1.7	30
wetlands *	2.6	-	0.1	0.0008	0.03
lakes **	1.5	-	0.09	0.007	0.26
rivers	-	-	0.02	0.0002	0.006

Notes: 1) all estimates are approximations and vary according to the methods used to derive them; for consistency we have taken data from a single source. * in the traditional sense, ie. marshes, swamps, mires, lagoons, floodplains etc; ** excluding saline lakes.
Source: Anon. (USSR Committee for the International Hydrological Decade) 1978.

The world water cycle is the overall process by which water is redistributed between sources and sinks, with more or less transient residence in rivers, lakes and living organisms. Water is moved over the Earth by rivers, by ocean currents and (manifest in weather patterns) by circulation of the atmosphere.

Over the oceans, evaporation exceeds input from rivers and rainfall, and over land, precipitation exceeds evaporation, but at global level a broad balance exists between the volume of water entering the atmosphere as water vapour and the volume leaving it as precipitation. Sub-globally there is considerable variation in the distribution of water, eg. there is about twice as much atmospheric water in equatorial than in temperate latitudes

Groundwater, ie. water below the Earth's surface held within rocks or between rock strata constitutes perhaps 30% of global freshwater resources. The more superficial deposits are linked to the global water cycle, and are used for human consumption or agricultural purposes, whereas the deeper layers tend to be somewhat saline and do not (except over geological time scales) participate in exchanges with other parts of the system.
Water in lakes and rivers constitutes less than one-hundredth of one percent (<0.01) of the world's total water volume; lake water is the largest component in this vanishingly small subtotal.

Water passing through an area of land is available either in the form of soil moisture ('green water') where it is used in production of natural or agricultural plant biomass, or in aquifers or surface systems ('blue water') where it is a component of aquatic ecosystems and is used for human social and economic production.

Table 2. Distribution by continent of freshwater resources

	Africa	Europe	Asia	Australia*	N. Am.	S. Am.
large lakes	30,000	2,027	27,782	154	25,623	913
rivers	195	80	565	25	250	1,000
reservoirs	1,240	422	1,350	38	950	286
ground water	5,500,000	1,600,000	7,800,000	1,200,000	4,300,000	3,000,000
wetlands **	341,000	'Eurasia'	925,000	4,000	180,000	1,232,000

Notes: 1) data refer to volume in km^3, except for wetlands which refer to area in km^2. 2) all estimates are approximations and vary according to the methods used to derive them; for consistency we have taken figures from a single source. * The 'Australia' column variously includes New Zealand or Oceania as well as Australia; ** in the traditional sense, ie. marshes, swamps, mires, lagoons, floodplains etc.
Source: Anon. (USSR Committee for the International Hydrological Decade) 1978.

There are very large regional differences in the distribution of freshwater in all its forms, depending on the volume of precipitation and the area and geomorphology of continental land surfaces, and deep geology, in the case of groundwater reserves (see Table 2). For example, South America has few lakes - only about one twentieth of the lake volume average for other continents, but around four times as much water flowing in rivers, and a very large total wetland area (this high discharge volume may underlie the extreme diversity shown by Amazon fishes).

WATER QUALITY

In contrast to the World Ocean, which is relatively uniform in composition over very large distances, waters on the Earth's surface vary widely over short distances, according to catchment geology, land cover and climate, and the materials of anthropogenic origin introduced to them.

Important variables affecting water composition include: solubility and weather resistance of basin rocks, distance from the marine environment (aerosol source), aridity, nutrient flow through basin vegetation, temperature, and uplift rates. Some watercourses are naturally unfit or poorly suited for some human uses, including drinking (Meybeck and Helmer, 1989).

Anthropogenic changes in water quality are superimposed on the natural background variations. A similar sequence of water quality issues became apparent in both Europe and North America during rapid socio-economic development over the past 150 years. Problems of faecal and other organic pollution were evident in the mid-19th century, followed by salinisation, metal pollution, and eutrophication in the first half of the 20th century, with radioactive waste, nitrates and other organic micropollutants, and acid rain most prominent in recent decades (Meybeck and Helmer, 1989). At the same time, the scale of water quality problems tends to increase from local to regional and global. Newly-industrialising countries are likely to face these problems over a much more compressed period, and typically without the capacity to monitor and analyse water quality, or manage water use appropriately.

Table 3. Major water quality issues in different systems

	rivers	lakes	reservoirs	groundwater
organic micropollutants	•••	•••	•••	•••
trace elements	•••	•••	•••	•••
organic matter (exogenous)	•••		•••	
eutrophication		•••	•••	
acidification		•••	•••	
pathogens	•••			
dams, diversions etc	•••			
suspended solids	•••			
nitrate				•••
salinisation				•••

Note: ••• indicates severe or global or significant regional deterioration, absence of symbol indicates not globally important, but may be of local significance.
Source: modified after Chapman (1992).

Levels of organic micropollutants (organochlorine pesticides, polychlorinated biphenyls, inductrial solvents) and of trace elements (mercury, arsenic, cadmium, copper, etc) give rise to water quality problems worldwide in the four main classes of water system (Table 3) (Chapman, 1992; UNEP, 1991, 1995). With regard to quality for human use, contamination by pathogens of faecal origin is the major problem in river systems, and eutrophication probably the most widespread problem affecting lake and reservoir waters.

RIVERS AND CATCHMENT BASINS

A river system is a complex but essentially linear body of water draining under the influence of gravity from elevated areas of land toward sea level. The typical drainage system consists of a large number of smaller channels at higher elevation merging as altitude falls into progressively fewer but larger channels, which in simplest form discharge by a single large watercourse. Most such systems discharge into the coastal marine environment; some discharge into lakes within enclosed inland basins; a few watercourses in arid regions enter inland basins where no permanent lake exists.

The source area of all the water passing through any given point in the drainage system is the *catchment* area for that part of the system. In parallel with the hierarchical aggregation of tributaries of the major river system, sub-catchments aggregate into a single major catchment basin; this is the entire area from which all water at the final discharge point of the system - ie. usually the sea - is derived. Strictly, the *watershed* is the line of higher elevation dividing one catchment basin from another, but this term is increasingly used as a synonym of catchment.

The speed and internal motion of river water depends largely on water volume and the shape of its channel. These factors typically differ greatly through the river system, from narrow, steep and fast upland feeder streams, to broad level and slow downstream reaches. Combined with differences in depth, riparian vegetation, seasonal variation in flow, and other factors, there is a great variety of potential habitats. Different organisms within the system tend to be adapted to different sectors of it, with consequent differences in form and function.

Two features are of primary importance with respect to the habitat quality of a river:

- materials, such as nutrients, pollutants or sediment particles are capable of entering the drainage system from any point within the watershed boundary of that system, and

- dissolved substances or particles are transported in a downstream direction and so can have an effect far distant from the point of entry (eg. sediment particles derived from watershed slopes can be carried into the coastal and marine environment where they frequently have an adverse effect on local habitats).

A large river and its drainage basin make up a large-scale ecosystem, with both terrestrial and aquatic components, which must be addressed in an integrated manner for management interventions to have a chance of success; ie. the catchment is the basic unit of management at the landscape scale.

THE AGE OF FRESHWATER SYSTEMS

Freshwater habitats are widely considered to be transient in time and space in comparison with both terrestrial and marine habitats. This is broadly true, certainly for very small or very shallow freshwater habitats. However, although individual water bodies vary in extent and persistence, the main types of freshwater habitat have probably existed since precipitation first fell on the Earth, and large rivers are probably much longer-lived as a class of systems than lakes (Gray, 1988).

River systems can change course radically as a result of deposition and erosion of their channel, and the uplift and erosion of watershed uplands. Despite the dynamic physical state of these systems, large rivers rarely disappear, and although direct evidence is scarce, indications are that some have been in continuous existence for tens of millions of years. This is consistent with the fact that running waters include representatives of almost all taxonomic groups found in freshwaters, and that several invertebrate taxa occur only in running waters or attain greatest diversity there.

The great majority of existing lakes, of which around 10,000 exceed 1 km^2 in extent, are geologically very young, and occupy basins formed by ice masses or glacial erosion during recent ice ages (Gorthner, 1994). These lakes date from the retreat of continental ice-sheets some 10,000 years before present. All such lakes are expected to fill slowly with sediment and plant biomass, and to disappear within perhaps the next 100,000 years along with any isolated biota.

Only about 10 existing lakes are known to be much older (Gorthner, 1994; and see Table 15), and most of these occupy basins formed by large scale subsidence of the Earth's crust, dating back to at most 20 million (Lake Tanganyika) or 30 million (Lake Baikal) years before present.

There is good evidence that some extinct lake systems in the geologic past were very large and very long-lived under different climatic and tectonic conditions. In general, the long-lived lakes are of particular interest in terms of biodiversity because these systems tend to be rich in species of several major groups of animals and many of these species are restricted to a single lake basin.

USES OF FRESHWATER SYSTEMS AND SPECIES

Humans rely heavily on biological resources in freshwaters, and use freshwater systems for a wide range of purposes. A large river provides a moving and apparently endlessly renewable stream of water, for transport, water supply, waste disposal, and from which food and hydroelectric energy can be extracted.

In addition to utilitarian benefits derived from freshwaters and freshwater biodiversity, humans also derive many benefits from freshwater systems as elements in the landscape, particularly so in wildlands, but also in highly modified agricultural or urban settings. The aesthetic and cultural benefits are derived in part from the visual appearance of the system in the landscape setting, and may not depend directly on the health of freshwaters, or the levels of biodiversity therein.

The principal use of freshwater species, not considering properties of aquatic systems themselves, is as food. Subsidiary uses include the aquarium trade, materials for medicinal or ornamental use, and as fertilizer. For many human communities, particularly in countries less-developed industrially, capture fisheries provide a major portion of the diet. Finfishes aside (see below), other exploited animal groups in inland waters are far less important globally but may still be highly significant (see Table 4).

Table 4. Animal groups exploited in inland waters

group		use
crustaceans	crayfishes, shrimps	food
molluscs	mussels, clams	food, pearls
frogs	mainly Ranidae	food
crocodilians		food, leather, ranch stock
chelonians	turtles, especially softshells (Trionychidae)	food, medicinal products (esp. E Asia)
waterfowl	ducks, geese, and others	food, sport hunting
fur-bearing mammals	beavers *Castor*, otters (subfamily Lutrinae) and muskrats (*Ondatra zibethicus*, *Neofiber alleni*),	skins
sirenians	manatees (Trichechidae)	food, also used on a small scale for biological control of weeds

Relatively few plants associated with inland waters are heavily exploited in the wild state; most are marginal or wetland species. Some (eg. *Aponogeton* spp. in Madagascar) are collected for use as ornamentals; reeds are used as building materials (eg. thatch); and some are collected for food or as medicines (eg. *Spirulina* algae). Rhizomes, tubers and seeds (rarely leaves) of aquatic and wetland plants are used as a food source, mainly in less developed regions where they can be important to food security in times of shortage, but globally they make a relatively minor contribution to human nutrition. Most important are some forms of edible aroid (Araceae), notably some cultivars of *Colocasia* (taro) and the giant swamp taro *Cyrtosperma chamissonis* which grow in flooded conditions and are important food crops in the Caribbean, West Africa and the Pacific islands. Conservation and collection of wild forms of these is considered a high priority. Sago Palms *Metroxylon* spp. in southeast Asia and the Pacific and Watercress *Rorippa nasturtium-aquaticum* in Europe are other examples of cultivated aquatic plants whose wild relatives merit conservation.

Rice is the major cultivated wetland plant, and provides the staple food of around half the world's people. Most current strains are based on Asian Rice *Oryza sativa* and African Rice *O. glaberrima*. Worldwide, more than 500 million metric tonnes of rice are produced each year, from around 150 million hectares; most production is based on rice paddies, which form an important artificial wetland ecosystem in the tropics, especially in Asia. There are about nineteen species in the genus *Oryza*; wild populations of some are in decline but varieties of *O. sativa* are well represented in germplasm collections, notably at the International Rice Research Centre in the Philippines.

Aquatic plants have been widely used for medicinal purposes, documented for at least two millennia, but such use appears at present to be minor and probably of real significance in few areas. However, interest in ornamental or aquarium water plants is very widespread and of some economic importance.

The true value to humans of different inland water ecosystems can only be estimated by seeking more comprehensive means of evaluating these systems in economic, social and cultural terms, so as to take account of the less tangible values of ecosystem goods and services, including those provided by biological diversity. A recent attempt to ascribe a global value to ecosystems (Costanza *et al.*, 1997) estimated mean values per hectare of major ecosystem types, taking as many of these less tangible factors as possible into account. Of non-marine ecosystems, wetlands (average value US$ 14,785 per hectare) and lakes and rivers ($8,498 per ha) were several times more valuable per unit area than terrestrial ecosystems such as forests ($969) and grasslands or rangelands ($232). Taken together, inland water ecosystems were estimated to contribute more to total global flow value (US$ 6579 x 10^9 per year) than all other non-marine ecosystems combined (US$ 5740 x 10^9 per year) despite their far lesser extent. This provides a strong case for effective conservation management of extant inland water ecosystems.

FRESHWATER FISHES AS FOOD

Where countries have access to both marine and inland aquatic resources, reported yield from inland waters is a small fraction of marine yield, a pattern reflecting the higher productivity of marine shelf waters and reinforced by weak marketing and distribution infrastructure for freshwater catch. Even in land-locked countries, the recorded inland harvest is often, but not always, low both in absolute size and in relation to consumption of meat and other agricultural produce.

The total inland water fishery production has two components: capture fisheries and aquaculture. National statistics do not adequately reflect the actual magnitude or location of inland fisheries. The reported inland capture production is certainly an under-estimate because much of the catch is made far from recognised landing places where catches are monitored, and is consumed directly by fishers or marketed locally without ever being reported. The evidence suggests that actual capture fisheries catch may be twice the reported total, ie. around 12 million mt per year (Coates, 1995), and inland waters are suspected by some to provide food (as opposed to oils and meals) in amounts not much less than the recorded marine catch (Borgström, 1994).

Inland water capture fisheries, particularly in countries less-developed industrially, do provide a staple part of the diet for many human communities. This is the case in West Africa generally, locally in East Africa, and in parts of Asia and Amazonia. In some land-locked countries inland fisheries are of crucial importance, providing more than 50% of animal protein consumed by humans in Zambia (Scudder and Conelly, 1985), and nearly 75% in Malawi (Munthali, 1997). Fish protein may be critical in times of food stress. It is impossible at present to develop a global view of the rôle of inland fisheries because these operate mainly at artisanal and local level in rural areas, in general far outside the scope of available statistical data.

Table 5 shows reported inland fishery data for a selection of countries. It should be noted that two-thirds of the 30 countries showing the highest apparent per capita consumption of inland fish are classed as LIFDs (low income food-deficit countries), and around half of those with the highest catch. Bangladesh is foremost

Table 5. Inland water fish: select data on catch and consumption

	annual catch	LIFD	mt	apparent consumption	LIFD	mt/cap.
1	China	+	13,752,283	Finland		10.79
2	India	+	3,151,988	Tanzania	+	9.99
3	Indonesia	+	1,172,772	Uganda		9.89
4	Bangladesh	+	969,224	Hong Kong		9.66
5	Peru		581,170	Macau		9.49
6	USA		567,608	Zambia	+	8.66
7	Viet Nam		423,516	Turkestan	+	8.21
8	Romania		406,330	Congo	+	7.44
9	Philippines	+	350,202	Bangladesh	+	6.82
10	Tajikistan	+	306,467	Malawi	+	6.70
11	Tanzania	+	295,333	Cambodia	+	6.69
12	Japan		271,762	Norway		6.34
13	Egypt	+	255,915	Laos	+	6.25
14	Myanmar		243,682	China	+	6.07
15	Brazil		238,438	Japan		5.89
16	Uganda		232,090	Mali	+	5.87
17	Syria	+	200,141	Chad	+	5.70
18	Taiwan		198,322	Kenya	+	5.46
19	Mexico		192,781	Korea D P R	+	5.06
20	Kenya	+	185,386	Azerbaijan	+	4.77
21	Zaire	+	168,668	Philippines	+	4.69
22	Ukraine		139,700	Thailand		4.58
23	Thailand		134,643	Iceland		4.45
24	Korea D P R	+	124,883	Cent Af Rep	+	4.12
25	Nigeria	+	124,148	Sierra Leone	+	4.06
26	Iran		117,791	Benin	+	3.82
27	Russia.		116,108	Burundi	+	3.63
28	France		111,388	Viet Nam		3.56
29	Italy		102,649	Indonesia	+	3.53
30	Germany		91,910	Senegal	+	3.52

Notes: data are annual means for 1990-1995; 'catch' includes aquaculture plus capture fisheries, only the 30 countries with the highest reported catch and calculated apparent consumption are shown; + = LIFD = low income food-deficit country.

Sources: calculated from data kindly supplied by Adele Crispoldi (Fishery Statistician, FAO).

among countries appearing in both lists; others include China, Indonesia, Viet Nam.

Overall inland capture production has risen moderately during the decade from 1984, around 1.7% annually, but there are significant regional differences. Inland production has declined in Europe and the former USSR, mainly because of deteriorating habitat quality and excess exploitation. In Asia, excluding new states of the former USSR, and in Africa, production has risen. However, this cannot be attributed to any improvement in the health of inland waters. Increase in Asia is attributed mainly to fisheries based on stocking of large artificial reservoirs created during recent rapid economic development, and increase in Africa is mainly due to capture fisheries in the Rift Lakes, where the introduced Nile Perch is the basis of a significant export trade system.

It is difficult rigorously to assess the condition of inland fish stocks because they appear able to respond rapidly to changing environmental conditions. However, there is a consensus that, regionally, most stocks are fully exploited and in some cases over-exploited.

Exploitation has become more efficient because of new technologies, and developing infrastructure has allowed easier access to freshwater resources. Some stocks, especially in river fisheries, appear to be in decline, but this is seemingly a result mainly of anthropogenic changes to the freshwater environment.

Inland fisheries, and freshwater biodiversity generally, do not receive sufficient attention in local, catchment-wide or national planning decisions. These sectors are often strongly impacted by decisions made in eg. the hydroelectric, navigational, flood control or agricultural development sectors, without reference to the need to maintain biodiversity or fishery production.

Salient features of inland water fisheries are summarised in Table 6.

THE IMPORTANCE OF INLAND CAPTURE FISHERIES FOR FOOD SECURITY

In recent years reported inland production has made up around 7% of the world total capture production. Despite this relatively low figure, and without taking account of under-reporting of inland capture, inland production has special significance because (Coates, 1995):

- many more people have access to inland waters than to coastal marine waters; gears for subsistence fishing do not have to be technologically advanced (although such equipment is increasingly available) and costly to purchase, and often many sectors of the community are involved in inland capture fisheries;

- a greater proportion of the inland catch appears to be used for direct human consumption, close to point of origin;

- some countries are land-locked and have no internal source of fish other than freshwaters;

- most of the marine catch is landed by highly industrialised fleets from a small number of countries but inland production exceeds marine landings in about 25% of reporting countries, including a large number of Low Income Food Deficit Countries;

- waste through discarded bycatch is large in marine fisheries but negligible inland.

INTERNATIONAL INLAND WATERS

Inland waters typically intersect several subnational administration units (counties, provinces, etc) and are subject to management and use decisions made within several different sectors (forestry, navigation, fishery, waste disposal, recreation, etc). Although it has been recognised for some time that the catchment basin is the fundamental unit within which management must be formulated, reconciling the many different interests concerned and coordinating actions have proved difficult.

Waters that delineate or cross international boundaries present a special class of management issues. Such waters and the living resources they contain are shared by one or more countries, and require positive international collaboration for effective use and management.

Available water in any given country within an international basin (or other administrative unit within a basin more generally) can be divided into endogenous, ie. locally generated runoff available in national aquifers and surface water systems, and exogenous, ie. remotely generated runoff imported in flow from upstream. Some countries (eg. Canada, Norway) have an abundance of water from endogenous sources, others (eg. Egypt, Iraq) have a small endogenous supply but large exogenous volumes (others have small supplies from both sources). Use of exogenous water carries an increasing risk because of dependence on sufficient supply from upstream countries.

The United Nations Register of International Rivers (Anon., 1978) recognised 214 major international river basins in 1978. Since that time, fragmentation of some previous country units, eg. the USSR, has compounded problems of international cooperation by increasing the number of countries having a share of international inland waters. A preliminary revised listing of countries within basins included in the present assessment is incorporated in Annex 1.

Table 6. Summary of key aspects of continental freshwater fisheries

Features	Issues
AFRICA	
Africa below the Sahara has a large variety of inland water bodies, including upland crater lakes, rift lakes, and major floodplain rivers. Fisheries make an important contribution to food security in sub-Saharan Africa, and almost all production is consumed within the region. Nigeria, Zaire, and East Africa (Kenya, Uganda, Tanzania) contribute most to overall reported catch. Inland fisheries in North Africa very small; most production in Egypt, based on the Nile and L. Nasser. Continent catch has increased up to 1990 and then levelled.	Catch in many areas is subject to great annual fluctuation depending on extent of drought or flood. Exploitation of natural stocks is high (but below estimated total potential catch at continent level). Fishing pressure is increasing and most fisheries show signs of intensive exploitation.
Floodplain fisheries, especially around L. Chad and the inland delta of the Niger, dominate production in West and Central Africa and the Sahelian region. Floodplain systems tend to allow rapid stock recovery after heavy exploitation and there is no overall evidence of excess harvest.	The number of fishers using the inland Niger delta in Mali has risen over the two decades to 1990 and there are signs of local over-fishing. The artificial L. Volta in Ghana, with a steady total annual yield but greatly reduced individual catch by an increasing number of fishers.
Production in Eastern Africa is based mainly on natural lakes, the larger of which are shared between countries. The largest fishery by far (around 25% of total inland production in Africa) is for Nile Perch in L. Victoria, and this generates significant export earnings. Easy access, good transport and market proximity mean that most waters are exploited at or above maximum sustainable levels, eg. in Rwanda and the Malawi sector of L. Malawi.	There is an increasing need for management of inland fisheries. Remote regions and lake stocks of small pelagics may provide for increased production from natural sources.
Inland fisheries mostly remain at small-scale artisanal level, which is advantageous in that it tends to maintain social patterns in waterside communities while avoiding the drive to over-exploitation characteristic of many commercial fisheries.	Large lakes are increasingly subject to pollution, including waste discharge and siltation. Many lakes have very clear water and high fish production based on a deep zone of primary production, but land conversion to agriculture in catchment areas, leading to increased turbidity, is an increasing concern.
	Floodplains and other wetlands are continually at risk from agricultural expansion. Damming on the Senegal River has restricted fish movement and low flow in drought conditions reduces production.
NORTH AMERICA	
The recreational catch appears to greatly exceed commercial catch, and considerable resources are devoted to environmental restoration and the maintenance of sport fish stocks.	Damming, drainage, pollution and sedimentation have led to a widespread and locally severe decline in the health of fish stocks in North America during the 20th century. This has been marked in western USA, where several species extinctions have occurred. Intensive management directed in part at sport fisheries has locally reversed this trend.
Non-recreational fisheries are based mainly on the Great Lakes region and on migratory salmon stocks. The latter are particularly important for indigenous people in the northeast Pacific and northwest Atlantic.	

Features	Issues
SOUTH AMERICA, CENTRAL AMERICA	
Because of strong traditional preference for meat, fish consumption in the continent as a whole is relatively low. Total reported catch relatively low although region includes two of the world's largest drainage basins (Amazon, Parana-Paraguay). Small-scale river and lake fisheries are locally important to food security. Fisheries in the tropics largely based on rivers; but in cooler and cold temperate southern areas, and mountains, lakes and reservoirs more important. 'Black water' systems, draining lowland forests tend to have low productivity; higher in 'white water' systems draining uplands. Fisheries often artisanal, but heavily commercial on the Amazon with some features of marine fisheries (over-capitalisation, local over-exploitation). Inland catch near zero in Caribbean region due to lack of suitable waters. Cuba has a nutritionally important, stable and well managed fishery based on stocked reservoirs (largely reported as aquaculture). Lake eutrophication may be cause of increased catch in El Salvador, and in Mexico systematic stocking of alien fishes has increased catch.	Overall catch rose up to late 1980s then declined somewhat. Fisheries dominated by characins and catfishes, but introduced species (tilapia, black bass, carp) becoming important. Over-fishing is evident locally. Catch from Amazon system appears well below potential, but reported catch is mostly from the river mouth and around urban centres. A significant part of total catch in Brazil is from hydro impoundments, eg. on the Upper Parana. Reported catch in Bolivia is relatively low, based mainly on the Amazon system, the Pilcomayo, and a small fishery on Lake Titicaca (shared with Peru). Recent decline in Colombia has been attributed to excess catch and local pollution. Mineral extraction has major impact on rivers and lakes. Waste copper, zinc, cadmium apparently responsible for fishery decline in Lake Poopo (Bolivia). Mercury, used in gold extraction, is accumulating in river fishes and being widely dispersed, eg. in the Araguaia basin (Brazil). Agriculture is seen as major pollution source (silt, pesticides, fertilizer). Farming communities in floodplain areas turning increasingly to fishing because of land competition with ranchers and falling commodity prices.
ASIA	
Reported catch highest of all continent regions, showing a steady increase to peak around 1990, but catch statistics are relatively poor. Inland fisheries are especially important in several countries in the region, notably Bangladesh and Cambodia, where inland harvests exceed marine catch. China alone produces around half the world total reported yield from inland capture fisheries, and around 80% of aquaculture yield; but stocking of rivers contributes greatly to capture catch (and begins to erase the distinction between capture and aquaculture). Recent upward trends in reported inland catch in China appears to be due to stock enhancement of lakes and reservoirs (often with attempts to eradicate natural predators).	Up to one half of the inland catch in Bangladesh is based on *Hilsa* (a clupeid fish that migrates upstream to spawn) but stocks have declined upstream because of barrages on the lower Ganges. Natural fisheries in India are in some decline but in South Asia generally stocking of reservoirs and controlled fishing have supplied an increasing proportion of total inland catch. In Cambodia, the major part of the inland catch is derived from Tonle Sap lake and surrounding floodplains, but the yield has declined since the 1960s, apparently because of excess exploitation and environmental degradation, including silting up of drainage systems following forest clearance and agricultural conversion. River fisheries have in general been severely degraded by development pressures and water quality is widely too poor to sustain fisheries.

Features	Issues
EUROPE	
Catches have risen in western Europe although inland resources are not of great economic importance to most countries. The volume of fish production is low to moderate, contributing around 16% of the world production. The species diversity of the catch is low. Eastern Europe is a major producer due in part to the extensive resources of the Danube delta, also to traditional use of fishponds Recreational fishing is, or is becoming, the major component and consumption is typically on a modest scale, largely for local use. It appears that there has been a decline in production from these fisheries, however, recreational fishing remains largely undocumented. Aquaculture production has fallen somewhat. A rise is expected within the transitional countries of Eastern Europe. The development of these may be constrained by size availability	There has been a rise in recreational fishing and this has caused a conflict with those still utilising the resources at a commercial level. European rivers have faced a decline in stocks due to pollution from industrial effluent, domestic sewage and agricultural run off. Many basins have been affected by damming, creating problems for migratory species . Most lakes have undergone severe environmental degradation over the last decade. Many have become eutrophic due to pollution and the fish populations reflect this, although many (such as Lake Geneva) now have management programmes which aim to combat the pollution. The demand for fish remains higher than production and the import of fish from other continents will continue to be necessary.

Notes: this table outlines key features of inland water fisheries and is a highly selective and simplified overview of a complex subject with a vast technical literature.
Sources: information derived mainly from FAO (1996) and Coates (1995).

2. BIODIVERSITY IN FRESHWATERS

SPECIES NUMBERS IN FRESHWATERS

At high taxonomic levels the diversity of freshwater organisms is much narrower than on land or in the sea: no extant phyla or classes, and few orders, are restricted to freshwater habitats. The number of species overall (species richness) is low compared with marine and terrestrial groups. However, species richness in relation to habitat extent is extremely high in many freshwater groups.

For example, about 10,000 (40%) of the 25,000 known fish species are freshwater forms. Given the distribution of water on the Earth's surface this is equivalent to one fish species for every 100,000 km^3 of sea water, compared with one species for every 15 km^3 in freshwaters. This high diversity of freshwater fishes relative to habitat extent is probably promoted by the extent of isolation between freshwater systems. Many lineages of fishes and invertebrates have evolved high diversity in certain water systems, and in some cases, species richness and endemism tend to be positively correlated between different taxonomic groups (eg. Watters, 1992).

At global level, species richness increases strongly toward the equator; ie. in most groups of organisms, there are many more species in the tropics than in temperate regions. The same applies to freshwater fishes in general and to other groups in freshwaters, although certain groups, eg. freshwater crayfish, are much less diverse in the tropics than temperate regions. The number of fish species present in rivers is highly correlated with the area and annual discharge of the drainage basin (especially the latter).

Table 7 provides an outline of the major groups of plants and animals present in freshwaters. There are more than 600 species of freshwater fungi known, currently more from temperate regions than from the tropics, although probably only a small fraction of existing species have been described, and the tropics have been little sampled (Goh and Hyde, 1996). There is no group of plants as diverse and species-rich in freshwater habitats as fishes, bivalve molluscs, dragonflies and other animal groups. Although important along water margins, and sometimes on the water surface, plants other than microscopic forms are in general nowhere as prominent in freshwater ecosystems as animals.

Table 7. The major groups of organisms in freshwater

General features	Significance in freshwaters
Viruses	
Microscopic; can reproduce only within the cells of other organisms, but can disperse and persist without host.	Cause disease in many aquatic organisms, and associated with water-borne disease in humans (eg. hepatitis).
Bacteria	
Microscopic; can be numerically very abundant, eg. 1,000,000 per cm^3, but less so than in soils. Recycle organic and inorganic substances. Most derive energy from inorganic chemical sources, or from organic materials.	Responsible for decay of dead material. Present on all submerged detritus where a food source for aquatic invertebrates. Many cause disease in aquatic organisms and humans.
Fungi	
Microscopic. Recycle organic substances; responsible for decay of dead material; tend to follow bacteria in decomposition processes. Able to break down cellulose plant cell walls and chitinous insect exoskeletons.	Present on all submerged detritus where a food source for aquatic invertebrates. Some cause disease in aquatic organisms and humans.
Algae	
Microscopic and macroscopic; include variety of unicellular and colonial photosynthetic organisms. All lack leaves and vascular tissues of higher plants. Green Algae (Chlorophyta) and Red Algae (Rhodophyta) include freshwater species; Stoneworts (Charophyta) mostly freshwater.	Responsible for most primary production (growth in biomass) in most aquatic ecosystems. Free-floating phytoplankton main producers in lakes and slow reaches of rivers; attached forms important in shallow parts of lakes and streams.
Plants	
Photosynthetic organisms; mostly higher plants that possess leaves and vascular tissues. Mosses, quillworts, ferns important in some habitats. Some free-floating surface species (eg. Water Fern *Salvinia*, Duckweed *Lemna*); most are rooted forms restricted to water margins.	Provide a substrate for other organisms and food for many. Trees are ecologically important in providing shade and organic debris (leaves, fruit), structural elements (fallen trunks and branches) that enhance vertebrate diversity, in promoting bank stabilisation, and in restricting or modulating flood waters.
Invertebrates: protozoans	
Microscopic mobile single-celled organisms. Tend to be widely distributed through passive dispersal of resting stages. Attached and free-living forms; many are filter-feeders.	Found in virtually all freshwater habitats. Most abundant in waters rich in organic matter, bacteria or algae. Feed on detritus, or consume other microscopic organisms; many are parasitic on algae, invertebrates or vertebrates.
Invertebrates: rotifers	
Near-microscopic organisms; widely distributed; mostly attached filter-feeders, some predatory forms.	Important in plankton communities in lakes and may dominate animal plankton in rivers.
Invertebrates: myxozoans	
Microscopic organisms with complex life cycles, some with macroscopic cysts. Formerly classified with protozoa but are metazoa.	Important parasites in or on fishes.

General features	Significance in freshwaters
Invertebrates: flatworms	
A large group of worm- or ribbon like flatworms, includes free-living benthic (Turbellaria), and parasitic forms (Trematoda, Cestoda).	Turbellaria include mobile bottom-living predatory flatworms. The Trematodes includes various flukes, such as the tropical schistosome that causes *bilharzia*; Cestodes are tapeworms: both these groups are important parasites of fishes and other vertebrates including humans. Molluscs often intermediate hosts.
Invertebrates: nematodes	
Generally microscopic or near-microscopic roundworms.	May be parasitic, herbivorous or predatory. Typically inhabit bottom sediments. Some parasitic forms can reach considerable size. Poorly known; may be more diverse than recognised.
Invertebrates: annelid worms	
Two main groups in freshwaters; oligochaetes and leeches.	Oligochaetes are bottom-living worms that graze on sediments; leeches are mainly parasitic on vertebrate animals, some are predatory.
Invertebrates: molluscs	
Two main groups in freshwaters; Bivalvia (mussels etc) and Gastropoda (snails, etc). Very rich in species; tend to form local endemic species.	Snails are mobile grazers or predators; bivalves are attached bottom-living filter-feeders. Both groups have speciated profusely in certain freshwater systems. The larvae of many bivalves are parasitic on fishes. Because of the feeding mode, bivalves can help maintain water quality but tend to be susceptible to pollution.
Invertebrates: crustaceans	
A very large Class of animals with a jointed exoskeleton often hardened with calcium carbonate.	Include larger bottom-living species such as shrimps, crayfish and crabs of lake margins, streams, alluvial forests and estuaries. Also larger plankton: filter-feeding Cladocera and filter-feeding or predatory Copepoda. Many isopods and copepods are important fish parasites.
Invertebrates: insects	
By far the largest Class of organisms known. Jointed exoskeleton. The great majority of insects are terrestrial, because they are air-breathing.	In rivers and streams, grazing and predatory aquatic insects (especially larval stages of flying adults) dominate intermediate levels in food webs (between the microscopic producers, mainly algae, and fishes). Also important in lake communities. Fly larvae are numerically dominant in some situations (eg. in Arctic streams or low-oxygen lake beds), and are vectors of human diseases (eg. malaria, river blindness).
Vertebrates: fishes	
More than half of all vertebrate species are fishes. These are comprised of four main groups: hagfishes (marine), lampreys (freshwater or ascend rivers to spawn), sharks and rays (almost entirely marine), and ray-finned 'typical' fishes (>8,500 species in freshwaters, or 40% of all fishes).	Fishes are the dominant organisms in terms of biomass, feeding ecology and significance to humans, in virtually all aquatic habitats including freshwaters. Certain water systems, particularly in the tropics, are extremely rich in species. Many species are restricted to single lakes or river basins. They are the basis of important fisheries in inland waters in tropical and temperate zones.

General features	Significance in freshwaters
Vertebrates: amphibians	
Frogs, toads, newts, salamanders, caecilians. Require freshwater habitats.	Larvae of most species need water for development. Some frogs, salamanders and caecilians are entirely aquatic; generally in streams, small rivers and pools. Larvae are typically herbivorous grazers, adults are predatory.
Vertebrates: reptiles	
Turtles, crocodiles, lizards, snakes. All crocodilians and many turtles inhabit freshwaters but nest on land. Many lizards and snakes occur along water margins; a few snakes are highly aquatic.	Because of their large size, crocodiles can play an important role in aquatic systems, by nutrient enrichment and shaping habitat structure. They, as well as freshwater turtles and snakes are all predators or scavengers.
Vertebrates: birds	
Many birds, including waders and herons, are closely associated with wetlands and water margins. Relatively few, including divers, grebes and ducks, are restricted to river and lake systems.	Top predators. Wetlands are often key feeding and staging areas for migratory species. Likely to assist passive dispersal of small aquatic organisms.
Vertebrates: mammals	
Relatively few groups are strictly aquatic (eg. River Dolphins, platypus), several species are largely aquatic but emerge onto water margins (eg. otters, desmans, otter shrews, water voles, water oppossum, hippopotamus).	Top predators, and grazers. Large species widely impacted by habitat modification and hunting. Through damming activities, beavers play an important role in shaping and creating aquatic habitats.

Among the 'lower' (non-vascular) plants, the mosses and liverworts are virtually all terrestrial, although flourishing only in moist environments; but the larger algae are primarily aquatic. The larger algae comprise some 5,000 species in three major groups (the green, brown and red algae), the great majority of which are marine or brackish water forms ('seaweeds'). The green algae Chlorophyta include one order of around 80 species (Ulotrichales) that is mainly freshwater. However, one major group sometimes associated with the green algae - the stoneworts (Charophyta) - is almost entirely freshwater. The stoneworts include some 440 species, most of which are endemic at continent level or below; they tend to be very sensitive to nutrient enrichment and have declined in many areas (Tittley, 1992).

The higher (vascular) plants include ferns and allies (pteridophytes), conifers and allies (gymnosperms) and flowering plants (angiosperms). It has been estimated that at most 2 percent of pteridophytes and 1 percent of angiosperms, ie. up to 250 and 2,500 species respectively, are aquatic forms (Sculthorpe, 1967). These groups together comprise around 400 families; only some 33 of these include aquatic species, and most of these are not rich in species. Most of these aquatic species occur in freshwaters but some 50 species of seagrass grow in shallow coastal marine habitats. Table 8 includes basic information on a small selection of the approximately 33 plant families that include freshwater species.

Table 8. Aquatic plants: a selection of species-rich or economically important groups

group	common name	spp no.	distribution	ecology
Charophyta	stoneworts	440	cosmopolitan	freshwater
Pteridophyta				
Salviniaceae	water ferns	10	tropical, warm temperate	freshwater, free-floating, some ornamentals, includes *Salvinia auriculata* a major weed pest in Africa, Sri Lanka and elsewhere
flowering plants				
Acoraceae	sweet flag	2	Old World, N America	aromatic marshland emergent herb, rhizomes widely used medicinally, leaves for scent, etc
Haloragidaceae	water milfoils, etc	145	cosmopolitan, especially southern hemisphere	freshwater aquatics or in moist areas, some shrubs, mostly herbaceous
Hydrocharitaceae	waterweed, frog's bit, etc	90	cosmopolitan, mainly tropical	freshwater, some marine' includes important aquarium plants and a some major weeds eg. *Elodea canadensis*
Nymphaeaceae	water lilies	75	cosmopolitan	freshwaters only; some ornamentals, some yield edible seeds and rhizomes
Podostemaceae		280	tropical, many species are narrow endemics	moss-like herbs of stony rivers, including hill torrents
Pontederiaceae	water hyacinth	34	tropical	freshwater, includes the world's most widespread and pestilential aquatic weed *Eichhornia crassipes*
Potamogetonaceae	pondweeds	100	cosmopolitan	fresh and brackish waters, food source for animals and sometimes humans
Trapaceae	water chestnut	15	Old World	freshwaters only, free-floating, fruits a staple food in parts of Asia

Note: This table includes basic information on a small selection of the few plant families that include freshwater species.
Source: based on data in Sculthorpe (1967) and Mabberley (1997).

Several species of aquatic plant, particularly free-floating species able to spread rapidly by vegetative growth, but also other forms, have dispersed widely over the globe and become major pest species. They block drainage channels, sluices and hydro-electric installations, impede boat traffic, and hinder fishing. In recent decades the question of how best to control or eradicate pest species has been the foremost issue in conservation and management of aquatic plants.

Animal species are considerably more diverse and numerous in inland waters than plants. Most of the major groups include terrestrial or marine species as well as freshwater forms. Apart from fishes, important groups with inland water species include crustacea (crabs, crayfishes and many smaller organisms), molluscs (including mussels and snails), insects (including stoneflies Plecoptera, caddisflies Trichoptera, mayflies Ephemoptera), sponges, flatworms, polychaete worms, oligochaete worms, numerous parasitic species in various groups, and numerous microscopic forms. Palmer *et al.* (1997) provide a review of diversity and the ecological rôle of microorganisms and microinvertebrates in freshwater sediments.

DISTRIBUTION PATTERNS OF FRESHWATER ORGANISMS

Freshwater lineages that originated within continental water systems may show general patterns of distribution similar to terrestrial groups, corresponding more or less to broad biogeographic realms. Lineages of marine origin may remain restricted to peripheral systems corresponding to the area where the ancestral forms moved into freshwater.

Unlike many terrestrial species, that can disperse widely in suitable habitat, the spatial extent of the range of strictly freshwater species tends to correspond to present or formerly continuous river basins or lakes; these species include fishes and most molluscs and crustaceans. Watersheds between river basins are the principal barriers to their dispersal between systems, and their ranges are extended mainly by physical changes to the drainage pattern (eg. river capture following erosion or uplift can allow species formerly restricted to one system to move into another), or by accidental transport of eggs by waterbirds, or by flooding.

In many instances, the range within a system will also be restricted by particular habitat requirements (variations in water turbulence or speed, shelter, substrate, etc). These frequently differ between different stages in the life cycle (eg. in fishes, different conditions and different sites are often required for egg deposition and development, for early growth of fry, and for feeding and breeding of adults).

Many cave or subterranean freshwater aquatic species (eg. of fishes, amphibians and crustaceans) have very restricted ranges, perhaps consisting of a single cave or aquifer, and very limited opportunities for dispersal, depending on the surrounding geology and the consequent morphology of the water system occupied.

Insects with an aquatic larval phase but a winged adult phase are often restricted to particular river basins (even if adults disperse widely, they may not find suitable habitat), but in general are much less restricted in this way than entirely aquatic species. A relatively large number of species, particularly of crustaceans, occupy temporary pools and have a desiccation-resistant stage that can undergo long-range passive dispersal between drainage basins; some such species are thus widely distributed.

Vascular plants are essentially terrestrial forms, and existing aquatic species are derived from terrestrial ancestors; several different lineages include aquatic species and this transition has therefore occurred several times. Most inland water plant species are relatively widespread, ranging over more than one continental land mass; many are cosmopolitan, occurring around the world and on remote islands. Of the widespread forms, some are essentially northern temperate species extending to a great or lesser extent into the tropics; some are mainly tropical. Tropical regions of Asia, Africa and South America appear to be most rich in species restricted to a single continent, or to a single country or smaller area (Sculthorpe, 1967).

The Podostemaceae is particularly noteworthy for its many monotypic genera, and a large number of narrowly endemic species, in at least one instance with several forms restricted to different stretches of a single river; tropical South America, Madagascar, Sri Lanka, India, Myanmar, and Indonesia hold such localised species (Willis, in Sculthorpe, 1967).

A large number of species have been spread by intentional or accidental human introductions to areas beyond their native range, and in many cases have occupied vast areas and had serious ecological impacts.

SPECIES DIVERSITY

The general goal of biodiversity conservation is to minimise loss of irreplaceable biodiversity. This not only includes individual species, but also habitats and ecosystems where these are known to be unlikely to regenerate naturally or difficult to restore artificially. The first step in planning for biodiversity conservation at any geographic scale is to assess the diversity of natural resources present and identify those which are most important, or in this context, most irreplaceable.

The species diversity of an area can be evaluated in different terms:

- an area with a large number of species (high *species richness*) can be described as more diverse than an area with fewer;
- an area with more species restricted to it (ie. more *endemics*), includes more diversity than one with few or none,
- an area with representatives of more higher taxa (ie. groups higher than species level, such as genera, families, or classes), is more diverse than one with fewer

- an area with more phylogenetically 'primitive' taxa (eg. lungfishes or sturgeon among fishes) is more diverse than areas with representatives only of more recent radiations.

A collation and analysis of expert opinion on the location of areas of special importance for inland water biodiversity, assessed in terms of species richness and endemism, is provided in Chapter 4 of this document.

Species diversity is not the sole criterion to be used in prioritising species or sites for conservation action. Human attitudes and values also determine the significance attached to elements of biodiversity: areas supporting species threatened with extinction, or which are consumed or which yield important commodities, may with justification be rated more highly than areas not supporting such species.

3. STATUS, TRENDS AND THREATS

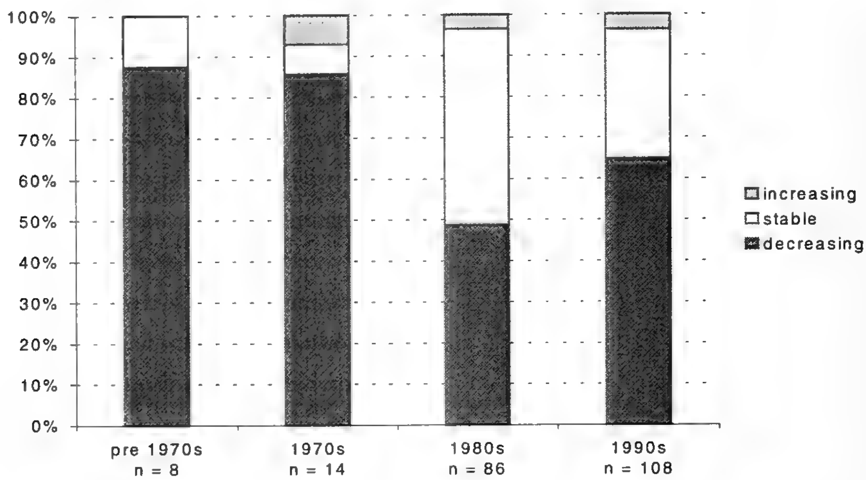
THE STATUS OF FRESHWATER BIODIVERSITY

Awareness has been growing during the past decade of the unique nature of much freshwater biodiversity, of the array of factors that in the past and at present have an impact upon freshwater species, and the extent to which real damage has already been done (recent reviews: Abramovitz, 1996, McAllister *et al.* 1997). The evidence is uneven in geographic scope, but decline in habitat quality and species populations is typical in the countries and regions where good field information is available, and real concern for the status of freshwater species worldwide is justified. While much general interest has been stimulated in the more spectacular of the terrestrial habitats and species, knowledge of the diversity and importance of the species hidden beneath the surface of freshwaters has remained very largely within the academic scientific community.

Many human activities tend to promote fragmentation of natural and often species-rich habitats (eg. floodplain rivers) and the spread of highly-managed species-poor habitats (eg. channelised rivers and reservoirs). Small isolated populations tend to be more sensitive than larger connected ones to demographic factors (eg. random events affecting the survival and reproduction of individuals) or environmental factors (eg. spread of disease, changes in food supply). The risks of this kind of distribution pattern may be compounded by other external threats, such as excess exploitation, introduced predators or pollution events.

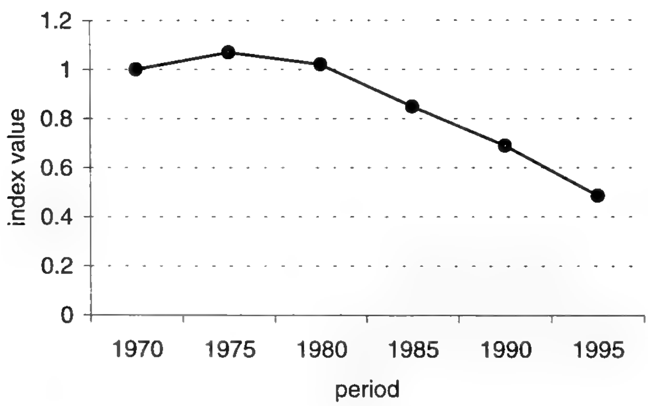
In a first attempt to obtain an overview of global trends in inland water biodiversity, qualitative information on population trends (ie. whether increasing, stable or decreasing) in a sample of more than 200 freshwater, wetland and water margin vertebrate species has been collated. This is represented in summary form in Figure 1. Most species in each decade are in decline. Although the sample size is very small in earlier decades, the proportion of species with an increasing trend has grown somewhat during the 1990s. Quantitative time-series population data are extremely scarce, but could be found for a subset of 70 species. An index generated from these data (Figure 2) shows a decline of around 50% from the 1970 baseline, seemingly ample justification for recent concern about the health of inland water ecosystems and the status of their biodiversity.

Figure 1. Population trends in sample of inland water species



Notes: derived from qualitative trend information on freshwater and wetland species (19 mammals, 92 birds, 72 reptiles, 44 fishes).
Source: prepared by WCMC for WWF *Living Planet Report 1998* (Loh *et al.*, 1998); modified from Fig. 10.

Figure 2. Inland water biodiversity index



Notes: derived from quantitative trend information on freshwater and wetland species (3 mammals, 49 birds, 8 reptile, 10 fishes).
Source: prepared by WCMC for WWF *Living Planet Report 1998* (Loh *et al.*, 1998); modified from Fig. 2b.

THREATENED FISHES

The distribution and systematics of fishes are inadequately known, although they are certainly the best-known species-rich and cosmopolitan group in freshwaters; their conservation status may exemplify the situation in other groups of organisms. Recent experience is that wherever fish faunas are studied, more species than suspected turn out to be threatened, or cannot be re-recorded at all (example reviews: Moyle and Leidy, 1992; Stiassny, 1996; Reinthal and Stiassny, 1991, Kirchhofer and Hefti, eds., 1996, and see IUCN, 1996).

Table 9. Numbers of threatened freshwater fishes in select countries

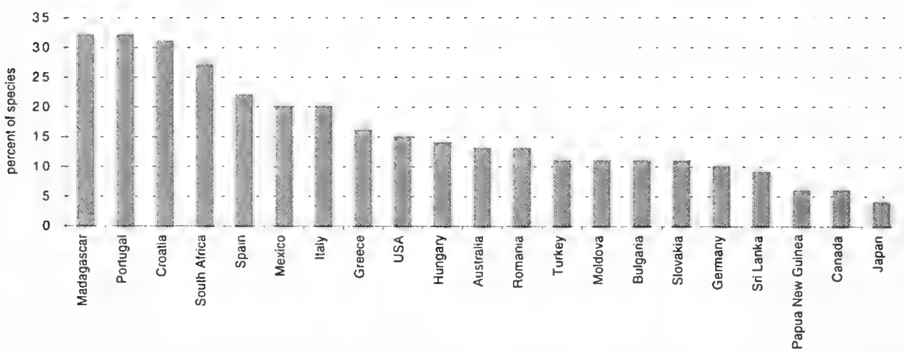
	total species	threatened species	percent threatened
USA	822	120	15
Mexico	384	77	20
Australia	216	27	13
South Africa	94	25	27
Croatia	64	20	31
Turkey	174	18	11
Greece	98	16	16
Madagascar	41	13	32
Papua New Guinea	195	12	6
Hungary	79	11	14
Canada	177	11	6
Spain	50	11	22
Romania	87	11	13
Italy	45	9	20
Moldova	82	9	11
Portugal	28	9	32
Bulgaria	72	8	11
Sri Lanka	90	8	9
Germany	68	7	10
Slovakia	62	7	11
Japan	150	7	4

Notes: These are the 20 countries whose fish faunas have been evaluated completely, or nearly so, and which have the greatest number of globally-threatened freshwater fish species.
Source: The threatened species data in this table were collated for *The 1996 IUCN Red List of Threatened Animals*. The estimates of total fish species present are all approximations.

Table 9 shows a selection of the very few countries where the status of the native fish fauna has been fully evaluated using the new IUCN threat category system. The countries are those with the twenty highest counts of globally-threatened species (ie. the entire species is at risk of extinction). In several countries 20-30% of the fish species present are threatened at this level; the mean for all 20 countries listed is around 17% (see Figure 3). This is certainly an underestimate because it covers only the species that meet the criteria for Critically Endangered, Endangered or Vulnerable listing under the new category system; it does not include those that are declining in parts of the range but are not yet threatened as a species, nor those that lack the information needed to make an assessment.

Among other freshwater groups, four of the five river dolphins and two of the three manatees are threatened, as are several smaller aquatic mammals, also around 40 freshwater turtles, more than 400 inland water crustaceans, and hundreds of bivalve and gastropod molluscs.

Figure 3. Freshwater fish species: percent threatened in selected countries



Note: these are the 20 countries with the highest numbers of globally threatened fish species, selected from the few countries where the fish fauna has been comprehensively assessed.
Source: based on data compiled by WCMC, in part for *The 1996 IUCN Red List of Threatened Animals.*

EXTINCT FISHES

A species is extinct when the last individuals have died without leaving offspring (or, in a different sense, may be termed extinct when over evolutionary time a given lineage has branched into two or more lineages). The fossil record suggests that extinct species greatly outnumber living ones, perhaps by one thousand to one; this, and evolutionary theory, suggests that extinction is probably the ultimate fate of all species.

Most extinctions indicated in the fossil record have taken place during about five geologically very short periods; a corollary of this is that extinction rates have been relatively low over geological time in general. The average lifespan of a species in the fossil record is 5-10 million years, and if 12-13 million species now exist, the general background extinction rate may be between one and three species per year. For mammals, the average lifespan of species in the fossil record is one million years, which suggests one natural extinction every 200 years among the contemporary fauna.

Recent extinctions are likely to be recorded with significant accuracy either where circumstances favour preservation of hard remains in good number or where naturalists of the past century recorded the fauna or flora with sufficient care that they set a firm baseline against which the composition of the modern biota may be assessed. It is exceptional to observe the actual process of extinction. Typically, many years elapse before sightings of a species become sparse enough to generate concern, and many more years are likely to pass before negative evidence (ie. failure to find the species) accumulaies to the point where extinction is the most probable explanation.

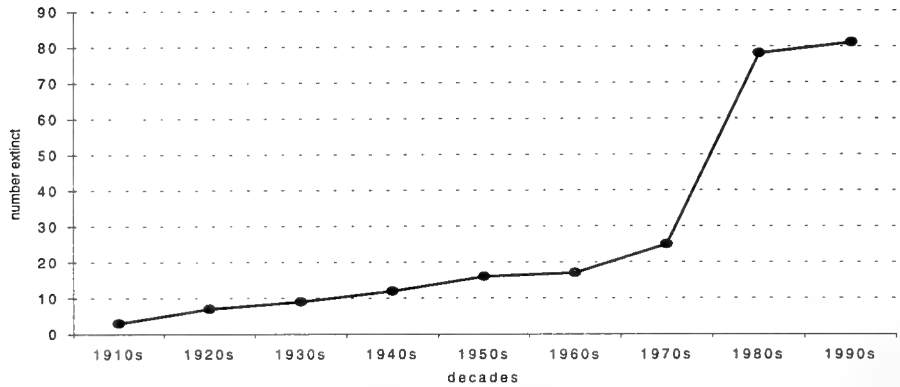
Table 10. Freshwater fish extinctions: number of known species extinctions by decade

	1890s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s
number	2	1	0	4	2	3	4	1	8	53	3
total		3	3	7	9	12	16	17	25	78	81

Notes; Data refer to globally extinct species, not national or geographic populations. 91 fish species were listed as extinct in the wild in 1996; this table includes 50 Lake Victoria cichlids all treated here as becoming extinct during the 1980s, and 31 other species for which estimated extinction times are available. A further 10 species could not be assigned to a decade.
Source: based on data compiled by WCMC, in part for *The 1996 IUCN Red List of Threatened Animals.*

Evidence for extinction of aquatic species is even less likely to be available than in terrestrial environments. However, some 81 fish species are recorded to have become extinct during the past century, and a further 11 are extinct in the wild but remain as captive populations (see Table 10 and Figure 4). This is far higher than estimated background animal extinctions. A major proportion of known extinctions have resulted from the ecological effects of the apparently deliberate introduction of the Nile Perch *Lates niloticus* into Lake Victoria in the mid-20th century. The state of knowledge of freshwater fish faunas is so incomplete that other species could well have been lost before being discovered by scientists and formally described.

Figure 4. Freshwater fish extinctions: graph to show known species extinctions by decade



Notes: Data refer to globally extinct species, not national or geographic populations. 91 fish species were listed as extinct in the wild in 1996; this table includes 50 Lake Victoria cichlids all treated here as becoming extinct during the 1980s, and 31 other species for which estimated dates are available. A further 10 species could not be assigned to a decade.
Source: based on data compiled by WCMC, in part for *The 1996 IUCN Red List of Threatened Animals.*

GLOBAL CHANGES TO FRESHWATER SYSTEMS

Changes to the structure and quality of the freshwater environment are brought about by many different human activities. Many such changes are sufficiently large-scale and radical as to be obvious to a human observer (eg. dam construction); others occur on a much smaller scale and without visible effect (eg. release of sublethal pollutants). It is now clear that multiple habitat changes can have a cumulative impact on freshwater species, and there is evidence of a widespread and often severe decline in freshwater biodiversity.

External factors affecting populations of freshwater species include:

- simple habitat loss resulting from withdrawal of water for human use,
- a variety of changes in habitat condition as a direct or indirect effect of human activities, including competition or predation by introduced non-native species, and
- direct exploitation.

Although humans have always made use of freshwater systems and species, the last 200 years (the Industrial Revolution, the growth of cities, the spread of high-input agriculture) have brought about transformations on an unprecedented scale. The rate of water withdrawal rose steeply at the start of the present century, and further after mid-century. Over the same period the volume of river water polluted to some degree by waste water has similarly risen.

Major changes in the distribution of water on the continents has resulted mainly from withdrawals for irrigation, and secondarily from domestic and industrial use (L'Vovich, *et al.*, 1990). Other factors are impoundment, wetland drainage and flood control. These physical changes have consequences for aquatic species: many large reservoirs have been created, river systems have been heavily disturbed, wetlands have been drained and the load of inorganic and organic pollutants in flowing waters has increased. From a water quality viewpoint, the major challenge is to address the increasing volume of polluted waste water from industrial and agricultural processes.

The various anthropogenic factors that impact upon freshwater systems can usefully be classified according to spatial scale and the location of effects (Table 11). As a general rule, wherever impacts have been investigated and changes in biological diversity demonstrated, multiple factors are involved.

Table 11. Scale and source of factors impacting freshwater biodiversity (rivers)

spatial scale	source of impact
Supra-catchment	Acid rain Inter-basin water transfer
Catchment	Deforestation, afforestation Urbanisation Agricultural development Land drainage
River corridor	Flood protection Flow regulation; dams, weirs, channelisation Riparian vegetation removal Dredging, mining
In-stream	Material pollution; organic, inorganic Thermal pollution Abstraction Navigation Exploitation of native species Introduction of alien species

Source: after Boon (1992).

Acid deposition through precipitation has been recognised as a regional transboundary phenomenon since the 1960s. Industrial emissions of sulphur and nitrogen oxides (SO_2, NO_x), mainly a result of fossil fuel combustion, are the principal source of acid rain. Most evidence of acid rain and its effects relates to

North America and Europe, but emission rates are rising steeply in rapidly industrialising countries elsewhere. Acid rain in one country may be a consequence of compounds released into the atmosphere by industry in another country hundreds of kilometres distant. The geology, soil and vegetation of drainage basins will strongly influence the acidification process: coniferous forests (with acidic leaf litter) over granitic rocks will tend to promote acidification, whereas calcareous soils over limestone will exert a strong buffering effect on percolating water. Acid rain has been shown to decrease species diversity in lakes and streams. It has not been implicated in any recorded species extinction nor any major species decline. It has not yet been shown to be a significant issue in tropical freshwaters, where global freshwater diversity is concentrated.

Removal or extension of forest cover, or any anthropogenic interference with soils and land cover (eg. agriculture, urbanisation, road construction, mining), will modify the rate of runoff from catchment slopes and also the density of particles carried in the drainage system. All moving waters will carry some mass of suspended material, and there is considerable natural variation in this in space and time, but logging can increase sediment load by up to 100% for a short period, and 20-50% over the longer term. Sediment reaching lakes will be deposited and in effect enter long-term storage; depending on water velocity, sediment in rivers will settle out on floodplains or other parts of the course, or be carried into the coastal marine environment.

Increased sedimentation can have several effects on aquatic biodiversity: deposition can radically change the physical environment of species restricted to particular conditions of depth, light penetration and velocity; it is a major carrier of heavy metals, organic pollutants, pathogens and nutrient; it can interfere mechanically with respiration in gill-breathing organisms; and it can damage coral reef systems in the coastal environment.

Floodplain areas of large rivers tend to be regarded as wasteland suitable for draining and agricultural development; this destroys highly productive floodplain fisheries and modifies flow in the main course.

Dam construction and channelisation also strongly disrupt natural production cycles, including migration of fishes that ascend rivers from downstream areas or the sea in order to spawn. A review of hydrological change in the northern hemisphere as a result of dams and flow regulation is provided by Dynesius and Nilsson (1994). Fish production can be maintained or increased in some circumstances, in reservoirs or floodplain canals, although natural aquatic biodiversity is expected to decrease. For example, dam construction has so severely disrupted flow in the Colorado River

(USA) that all native fishes in the lower reaches are in decline or extirpated (Moyle and Leidy, 1992).

Dam construction is the prime cause of extinction in the gastropod fauna of the Mobile Bay drainage in USA. Historically, the freshwater snail fauna of Mobile Bay basin was probably the most diverse in the world, followed by the Mekong River. Nine families and about 118 species were known at the turn of the century to occur in the Mobile Bay drainage. Several genera and many species were endemic, particularly in the Pleuroceridae. Recent surveys suggest at least 38 species are extinct (32%); decline in species richness ranges between 33% and 84% in the main river systems. The richest fauna was in the Coosa River and this system has undergone the greatest decline (from 82 to 30 species). Almost all the snail species presumed extinct were members of the Pleuroceridae and grazed on plants growing on rocks in shallow oxygen-rich riffle and shoal zones. The system has 33 major hydroelectric dams and many smaller impoundments, as well as locks and flood control structures. A combination of siltation behind dams, and submergence of shallow water shoals has removed the snails' former habitat. Where habitat remains it has diminished in area and become fragmented.

Globally, pollution and habitat modification are the most widespread and pervasive factors known to cause decline in fisheries. Water quality maintenance has generally been given much lower priority than industrial growth, and many river systems in developed countries are degraded as a result. Some countries have devoted resources to habitat restoration, with recent evidence of success. For example, the Rhine was a wild salmon-rich river two centuries ago, but by the 1970s, heavy pollution (combined with dam construction, channelisation, floodplain modification, and introduction of non-native fishes) led to marked decrease in populations of many fish species and collapse of fisheries. Since the end of the 1970s, water quality has improved and the decline in populations has slowed or reversed (Lelek, 1989, 1996).

Many smaller lakes have been affected, particularly by domestic and industrial wastes, and fisheries have declined or disappeared. Low levels of nutrient enrichment may stimulate production. There is growing concern for larger lakes, including the Rift Valley system in eastern Africa, where increased urbanisation and agricultural development are affecting catchment areas, with eg. increased sediment loads entering lake waters locally. The impact of these developments on biodiversity and fisheries is not known in detail.

There are major regional differences in the present and expected future impact on biodiversity and fish production of habitat degradation. Some of the most developed countries appear to have passed the peak of freshwater habitat modification, and are investing in water quality controls and rehabilitation measures. Some of the countries that are now undergoing rapid industrial development are a considerable distance from this state, and their freshwater habitats are likely to come under increasing pressure in coming years. The heaviest impacts are likely to be felt in eastern Europe, South and South-east Asia, with increasing industrial effluent and hydroelectric development, and in Africa, where water extraction and agricultural development for increasing human populations may be the principal impacts.

Unplanned or poorly planned introduction of non-native species and genetic stocks is a major threat to freshwater biodiversity (eg. Moyle, 1996). Such introductions can have negative or positive effects on fishery production. Table 12 and Figure 5 show the scale of introductions in recent decades; it is a reasonable assumption that all successful introductions will have an impact on existing population levels and community structure, and many changes are likely to be undesirable.

Lake Victoria, the largest tropical lake in the world, provides a classic example of the potential negative impacts of species introductions. Until some 30 years ago, when the large top predator, the Nile Perch *Lates niloticus*, was introduced, the lake supported an exceptional 'species flock' of around 300 species of haplochromine cichlid fishes as well as smaller numbers from other families. Not all the species have yet been formally described; many of these are known among aquarists and others only by informal common names. At least half and up to two-thirds of the native species are believed to be extinct or so severely depleted that too few individuals exist for the species to be harvested or recorded by scientists. The evolutionary processes behind this adaptive radiation, involving an immense variety in teeth and jaw morphology and feeding niches, have been the subject of considerable scientific research which has contributed to development of modern theories of evolutionary diversification. Additional factors in decline of the Victoria cichlids are excess fishing pressure, already evident before introduction of Nile Perch, and possible competition from tilapiine cichlids that were also introduced. The lake itself has now become depleted of oxygen, and a shrimp tolerant of oxygen-poor waters provides a major food source for the Nile Perch. In recent years the Nile Perch, and one of the introduced tilapiines form the basis of a high-yielding fishery, and an important national and export trade. It is unlikely that such high yields will be maintained.

Although it is of interest to distinguish the general factors that adversely affect freshwaters and their biodiversity, it is more useful from a management viewpoint to distinguish the various specific types of impact and the specific human activities that generates those impacts. Richter *et al.* (1997) termed these ‘stressors’ and ‘sources’ respectively, and analysed expert opinion on their identity in relation to more than

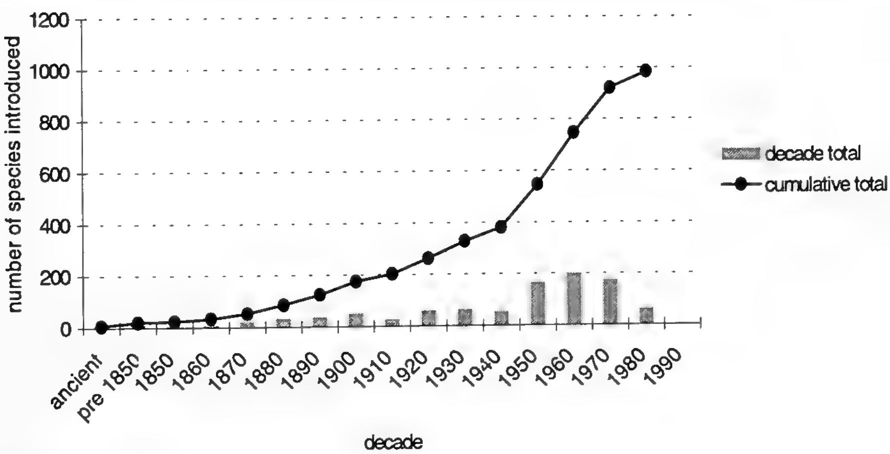
100 threatened aquatic species in the USA. Some 40 individual stressors were identified, grouped into six principal classes.

Table 12. Fish introductions: inland species by continent and decade

decade	Africa	Asia + 'USSR'	Europe	Mid East	N Am	Oceania	S Am	decade total	running total
ancient	0	1	4	0	1	1	0	7	7
pre 1850	0	4	9	0	0	0	0	13	20
1850	2	0	0	0	0	0	2	4	24
1860	1	0	2	0	0	5	1	9	33
1870	0	3	9	0	0	6	2	20	53
1880	0	2	27	0	3	0	1	33	86
1890	2	1	27	0	4	0	4	38	124
1900	3	6	14	0	1	10	17	51	175
1910	6	11	5	0	1	0	5	28	203
1920	19	6	14	1	2	9	8	59	262
1930	16	11	14	1	1	5	17	65	327
1940	12	10	4	1	0	5	21	53	380
1950	67	21	11	1	9	13	44	166	546
1960	44	37	40	7	10	21	41	200	746
1970	35	20	43	1	2	3	71	175	921
1980	1	7	14	0	1	2	37	62	983
total	208	140	237	12	35	80	271	983	

Source: compiled from data in Welcomme (1988).

Figure 5. Fish introductions: graph to show known inland species introductions by decade



Source: compiled from data in Welcomme (1988).

The threat classes identified were reported to arise from a relatively small number of primary sources, chiefly from different kinds of land use. Analysis of reported stressors and their sources for all 135 threatened species assessed indicates that three fundamental threat sources are most important (1-3 in Table 13). However, there was significant variation in results with respect to the groups of organism assessed, their geographic origin within the USA, and to historic *versus* current conditions. An important conclusion from this analysis is that it is not possible to derive a single global ranking of threats and their effects to guide conservation action; it will always be essential to evaluate local history, local conditions and individual species ecology in order to focus management efforts.

Table 13. Summary of sources of stressors affecting threatened aquatic species in USA

	primary source of threats	threat classes	effects
1	Agricultural land use	agricultural non point source pollution	Streambed sedimentation, suspended sediment loading, nutrient loading
2	Power generation	impoundment operations for hydroelectric and agricultural purposes	altered hydrology, habitat destruction and fragmentation
3	Exotic species	introduced non-native species	competition, genetic alteration, parasitism, predation
4	Municipal land use		pollution, land/waterway conversion

Note: information relates to analysis of species in USA.
Source: summarised from text in Richter *et al.*, (1997).

THE STATUS OF LAKES

Although there is much evidence for widespread decline in the health of many freshwater habitats, this is very variable in scope and quality. We have attempted to derive a semi-quantitative global assessment of change over recent decades in the condition of freshwater lakes. The study is based on *Project Aqua*, a project initiated by the *Societas Internationalis Limnologiae* in 1959, with the aim of documenting information on more than 600 water bodies judged worthy of conservation. A provisional list was issued in 1969 by the International Biological Programme, and a revised enlarged version was published with the additional support of IUCN in 1971 (Luther and Rzóska, 1971). So far as possible, data on each system were collated by national or regional specialists and presented in a standard numbered format; the information relates essentially to the 1960s.

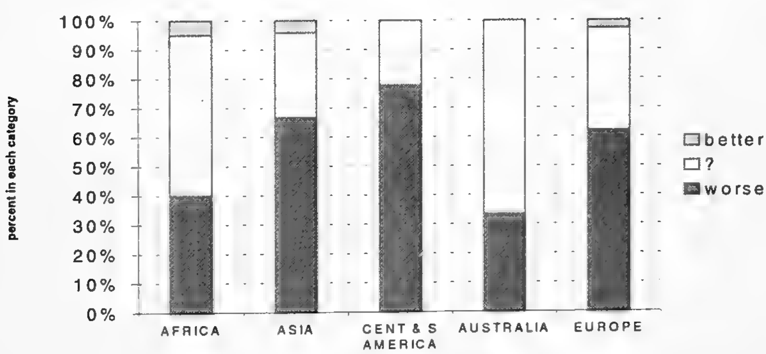
A substantial number of systems treated in *Project Aqua* are also treated in later information sources, and in these cases it is often possible, taking the 1960s data as a baseline, to make an assessment of condition at a later time point and determine the direction of change. Of later sources, we have relied mainly on volumes such as *The Directory of Asian Wetlands* (Scott, 1989) and companion works dealing with other continents. The directories in many cases contain information relating to the 1980s and 1990s. We have also extracted information, often from the 1990s, from the Lakes Database (see references for web address) maintained by the International Lake Environment Committee Foundation. We have compared available entries (at least two, sometimes three) for 93 systems and scored each according to whether its condition appears to have deteriorated (or impacts have increased), improved, or no change is reported (this can mean 'no new information').

Table 14. Change in lake condition: a preliminary assessment

	number in sample	worse	?	better
AFRICA	20	8	11	1
ASIA	24	16	7	1
CENT & S AMERICA	9	7	2	0
AUSTRALIA	3	1	2	0
EUROPE	37	23	13	1
total	93	55	35	3

Note: sample of 93 lakes (and a small number of other wetland types); "worse" = condition deteriorated or impacts increased; "?" = no change reported; "better" = condition improved or remedial measures reported. **Source**: data sources cited in text; prepared by WCMC for WWF *Living Planet Report* (Loh *et al.*, 1998).

Figure 6. Changes in condition in a sample of lakes worldwide



Note: sample of 93 lakes (and a small number of other wetland types)); "worse" = condition deteriorated or impacts increased; "?" = no change reported; "better" = condition improoved or remedial measures reported. **Source**: data sources cited in text; prepared by WCMC for WWF *Living Planet Report* (Loh *et al.*, 1998).

The results are based on uneven sampling and non-standard reporting, but may be taken as valid indication of the general direction of change in recent decades (see Table 14). Most lakes in the sample have declined in quality, particularly those in Asia. However, not all remedial measures taken within the past ten years or so, or their beneficial effects, will have been reported in the information sources used. The data are graphed as percentages in Figure 6.

4. IMPORTANT AREAS FOR FRESHWATER DIVERSITY

If sites or areas of high diversity, often termed 'hotspots', can be identified, there is an opportunity to implement measures to conserve biodiversity and manage land use in a concerted and cost-effective manner. In the context of biological diversity, the word 'hotspots' was originally applied during the late 1980s to areas in tropical forest regions that each supported high concentrations of plant species found nowhere else, and which in most cases were also suffering higher than average rates of deforestation (Myers, 1988, 1990). The central point was that, although not necessarily small in absolute terms (the hotspots included entire islands, such as New Caledonia and Madagascar, and large sections of countries, such as all of Peninsular Malaysia) they included so many endemics that they collectively supported a large proportion of the world's total flora on a relatively small proportion of the world's surface. The term 'hotspots' is now widely applied to any area that appears to be of especially high biodiversity value.

Considerable interest remains in identifying hotspots. This is partly because of the scientific interest attached to the search for natural patterns in the distribution of species, but primarily because conservation measures undertaken in 'hotspot' areas can in theory be extremely cost-effective because of the amount of biodiversity that can be maintained per unit cost.

Large and long-lived lakes have long been known to support high diversity in fishes, molluscs, crustaceans and others, sometimes in several groups (see Table 15). As sources of unique lineages, these lakes are indeed 'hotspots', and are the aquatic equivalents of islands such as Hawaii or the Galápagos.

However, lake sites are relatively easy to assess and compare, simply because lakes typically have clear and permanent boundaries. It is a much greater challenge similarly to identify, delimit and compare other areas important for freshwater biodiversity. This is in part because geographic boundaries are diffuse or otherwise difficult to determine, and in part because available diversity data are very sparse and have not been collected in a manner that allows standardised comparisons to be made.

For the present study, we have collated the preliminary views of a number of leading systematists and aquatic biologists (see Acknowledgements) on the identity of areas of special importance for a selection of key animal groups (freshwater fishes, molluscs, crayfish, crabs, and fairy shrimps). This 'expert opinion' approach is

Table 15. Physical and biodiversity features of major long-lived lakes

Lake	country	age (mill. yrs)	max depth (m)	vol. (km^3)	biodiversity
Baikal *Largest, deepest, oldest extant freshwater lake* (20% of all liquid surface fresh water on Earth)	Russia	25-30	1,637	23,000	very high spp richness, exceptional endemism in fishes and several invertebrate groups total animal spp: 1,825 endemic: 982 fishes: 56 spp., 27 endemic
Tanganyika	Burundi, Tanzania, Zambia, Zaire	20	1,470	18,880	very high spp richness, high endemism, especially high among cichlid fishes total animal spp: 1,470 endemic: 632 fishes: 330 spp., 241 endemic
Victoria world's second largest freshwater lake (area)	Kenya, Tanzania, Uganda	> 4 ??	70	2,760	high spp richness, especially of fishes exceptional endemism among cichlid fishes *many fish endemics depleted or extirpated following introduction of Nile Perch* fishes: ca 290 spp., ca 270 endemic
Malawi	Malawi, Mozambique Tanzania	>>2	780	8,400	very high spp richness, high endemism, especially high among cichlid fishes fishes: ca 640 spp., >600 endemic *more fish species than any other lake*
Titicaca world's highest navigable lake	Bolivia, Peru	3	280	890	moderate species richness and endemism (highest among fishes) total animal spp: 533 endemic: 61 fishes: 29 spp., 23 endemic
Biwa	Japan	4	104	674	moderate species richness and endemism (highest in gastropod molluscs and fishes) total animal spp: 595 endemic: 54 fishes: 57 spp., 11 endemic
Ohrid fed mainly by subterranean karst waters	Albania, Macedonia (FYR)	3	295	50	moderate species richness, exceptional endemism in several groups (planarians, oligochaetes, gastropod molluscs, ostracod crustaceans) fishes: 17 spp., 2 endemic

Notes: 1) A few other lakes have notable endemism among fishes, molluscs, crustaceans or other groups – among these are lakes Inle (Myanmar), Lanao (Phillippines); Malili (Indonesia) and the Cuatro Cienegas basin (Mexico) – but their ages are not yet firmly established. 2) Qualitative remarks (eg. "very high", "low") in the 'biodiversity' column are related to long-lived lakes, not to lake systems in general.
Source: collated from data in Martens *et al.*, 1994.

valuable in making effective use of readily available information, and although preliminary, has yielded the first global overview of freshwater biodiversity hotspots. Kottelat and Whitten (1996) have reviewed many aspects of freshwater biodiversity in Asia, including discussion of taxonomy, hotspots and policy. Regional assessments for Latin America (Olson *et al.*, 1997) and North America (Abell, *et al.*, 1998) are now available.

Although this indicative synthesis has a real heuristic value, it has not yet been possible to evaluate candidate areas against a globally consistent set of spatial and diversity criteria. A more comprehensive global analysis will require development of such criteria, and a prolonged phase of research and international consultation; we believe this is well justified by the results of the present study.

Table 16 lists in summary form some of the sites and areas that have been identified as of special importance for *more than one* of the groups (fishes, molluscs, crabs, crayfish, fairy shrimp). It is not intended to be a comprehensive global listing: it omits the large but imprecisely defined areas of known high diversity as listed more fully in Table 17; it omits diverse taxa not covered in this assessment (eg. amphipods, copepods, etc); and it does not mention sites of key importance mainly for one group of animals. See Maps 2-5; Map 2 shows the general location of areas noted in Table 16.

The fact that only two regions in South America are listed reflects the continuing lack of detailed information for taxa other than fishes. On the evidence of fishes alone the Amazon basin is likely to be exceptionally rich in other freshwater groups, but although known to be rich in freshwater crabs, for example, it is not possible to delimit special areas within the basin. However, this table is a valid reflection of current information and begins to meet the need for global information on the relative importance of hotspots of freshwater biodiversity.

This summary should be consulted in conjunction with Table 17, which outlines biodiversity and geographic information distilled from the material provided by contributors.

Table 16. Partial list of global hotspots of freshwater biodiversity

continent		area name	group 1	#	group 2	#	group 3	#
Africa	1	**L Malawi**	fishes	15	molluscs	27		
Africa	2	**L Tanganyika**	fishes	17	molluscs	28	crabs	1
Africa	3	**L Victoria**	fishes	19	molluscs	29		
Africa	4	**Madagascar**	fishes	20	molluscs	31	crabs	3
Africa	5	**Niger-Gabon**	fishes	21			crabs	4
Africa	6	**Upper Guinea**	fishes	2	molluscs	32	crabs	6
Africa	7	**lower Congo**	fishes	9			crabs	2
Eurasia	8	**SE Asia and Lower Mekong River**	fishes	71	molluscs	89	crabs	48
Eurasia	9	**Balkans** (southwest)	fishes	77	molluscs	82		
Eurasia	10	**L Baikal**	fishes	60	molluscs	84		
Eurasia	11	**L Biwa**	fishes	61	molluscs	85		
Eurasia	12	**L Inle**	fishes	63	molluscs	86		
Eurasia	13	**L Poso**	fishes	65	molluscs	88		
Eurasia	14	**Malili Lakes**	fishes	72	molluscs	88		
Eurasia	15	**Sri Lanka**	fishes	78			crabs	51
Eurasia	16	**Western Ghats**	fishes	81	molluscs	90	crabs	50
Aus	17	**SE Australia & Tasmania**	fishes	40,42	molluscs	46	crayfish	34
Aus	18	**SW Australia**	fishes	41			fairy shrimp	35
N Am	19	**East Mississippii drainage** (Ohio, Cumberland, Tennessee rivers)	fishes	96	molluscs	109	crayfish	92
N Am	20	**Mobile Bay drainage**	fishes	104	molluscs	108	crayfish	92
N Am	21	**western USA**	fishes	93	molluscs	105	fairy shrimp	93
S Am	22	**L Titicaca**	fishes	119	molluscs	134		
S Am	23	**La Plata drainage**	fishes	118	molluscs	135,136		

Notes: this table includes sites and areas noted in Table 17 (important areas…) that are identified as of particular importance for *more than one* of the groups discussed; see relevant entries in Table 17 for description; # - key to area code number in Table 17; the table is not intended to include *all* areas of global importance for freshwater diversity

Sources: See sources cited at end of Table 17.

Table 17. Important areas for freshwater biodiversity

	area name	group	remarks
AFRICA			
1	L. Tanganyika	crabs	Lake Tanganyika is the only East African Great Lake where endemic species of freshwater crabs occur: of the 9 species and 2 genera present, one genus and 7 species are endemic. [NC/RvS]
2	lower Congo	crabs	Diversity is marked in the Congo river basin, but appear highest in two areas, the lower parts of the basin (including Congo, Cabinda and former Zaire) and the upper reaches (including Rwanda/Burundi and parts of former Zaire). [NC/RvS]
3	Madagascar	crabs	Four genera and 10 species of freshwater crabs, all endemic, occur in Madagascar. [NC/RvS]
4	Niger-Gabon	crabs	Southeast Nigeria, southern Cameroon, and Gabon: 3 endemic genera and more than 10 endemic species of freshwater crabs (Cumberlidge, 1998). [NC/RvS]
5	upper Congo	crabs	Diversity is marked in the Congo river basin, but appear highest in two areas, the lower parts of the basin (including Congo, Cabinda and former Zaire) and the upper reaches (including Rwanda/Burundi and parts of former Zaire). [NC/RvS]
6	Upper Guinea	crabs	Upper Guinean rainforest, centred on Guinea, Sierra Leone, Liberia, and western Côte d'Ivoire (including Mount Nimba): 2 endemic genera and 5 endemic species of gecarcinucids (Cumberlidge, 1996a,b, 1998; Türkay & Cumberlidge, 1998). [NC/RvS]
7	southern Africa	fairy shrimp	2 endemic genera, 45 species, 38 endemic.South Africa proper: 34 species, 22 endemic. [DB]
8	Cape rivers	fishes	With 4 families and 33 species the fish fauna of Southern Africa is rather poor in comparison with most other parts of the continent; most species are cyprinids. However, there is marked local endemism; most rivers in the southern Cape region have three or four native endemics (several species are threatened). [WCMC]
9	Congo (Zaire) basin	fishes	General region of very high richness; second only to the Amazon basin in species richness. 25 families and 686 species have been reliably reported from the Congo/Zaire basin, excluding Lakes Tanganyika and Moero (Teugels and Guegan, 1994). Around 548 of the species present (c 70%) are endemic to this basin. The basin can be divided into four sections: Upper Lualaba, Cuvette Centrale, Luapula-Mweru, and the rapids.. [WCMC]
10	Congo 'cuvette centrale'	fishes	High richness plus marked endemism.. Around 690 species occur in the Congo system; the Cuvette Centrale section possibly has the highest species richness owing to the great diversity of freshwater habitats available. [WCMC]

	area name	group	remarks
11	Congo rapids	fishes	High richness plus marked endemism. The rapids between Kinshasa and the sea have a high concentration of fish species (150 species), 34 of which are endemic to this section. The caves near Thysville are fed by the Congo system and support one of Africa's few true hypogean fishes *Caecobarbus geertsi. Caecomastacembelus brichardi* and *Gymnanallabes tihoni*, not strictly cave fishes, have been collected in the Stanley Pool in riffles under flagstones or in crevices. [WCMC]
12	Cross River	fishes	Nigeria-Cameroon. 42 families, 166 species (Teugels et al., 1992); very high species diversity compared to the relatively modest catchment area, and marked endemism. Transitional ichthyofauna between the Nile-Sudan province and the Lower Guinea province. [WCMC]
13	L. Barombi-Mbo	fishes	This small (c 4.5 km2) crater lake in Cameroon has 15 species (plus another two present in the inflow stream, not the lake proper). At least 12 of the species are endemic, notably the 11 cichlids that form one of the two recorded 'species flocks' in West Africa. 4 of the five cichlid genera are endemic: Konia, Myaka, Pungu and Stomatepia. This very important site is at risk from over-fishing, the effects of introduced crustaceans and fishes, siltation from local deforestation and water pollution. [WCMC]
14	L. Bermin	fishes	A very small (c 0.5 km2) crater lake in southwest Cameroon with 2 non-endemic fishes and a remarkable species flock of 9 tilapiine cichlids. The cichlids are very small in size and not exploited; they are at some risk because of the very small distribution and deforestation in the surrounding area. [WCMC]
15	L. Malawi	fishes	30,800 km2.12 families, more than 645 species, most of them endemic to the lake. Rich species flocks among Cichlidae, and a small species flock of Clariidae. [WCMC]
16	L. Tana	fishes	The fish fauna of this large (3,150 km2) lake includes 21 species in 4 families and is dominated by lake endemic cyprinids. The large *Barbus* cyprinids form one of two recorded cyprinid species flocks (the other being that of Lake Lanao in Philippines, many species of which are severely threatened). [WCMC]
17	L. Tanganyika	fishes	32,000 km2. In the lake itself, 16 families, more than 165 species of cichlids and 72 non-cichlid species. Several 'species flocks' are present not only in Cichlidae, but also among Clariidae, Bagridae, Mochokidae, Centropomidae, Mastacembelidae. In the whole Tanganyika basin, there are 21 fish families (7 endemic to Africa), at least 185 cichlid species (180 endemic), and 145 non-cichlids (61 endemic). [WCMC]
18	L. Turkana	fishes	6,750 km2. 51 species, 35 genera, 17 families. High family and generic diversity, many of the species are lake endemic; cyprinids form the most diverse family. [WCMC]

	area name	group	remarks
19	L. Victoria	fishes	68,800 km2. 12 families, 238-288 species (many undescribed). High species diversity dominated by cichlids. The majority of species are lake endemic. [WCMC]
20	Madagascar	fishes	Around 140 fish species have been recorded from brackish and freshwaters of Madagascar (Stiassny & Raminosoa, 1994), although species richness is not remarkable, endemism is high. Two endemic families (Bedotiidae and Anchariidae) have been recognised in Madagascar, as well as 13 endemic genera and 43 endemic species. Most endemic species are restricted to freshwater habitats, mainly in eastern forested regions. About one quarter of endemic species are known only from the type locality. Blind cave fishes have been described from Madagascar: the gobiid *Glossogobius ankaranensis*, and the elotrids *Typheleotris madagascarensis* and *T. pauliani*. [WCMC]
21	Niger basin	fishes	General region of high richness. 36 families, around 243 species, with 225 primary freshwater species (Teugels and Powell, 1993 and unpublished data). Endemism moderate: 20 species endemic to Niger. The basin includes 11 of the 13 primary freshwater families that are endemic to Africa. Teugels and Powell (1993 and unpublished data) reported 164 primary freshwater fishes from the Niger delta in Nigeria, based on reference specimens for each species; the high diversity (73 % of the freshwater species in the entire basin) in this area is seriously threatened by oil-pollution. [WCMC]
22	Ntem River	fishes	Cameroon. High richness for area, plus marked endemism. 16 families, 94 species, 8 endemic. [WCMC]
23	Ogooue (Ogowe) River	fishes	Gabon. High richness for area, plus marked endemism. 23 families, 185 species, 48 species endemic to Ogowe. A relatively small drainage basin with a very high concentration of species. Many of the families represented are endemic to Africa. Available data certainly underestimate actual diversity (several new species are now being described, resulting from a collaborative project of Tervuren Museum, the American Museum of Natural History and Cornell University). [WCMC]
24	Sanaga River	fishes	Cameroon. 21 families; high concentration of species in a small river basin; probably at least 135 (and this figure is believed to be a significant underestimate) (Teugels and Guegan). Between 10 and 18 species endemic to the Sanaga. [WCMC]
25	Upper Guinea rivers	fishes	High richness for area, plus marked endemism. The Upper Guinea province includes coastal rivers from south of the Kogon River in Guinea, to Liberia, and has faunal affinities with the lower Guinea province and the Congo/Zaire. The fauna includes many taxa endemic to the area (Lévêque et al., 1989; Lévêque et al., 1990, 1992). Many small river basins, many of them still poorly investigated. Konkoure River (Guinea): 19 families, 85 species, at least 10 endemic species. Kolente or Great Scarcies River (Guinea-

	area name	group	remarks
			Sierra Leone): 19 families, 68 species. Jong River (Sierra Leone): 20 families, 94 species. Saint-Paul River (Liberia): 19 families, 76 species. Cess-Nipoué River (Liberia-Côte d'Ivoire): 20 families, 61 species. [WCMC]
26	Volta basin	fishes	General region of high richness. 27 families, about 139 species, 8 endemic to Volta basin. High species richness with 9 of the 13 African endemic primary freshwater fish families represented (Lévêque, 1997). [WCMC]
27	L. Malawi	moll.	Gastropods: 28 species, 16 endemic; 7 Endangered, 1 Vulnerable in 1996. Bivalves: 9 species, 1 endemic. [MSG]
28	L. Tanganyika	moll.	Gastropods: 68 species, 45 endemic. 32 Endangered. Bivalves: 15 species, 8 endemic. [MSG]
29	L. Victoria	moll.	Gastropods: 28 species, 13 endemic; 5 Endangered, 1 Vulnerable in 1996. Bivalves: 18 species, 9 endemic. [MSG]
30	Lower Congo basin	moll.	The region downstream of Kinshasa in Congo and Congo (DR) (former Zaire). Gastropods: 96 species, 24 endemic, 1 Endangered, 2 Vulnerable.Endemic Gastropods are almost all prosobranchs; 5 endemic 'rheophilous' (specialised for life in the rapids) genera, belonging to the Bithyniidae (*Congodoma, Liminitesta*) and Assimineidae (*Pseudogibbula, Septariellina, Valvatorbis*). Bivalves: no data. [MSG]
31	Madagascar	moll.	Gastropods: 30 species, 12 endemic, of which 1 Endangered. Genus *Melanatria* endemic. Bivalves: no data. [MSG]
32	Western lowland forest and Volta basin	moll.	Upper Guinea region in Ghana, Cote d'Ivoire, Sierra Leone, Liberia, Guinea. Around 28 gastropod species of which 19 endemic (and 9 near-endemic). 2 species ranked Critically Endangered in 1996. Bivalves: no data. [MSG]
AUSTRALASIA			
33	New Guinea-Australia	crabs	The Mollucas, New Guinea and northern Australia: more than 30 species of freshwater crabs belonging to 5 genera, all in the Parathelphusidae. [NC/RvS]
34	SE Australia	Cray fish	large area of high richness and endemism, centred on Victoria, 35 spp. and Tasmania, 19 spp. [KC]
35	SW Australia	fairy shrimp	19 species, 12 endemic. [DB]

	area name	group	remarks
36	Fly River PNG	fishes	High species richness, 103 species in Fly proper, and high local endemism, 12 endemics in system. [GA]
37	Kikori River Lake Kutubu, PNG	fishes	Headwaters of Kikori and Purari systems, with Lake Kutubu. High richness, 103 species and high endemism, 16 species in Kikori; plus 14 species in Lake Kutubu. [GA]
38	Kimberley District, WA	fishes	14 endemic species (a density second only in Australia to Tasmania and equal to southwest Western Australia), including 5 species within Prince Regent Reserve and 4 in the Drysdale River area); and 47 species in total. [GA]
39	Aikwa (Iwaka) R. Irian Jaya	fishes	River near Timiki, Irian Jaya. High species richness: around 78 species. [GA]
40	SE Australia	fishes	11 endemic species occur in coastal southeast Australia, a lower count per area than the other three areas cited here, and 42 species in total. [GA]
41	SW Western Australia	fishes	There are 9 endemic species (ie. density similar to the Kimberleys), and 14 species in total. [GA]
42	Tasmania	fishes	12 endemic species, a greater number per area than anywhere else in Australia, including 6 concentrated in the Central Plateau area; and 24 species in total. [GA]
43	Vogelkop, Irian Jaya	fishes	Moderate richness with high local endemism, around 14 endemic species, including Triton and Etna Bay lakes. [GA]
44	Great Artesian basin, Australia	moll.	Springs and underground aquifers. Important area of gastropod diversity. Bivalves: no data. [MSG]
45	New Caledonia	moll.	Springs and underground aquifers. Gastropods: 81 species, 65 endemic; 40 Vulnerable, 3 Endangered, 1 Extinct. Bivalves: no data. [MSG]
46	Western Tasmania, Australia	moll.	Springs and underground aquifers. Important area of gastropod diversity. 4 species Extinct. Bivalves: no data. [MSG]
EURASIA			
47	Indonesia	crabs	The area comprising Sumatra, Java, Borneo, Sulawesi and the southern Philippines has the greatest freshwater crab diversity in Indo-Australia, with representatives of the Parathelphusidae (10 genera and 71 species) and the Gecarcinucidae (5 genera and 21 species). [NC/RvS]

	area name	group	remarks
48	Myanmar-Malaysia	crabs	Northeast India (Assam), Myanmar, Thailand, the Mekong basin in southern Indochina, to the Malaysian peninsula and Singapore. In this region there are an estimated 30 genera and over 100 species of freshwater crabs in three families, the Potamidae, the Parathelphusidae and the Gecarcinucidae (Alcock, 1910; Bott, 1970b; Ng, 1988; Ng & Naiyanetr, 1993). [NC/RvS]
49	south China	crabs	Only the Potamidae occur in China, but more than 160 species and subspecies in 22 genera are present, most of which are endemic. The southern provinces of China represent the hotspot of biodiversity for this country (Bott, 1970b; Ng & Dudgeon, 1991; Dai, Zhou, & Peng, 1995; Türkay & Dai, 1997; Dai, 1997; Dai & Türkay, 1997). [NC/RvS]
50	south India	crabs	The freshwater crabs of the Indian peninsula south of the Ganges basin are all endemic to the subcontinent and belong to two families, the Gecarcinucidae and the Parathelphusidae (Alcock, 1910; Bott, 1970b). The west coast of the peninsula and the south show most diversity: an estimated 7 endemic genera and about 20 endemic species in two families (the Parathelphusidae and the Gecarcinucidae). A third freshwater crab family, the Potamidae, is found only in northern India but is not represented in the Indian Peninsula. [NC/RvS]
51	Sri Lanka	crabs	Sri Lanka: some 16 endemic species of freshwater crabs belonging to three genera, one of which (*Spiralothelphusa*) is endemic to the island (Bott, 1970c; Ng, 1995). [NC/RvS]
52	Italy	fairy shrimp	16 species, 7 endemic. [DB]
53	Borneo highlands	fishes	The fish fauna of the highlands of Borneo seems to be poor in absolute number of species, but many of them have developed specialisation for hill-stream habitats and are endemic to single basins. The area is still largely unsurveyed. About 50 known endemic species, but actual figure might be over 200 (Kottelat *et al.*, 1993). [MK]
54	Caspian Sea	fishes	Moderate species richness; although many species are shared with the Black Sea region, and/or the Aral basin, there is marked endemism, including the monotypic lamprey *Caspiomyzon*, around one dozen gobies, including monotypic genera *Asra* and *Anatirostrum*, also 3 *Alosa*. [WCMC]
55	Central Anatolia	fishes	An arid plateau with several endorheic lakes. About 20 endemic species, apparently underestimated by inadequate taxonomy. Adjacent areas also have a number of endemics. In urgent need of critical reassessment; probably one of the most poorly known fish faunas in Eurasia. [MK]

	area name	group	remarks
56	Coastal peatswamps and swamp forests of Malaysia, Sumatra and Borneo	fishes	Includes Bangka island. Extent along eastern coast of Borneo not known. Probably formerly present on Java but apparently cleared. About 100 endemic species in peat swamp forests, an habitat type often restricted to a narrow fringe along the coasts, still largely unsurveyed. Although peat swamps are traditionally considered as an habitat with poor diversity, good data for limited areas in Malay Peninsula and Borneo indicate that up to 50 species may be found within a small area (less than 1 km2), about half of them endemic and stenotypic. Most species have small distribution ranges (some possibly only a few km2) (Kottelat et al., 1993; Ng, 1994; Ng et al., 1994; Kottelat & Lim, 1995). [MK]
57	Coastal rain forest of southeast Asia	fishes	Thailand, Cambodia and southern Vietnam. Southern extent not known accurately. This habitat is largely destroyed in Thailand, and virtually unsurveyed in Cambodia and Vietnam. Endemic species expected in peat swamp forests (Kottelat, 1985, 1989). [MK]
58	High Asia.	fishes	Boundaries not known with accuracy; includes the Tibetan plateau and probably parts of Chinese Turkestan. Distribution and ecological data are sparse outside the Chinese literature. About 150 known fish species, about half of them endemic to this area (Wu & Wu, 1992). Survey probably still superficial as a result of difficulties of access. [MK]
59	Karstic basins of Yunnan, Guizhou and Guangxi	fishes	Boundary not known with accuracy. About 14 known species of cave fishes. Survey is still superficial and numerous additional species are expected (Chen & Yang, 1993, updated). [MK]
60	L. Baikal, Siberia	fishes	A species flock of 36 species of the family Cottidae (sculpins) (including the endemic "family" Comephoridae), 4 "ecologically differentiated stocks" (many probably endemic species using western concepts) of *Coregonus*, 2 of *Thymallus*, 2 of *Lota* (Smith & Todd, 1984). Endemic molluscs, gammarids, sponges, and Baikal seal. [MK]
61	L. Biwa, Japan	fishes	Reportedly 4 endemic species (counted in Masuda *et al.*, 1984). [MK]
62	L. El'gygytgyn, Siberia	fishes	An old lake formed on the site of a meteorite crater. 113 km2. Total fish diversity: 5 species, including an endemic genus and species (*Salvethymus svetovidovi*), an endemic species (*Salvelinus elgyticus*), and one species endemic to eastern Siberia (*Salvelinus boganidae*). Endemic diatom species and apparently endemic invertebrate(s) (Chereshnev, 1992; Chereshnev & Skopets, 1990). [MK]
63	L. Inle Myanmar/Burma	fishes	About 25 native fish species, about 10 of them endemic, including 3 endemic genera (Annandale, 1918; Kottelat, 1986). [MK]
64	L. Lindu, Sulawesi	fishes	Very limited information. One native and endemic species; others might be expected (Kottelat, 1990a). [MK]

	area name	group	remarks
65	L. Poso, Sulawesi.	fishes	10 native and endemic species, 2 endemic genera (both extinct ?) and with lake Lindu comprises the entire known distribution of the subfamily Adrianichthyinae (Kottelat, 1990a-c, 1991). Additional species might still be expected. [MK]
66	L. Thingvalla, Iceland.	fishes	5 native fish species, including 3 endemic Salvelinus (recent summary in Kottelat, 1997). [MK]
67	Lakes of British Isles.	fishes	A number of lakes host 1 or 2 species of *Salvelinus*, although information on individual lakes is usually inadequate. At the beginning of the century up to 14 species were recognised; although generally not accepted under later systematic conceptsmostly, recent work suggests that this figure may be underestimated. Also at least 5 endemic *Coregonus*, 1 endemic Clupeidae and potential for endemic *Salmo* (recent summary in Kottelat, 1997). [MK]
68	Lakes of Central Yunnan, China	fishes	Lakes Dianchi, Fuxian, Er Hai, Yangling, Yangzong, Xingyun, etc. have a distinctive fauna; despite the lakes being now in different river basins (Mekong, Yantgtze, Nanpangjiang), they have similar fauna, characterized by numerous endemic species in the genera *Cyprinus, Schizothorax, Anabarilius* and *Yunnanilus*. Exact up-to-date figures of the number of species are difficult to extract from the Chinese literature, but we have the following data: Dianchi: 25 native species, 11 endemic of which apparently all but 2 are extinct. The lake basin has 2 other endemics (Kottelat & Chu, 1988, updated); Fuxian: 25 native species, 12 endemic, + 2 endemic shared only with lake Xingyun (Yang & Chen, 1995); Er Hai: 17 native species, 9 endemic, several apparently extinct (Li, 1982, updated);Yangzong has (had) at least two endemics, Yangling and Xingyun at least one each. [MK]
69	Lough Melvin, Ireland.	fishes	Three endemic species of *Salmo* (recent summary in Kottelat, 1997). [MK]
70	lower Danube	fishes	The lower Danube basin has a relatively richer fauna (especially more diverse communities) than any European river. Endemics: about 6, possibly underestimated (counted in Kottelat, 1997). [MK]
71	Mainland South East Asian hills.	fishes	Northern boundary not clear as published data on actual fish distribution (and actual ground surveys) in southern China are too scanty. Could be subdivided into a) upper Song Hong (includes hills of Hainan and southern Nanpang Jiang); b) Annamite cordillera; c) upper Mekong, Chao Phraya and Mae Khlong basins; d) Salween, upper Irrawaddy, and southeastern Assam (including Tenasserim). Recorded fish fauna estimated to be over 1000 species (with an estimated 200-500 species still awaiting discovery), with 500 endemic to this area. Includes about some 400 known species endemic to head waters of individual sub-basins. The fauna of the lower reaches of the main rivers (excluded from this polygon) is richer (in terms of the number of species which can be observed at a given locality) but most have wide distributions crossing several

	area name	group	remarks
			river basins (Kottelat, 1989, 1990d, 1998). [MK]
72	Malili lakes, Sulawesi.	fishes	*Most important single site for aquatic biodiversity in Asia.* A complex of 5 lakes (Towuti, Matano, Mahalona, Wawontoa, Masapi) with endemic radiations of fishes of the families Telmatherinidae (3 genera, 15 species, all but one endemic), Hemiramphidae (3 endemic species), Oryziidae (3 endemic species), Gobiidae (at least 8, all but one endemic), prawns (about 12 species ?), crabs (4 species ?), molluscs (about 60 endemic species), etc. The distribution of the fishes is not uniform within the lakes, all but one of the species of lake Matano are endemic, while the others (and 2 genera) are endemic to Towuti, Mahalona, Wawontoa. Masapi has not yet been surveyed. Only 2 species of the Telmatherinidae are known outside this area. [MK]
73	Maros karst, Sulawesi	fishes	One endemic genus (possibly an artefact of limited collection; more surveys might show it to be present outside this area) and about 6 endemic species, including a cave species (Kottelat *et al.*, 1993, updated). [MK]
74	Mindanao, Philippines	fishes	About 30 endemic species of cyprinids fishes, including about 18 endemic species of Puntius in Lake Lanao (all but 2 or 3 reportedly extinct) (Myers, 1960; Kornfield & Carpenter, 1984). Cyprinids are fishes which live only in freshwater and cannot disperse in marine environment; several other families also occur in the island's freshwaters, but all are able to disperse through the seas. [MK]
75	Northwest Medi- terranean drainage	fishes	Includes Spain, Portugal, southern France and northern Italy. The total diversity in the whole area is quite low, the communities are quite poor, but this area holds 55 endemics, many with small distribution ranges. 3 of the Rhône endemics extend almost to the northern extremity of the basin. Endemics: 1 Petromyzonidae, 1 Acipenseridae, 1 Clupeidae, 34 Cyprinidae, 5 Cobitidae, 6 Salmonidae, 1 Valenciidae, 1 Cyprinodontidae, 2 Cottidae, 1 Percidae, and 4 Gobiidae (counted in Kottelat, 1997). [MK]
76	Palawan, Philippines	fishes	About 10 recorded species of cyprinid fishes, actual figure probably higher. [MK]
77	southwest Balkans	fishes	The total diversity in the whole area is quite low, the communities are quite poor, but the area holds 84 endemics, most of them with restricted or very restricted distribution ranges: 1 Petromyzonidae, 2 Clupeidae, 48 Cyprinidae, 8 Cobitidae, 1 Balitoridae, 1 Siluridae, 13 Salmonidae, 1 Valenciidae, 1 Gasterosteidae, 1 Percidae, and 7 Gobiidae. The systematics of many groups is still very poorly known and more species will be be recognised or even discovered in the future (possibly 10-20). Noteworthy are lake Ohrid with apparently 4 endemic *Salmo*, lake Prespa with apparently 7 endemic species and the Vardar basin with at least 8 endemic species (Kottelat, 1997). [MK]

	area name	group	remarks
78	southwest Sri Lanka	fishes	28 of the 91 native fish species of Sri Lanka are endemic to this area. Several of the species traditionally given the same name as Indian species are being revised and turn out to be specifically distinct, so that the figure will rise (Pethiyagoda, 1991, 1994). [MK]
79	Subalpine lakes	fishes	Stretches from lake Bourget in the West to Traunsee in the East. Numerous endemic Coregonus (possibly >27, several already extinct), at least two endemic Salvelinus and possibly some endemic *Salmo*. Some lakes have more complex communities, e.g. lake Konstanz with 4 *Coregonus*, 2 *Salvelinus*, 1 *Salmo* and several other species (recent summary in Kottelat, 1997). [MK]
80	Sundaic foothills and floodplains	fishes	Probably formerly present on Java, but is mostly cleared. About 400 known species. Most of the floodplain species are widely distributed over the whole area, while those of foothill streams have a more localised distributions and are of greater interest in terms of endemicity. Northern limit: Tapi basin in Peninsular Thailand (Kottelat et al., 1993; Kottelat, 1989, 1995). [MK]
81	Western Ghats, India	fishes	About 100 endemic fish species (estimated from Talwar & Jhingran, 1991, updated; Pethiyagoda & Kottelat, 1994, ms.). Difficult to give accurate figures. Many wide ranging "species" of fishes in South Asia in fact are complexes of species, so that the actual number of species is likely to increase significantly after adequate systematic revision. [MK]
82	Balkans region	moll.	Former Yugoslavia-Austria-Bulgaria-Greece. Springs and underground aquifers. Gastropods: c 190 species, some 180 endemic; 3 Extinct, 9 Critically Endangered, 10 Endangered, 3 Vulnerable. Bivalves: no data. [MSG]
83	Chilka Lake [brackish water]	moll.	Gastropods: 28 species, c 11 endemic. Bivalves: 43 species, 25 endemic. [MSG]
84	Lake Baikal	moll.	Gastropods: 147 species, 114 endemic. Bivalves: 3 species, 13 endemic. [MSG]
85	Lake Biwa	moll.	Gastropods: 38 species, 19 endemic. Bivalves: 16 species, 9 endemic. [MSG]
86	Lake Inle	moll.	Gastropods: 25 species, 9 endemic. Bivalves: 4 species, 2 endemic. Bivalves: 4 species, 2 endemic. [MSG]
87	Lake Ohrid and Ohrid basin	moll.	Gastropods: 72 species, 55 endemic, 1 Extinct. Bivalves: no data. [MSG]
88	Lake Poso and Malili Lakes system	moll.	Sulawesi. Gastropods: c 50 species , c 40 endemic. 1 Extinct. Bivalves: 5 species, 2 endemic. 1 Extinct. [MSG]

	area name	group	remarks
89	Lower Mekong River	moll.	Lower Mekong in Thailand-Laos-Cambodia. River habitat. Only ca. 500 km of the lower Mekong main course (with the tributary Mun River) has been well-studied. Gastropods: 121 species, 111 endemic. Two rissoacean groups dominate this entirely prosobranch assemblage of over 120 species, the pomatiopsid Triculinae (92 endemic species, 11 endemic genera) and the Stenothyridae (19 endemic species). Bivalves: 39 species, 5 endemic. [MSG]
90	north Western Ghats	moll.	River habitat. Gastropods: c 60 species,10 endemic.2 endemic genera *Turbinicola, Cremnoconchus*. The succineid genus *Lithotis* is known from two species: *L. tumida* not collected since its description in 1870, and L. rupicola only known from a single locality. The highly localised genus *Cremnoconchus* is the only littorinid living in a freshwater/terrestrial environment. Bivalves: 11 species, 5 endemic. [MSG]
91	Zrmanja River, Croatia	moll.	Gastropods: all are hydrobioid snails, 11 species, 5 endemic. Bivalves: no data. [MSG]
NORTH AMERICA			
92	southeast USA	cray fish	large area of high richness and endemism at generic and species level; including the eastern and southern Mississippi drainage (Ohio R, Tennessee R, to Ozark and Ouachita Mtns); 72 species in Alabama, 71 Tennessee. [KC]
93	western USA	fairy shrimp	26 species, 13 endemic. [DB]
94	Bear Lake	fishes	This lake is part of the Bonneville river basin and contains 1 local endemic (*Prosopium gemmiferum*); and 2 species that are now restricted to this site (*Prosopium spilonotus* and *P. abyssicola*) (Minkley *et al*, in Hocutt & Wiley, 1986). [WCMC]
95	Colorado basin	fishes	The largest basin of the west USA, this has high species richness and endemism, including 5 endemic genera of which only *Plagopterus* is monotypic (Bânârescu, P. 1991). About one third of the ichthyofauna of the Colorado is threatened, endangered or extinct due to dams and introduced species (Carlson, C.A., Muth, R.T. in Dodge, D.P. ed. 1989); 8 species appear in the 1996 IUCN Red List. [WCMC]
96	Cumberland Plateau (Cumberland +Tennessee rivers)	fishes	This area, consisting of the Tennessee and Cumberland river systems, has both the highest species richness and local endemism in North America. It is part of the highly diverse Mississippi basin, with some 240 species in total, 160 of which are present in both the Tennessee and Cumberland drainages, and 14 of these are endemic to the two basins. Of these 14, 10 are darters, 3 are minnows and 1 is a topminnow. The Tennessee has the greatest species diversity with 224 species including 25 endemics (as well as 64 not found in the Cumberland). The Cumberland has 176 native species,

	area name	group	remarks
			including 9 endemics and 16 species not shared with the Tennessee (Starnes& Etnier, in Hocutt & Wiley, 1986). [WCMC]
97	Death Valley region	fishes	There is a high level of local endemism associated with the dispersed pattern of springs and marshes. 4 families are present (Cyprinidae, Catostomidae, Cyprinodontidae and Goodeidae) with 9 species including an endemic species of Catostomidae (Minckley *et al*, in Hocutt & Wiley, 1986). Several are globally threatened, including 2 out of the 5 *Cyprinodon* species (*Cyprinodom radiosus* and *C. diabolis*) which are listed as endangered and vulnerable respectively in the 1996 IUCN Red List. [WCMC]
98	eastern USA	fishes	This is a general area of high species richness and endemism which, with the possible exception of the incompletely known East Asian fish species, represents the most diverse of all the freshwater faunas of the temperate zone (Bânârescu, P. 1991). This includes a) the Ozark Plateau, b) the Ouachita Mountains, c) the South Atlantic Central Plain and d) The Tennessee-Cumberland Plateau. [WCMC]
99	Klamath-upper Sacramento	fishes	The Klamath river basin contains 28 species in total with relatively high endemism. The 6 endemic species include 2 *Catostomus*, one *Chasmistes* and one *Gila* (Minckley *et al*, in Hocutt & Wiley, 1986). The ichthyofauna of the Sacramento differs from that of the Klamath and contains 4 genera that are confined to this river and a few neighbouring drainages (Bânârescu 1991). [WCMC]
100	Ouachita Mtns	fishes	This area includes parts of the lower Red and Ouachita rivers, each containing 133 species. The Ouachita and the Red River system both contain 18 endemic species (Cross, F.B. *et al* in Hocutt & Wiley, 1986). [WCMC]
101	Ozark Plateau	fishes	The Ozark Plateau is an area of high species diversity and particularly high local endemism in the southeast USA; it represents a concentration of the species-rich southwestern Mississippi drainage (more than 30 endemic fish species) (Bânârescu, P. 1991). [WCMC]
102	Rio Grande-Pecos confluence	fishes	The Rio Grande basin overall has over 60 endemic species (Bânârescu, P., 1991) and the Pecos, a tributary, has 5 (Smith, M.L, Rush Miller, R. in Hocutt & Wiley, 1986). Many of the endemics occur at the confluence of the two rivers, and many are listed as globally threatened in the 1996 IUCN Red List. [WCMC]
103	S Oregon-California rivers	fishes	These rivers share few family similarities with the eastern USA and have about 25% of the number of species but the region is high in local endemism. [WCMC]
104	southern Atlantic coastal plain	fishes	This includes the Alabama-Tombigbee river basin with a species-rich fauna, including about 40 endemic taxa (Swift, C.C. *et al.* in Hocutt & Wiley, 1986). This region also contains the Pearl River, with 106 species (Swift *et al* in Hocutt & Wiley, 1986), and the species rich lower Mississippi. [WCMC]

	area name	group	remarks
105	arid/semi-arid Western USA	moll.	Springs and underground aquifers. Gastropods: all are hydrobioid snails, c 100 species, at least 58 endemic. Great radiation in genus *Pyrgulopsis*. 3 extinct species, and all other are candidates for listing by USFWS. Bivalves: no data. [MSG]
106	Cuatro Cienegas basin, Mexico	moll.	Springs and underground aquifers. Gastropods: all are hydrobiids; 12 species, more than 9 endemic, 1 Critically Endangered, 3 Vulnerable in 1996. 5 genera (*Nymphophilus, Coahuilix, Paludiscala, Mexithauma, Mexipyrgus*) are endemic to this small area of 30 x 40 km. Bivalves: no data. [MSG]
107	Florida, USA	moll.	Springs and underground aquifers. Gastropods: mostly hydrobiid snails. 84 species, c 43 endemic. No bivalves. [MSG]
108	Mobile Bay basin	moll.	Tombigbee-Alabama rivers. River habitat. Gastropods: 118 species, 110 endemic; 6 endemic genera; greatest species richness (76 spp) in Pleurocercidae. 38 of the gastropod species believed extinct, 1 Endangered, 70 candidates for listing by USFW. Bivalves: 74 species, 40 endemic, 25 extinct. [MSG]
109	Ohio-Tennessee rivers	moll.	Eastern Mississippi drainage. River habitat. High species richness and endemism. 16 Extinct bivalves. [MSG]
SOUTH AMERICA			
110	Central America	crabs	The freshwater crabs of Central America belong to families (the Pseudothelphusidae and the Trichodactylidae) both of which are exclusively Neotropical. The region of Central America from Mexico to Panama, including some of the Caribbean islands holds at least 22 genera and over 80 species of pseudothelphusid crabs, and 4 genera and about 10 species of trichodactylids. The Isthmus of Tehuantepec in central Mexico is a hotspot of biodiversity for freshwater crabs in Central America (Alvarez & Villalobos, 1991; Rodriguez, 1986), and richness declines toward to the south and north. The seven species of freshwater crab belonging to a single genus found in Cuba are all endemic to that island (Chace & Hobbs, 1969). [NC/RvS]
111	S America	crabs	Two freshwater crab families (Pseudothelphusidae, Trichodactylidae) endemic to the Neotropics occur in South America. The former family includes air-breathing forms restricted to cooler stream habitats, often in mountain regions; the latter are gill-breathing and flourish in warmer lowland rivers. Freshwater crabs do not extend to southern Chile or southern Argentina. There are an estimated 17 genera and over 90 species of pseudothelphusids, found mainly in the highland regions of Peru, Ecuador, Colombia, Venezuela and the Guianas, and on the islands of the southern Caribbean, and 12 genera and over 40 species of trichodactylids found in the Amazon basin. The Cordilleras of Colombia (Rodriguez & Campos, 1989; Rodriguez & Pereira, 1992), coastal Venezuela and the Guianas (Rodriguez, 1986; Rodriguez & Pereira 1992), and the highland areas of Ecuador and

	area name	group	remarks
			Peru (Rodriguez & Sternberg, 1998) are all diversity hotspots for freshwater crabs. The Amazon basin is rich in species(Rodriguez, 1982, 1992; Magalhães & Türkay, 1996a,b,c), but most are widespread in the basin, and it is not possible yet to delimit special areas. [NC/RvS]
112	southern S America	fairy shrimp	18 species, 14 endemic. [DB]
113	Altiplano of the Andes	fishes	Species flock of *Orestias* with 43 or more species, representing an endemic subfamily, Orestiinae, of the Cyprinodontidae. [SK]
114	Amazon River basin	fishes	The Amazon (with adjacent Tocantins) basin probably has about 3000 species, and is one gigantic hotspot. The Amazon fauna equals or exceeds other continental faunas in species richness. Endemism in tributaries and subtributaries makes up most of the overall diversity, rather than the main Amazon itself. Only a few of the constituent rivers have been studied in any detail. [SK]
115	Aripuanã River, a tributary of the Madeira	fishes	A tributary of the Madeira; known to have a highly endemic but still little studied fauna upstream of the lowermost falls, with at least 10 endemic species, some restricted to rapids. [SK]
116	Central America between the Isthmus of Tehuantepec and Isthmus of Panama	fishes	280 freshwater fish species, all endemic. [SK]
117	Iguaçu River	fishes	Rio Iguaçu, on the border between Argentina and Brazil, tributary to the Rio Paraná. Its fish fauna is separated from the Rio Paraná by the Iguaçu Falls, which do not permit any migration. The fish fauna is highly endemic, with about 50 endemic species out of a total of 65 species (ca 80%). There are considerable difficulties with the nomenclature and systematic status of the Iguaçu fish species, most belonging to groups that have never been revised. Nonetheless, the high endemism will probably remain above 50%. The endemic fauna, mainly a running water one, is highly endangered by hydroelectric power projects, pollution and introduced species. The fauna is not protected. Basic information can be obtained from Agostinho and Gomes (1997). [SK]
118	La Plata basin, comprising the Uruguay, Paraguay and Paraná rivers	fishes	Comprising the Uruguay, Paraguay and Paraná rivers, with mainly endemic species, including numerous local endemics, and marked by numerous waterfalls providing isolation. Number of species unknown, but estimated fewer than 1000, possibly about 600. Taken together, the tributaries of the Paraná down to about Encarnación have a very high number of local endemics, often restricted to a single river, most of which are separated from the Paraná by one or more waterfalls near the mouth. Many of these have not been described or examined by a specialist, but are known only from

	area name	group	remarks
			occasional collections made before the Itaipu, Acaray and Yacyretá dams were constructed. Unfortunately, EIA for those dams did not result in any significant collections to show what species were in the area before the dams were built. A lesser collection of pre-dam fishes is available in MNHNP (Paraguay) and the Muséum d'Histoire naturelle de Genève (Switzerland). [SK]
119	Lago Titicaca	fishes	Lago Titicaca and smaller lakes of the Altiplano extending from Chile to Peru, hold a large number of species of the genus Orestias (Cyprinodontidae), 23 are endemic to Titicaca. The genus, with a total of 43 species has a narrow range from northern Chile to southern Peru. The lake species flocks may not be monophyletic (Parenti 1984), but the group certainly attained its present species richness in the area. The sister group are the North American Cyprinodontidae. Other highland Andean fish families include the Astroblepidae, ranging from Bolivia across Peru and Ecuador into Colombia, and many trichomycterid fishes (Trichomycteridae) occur. Lago Titicaca with its *Orestias* fauna is the only identifiable 'hotspot'. [SK]
120	Marowijne/Maroni River drainage	fishes	Marowijne/Maroni River drainage in Guyana and Surinam: known to have many endemic species above the falls, with the same genera as in the rest of the Guianas area. [SK]
121	Mata Atlántica.	fishes	The Mata Atlántica has numerous endemic species, in small mountain streams or in the few major river systems, most incompletely known. The Rio Ribeira has 77 species, and similar numbers appear to be in the other rivers. The Jequitinhonha is notable for several endemic species, including one of *Rhamdia*, which is otherwise represented by only a few widespread species in South America. The Mata Atlantica fauna extends to eastern Uruguay and southeastern Paraguay as numerous fragmented habitat patches, and although not high in species richness (perhaps around 150), has a large number of locally restricted species, with related species replacing each other from one river to another. [SK]
122	Mazaruni and Potaro Rivers in the Guyana highlands	fishes	Mazaruni and Potaro Rivers in the Guyana highlands: separated from the rest of the Essequibo system by falls, with several endemic species, but little explored. [SK]
123	Mesa Central, Mexico	fishes	Endemic subfamily Goodeinae of family Goodeidae with about 36 species. [SK]
124	Mexican Plateau	fishes	
125	Negro River and upper Orinoco River	fishes	Negro River and upper Orinoco River in Brazil, Colombia and Venezuela, with at least 700 species, probably nearer to 1000, many of which are endemic to the clear and black waters distinguishing the basin. [SK]

	area name	group	remarks
126	Nicaraguan lakes	fishes	The Nicaraguan Great Lakes (Nicaragua and Managua) in the San Juan Basin do not have great numbers of species (about 16 cichlids), but endemism is high (9 endemic species, 2 endemic genera). [SK]
127	Orinoco River basin	fishes	More than 1000 species, most of which may be endemic. There is much local endemism as habitats vary considerably, including lowland inundation savannahs, fast flowing mountain rivers, etc. Includes thus different biogeographic regions. [SK]
128	Oyapock River	fishes	Shared between Brazil and French Guiana, known to have many endemic species, especially rheophilic, from the lowermost falls upstream. Still little studied. [SK]
129	Pacific Coast of Colombia and Ecuador	fishes	Although a high-rainfall region there are few large rivers. The fauna is poor, but species are highly endemic to the region and to particular rivers or portions of rivers. In particular, the Baudó River and San Juan River in Colombia seem to have numerous endemics. Possibly the Atrato River should be included. [SK]
130	Patagonia	fishes	Argentina and Chile, from around the R Negro southward (except the most arid areas). Low diversity but endemic relict fauna of more general southern hemisphere type, with families such as Geotriidae and Galaxiidae, and also the endemic catfish family Diplomystidae with six species, the monotypic catfish family Nematogenyidae, and four species of the percoid family Percicihtyidae. This is not a hotspot of species richness, but a region of considerable local endemism, and a fauna completely different from that of the rest of South America. The Nematogenyidae are related to the Loricariidae and Trichomycteridae of northern South America (the Brazilian fauna), but the Diplomystidae are the most primitive living catfish family. The scaleless characid *Gymnocharacinus bergii* represents the Brazilian fauna, but lives isolated in one Patagonian locality in the Sumuncurá mountain which maintains about 22.5°C water temperature year-round. [SK]
131	Rio Panuco Basin	fishes	A small drainage with about 75 species, c 30% endemic, including several closely related species of *Herichthys* (Cichlidae). eastern Mexico, about 25 endemic out of about 75 known species. [SK]
132	Upper Uruguay River	fishes	The river is relatively well known from collections made by teams of the Museu de Zoologia of the Pontifícia Universidade Católica do Rio Grande do Sul during environmental impact assessment in the area, which is destined for numerous hydroelectric power plants. The MCP collections concern the middle and upper portions, located in Brazil. More than 130 species of fish are recorded from the middle and upper Uruguay, and the number is likely to rise to over 150 at least. About half of those may be endemic. Lucena & Kullander described 11 species of *Crenicichla* from the Uruguay River, and noted that this is double the number of a similar Amazonian river. Six of the species form a species flock originating on site and diversifying by trophic adaptation similar to cichlids of

	area name	group	remarks
			East African Lakes. The lower Uruguay river, along the Argentinian-Uruguayan border is very little studied, and may have fewer endemics. [SK]
133	Western Amazonia	fishes	Lowland Amazonian Peru, Ecuador and Colombia, and parts of Brazil, representing a large expanse of lowland Amazonia, very rich in species, but not well studied. Work in Peru and Ecuador suggest that there may be at least 1000 species in the area, and at least half may be endemic. [SK]
134	Lake Titicaca	moll.	Gastropods: 24 species, 15 endemic. Bivalves: no data. [MSG]
	Lower Uruguay River and Rio de la Plata	moll.	Argentina-Uruguay-Brazil. Gastropods: 54 species, 26 endemic. Bivalves: 39 species, 8 endemic. [MSG]
136	Parana River	moll.	More the 7 species, 7 endemic, of which 3 are extinct in the wild. Bivalves: no data. [MSG]

Notes:

1) This table presents information on areas identified as of special importance for diversity (species richness, and/or endemism) in the inland water groups treated (fishes, molluscs ['moll.' in table] , crabs, crayfish, fairy shrimps).
2) This is a preliminary synthesis, designed to represent expert opinion on relative levels of diversity for each taxon at continent level. In the absence of global criteria for relative importance, areas on different continents do not represent strictly equivalent levels of diversity.
3) The rows of data in this list are sorted first by continent, and secondly by the taxon concerned.

Sources: information has been derived from a number of sources, mainly as indicated by letters in square brackets in the 'remarks' text. GA - Gerald Allen, *in litt.* March 1998; MK - Maurice Kottelat, report compiled for this document; SK - Sven Kullander, report compiled for this document; MSG - report adapted by IUCN/SSC Mollusc Specialist Group, primarily by Philippe Bouchet and Olivier Gargominy, also Arthur Bogan and Winston Ponder; KC - Keith Crandall, information on distribution of crayfish genera and species; DB - Denton Belk, summary of fairy shrimp distribution patterns; NC/RvS - Neil Cumberlidge and R von Sternberg, report compiled for this document. For North American and African fishes, where source is WCMC, information has been extracted from available literature, with additional data and advice for Africa from Christian Lévêque and Guy Teugels. In most instances (MK, SK, MSG, NC/RvS, DB) contributors indicated the approximate location of the important areas concerned on a series of A3 sized base maps provided. These areas, and those identified from literature by WCMC were digitised as a basis for data presentation and future analysis.

5. DIVERSITY, RISK AND PRIORITIES: A FRAMEWORK FOR ANALYSIS OF RIVER BASINS

This chapter develops a global analysis of fish diversity at catchment level as the main element in an outline assessment of pressures and the relative global importance of river basins. An overall measure of relative wilderness value is used to estimate the magnitude of high-level regional and landscape scale effects on the current condition of catchment basins. Estimates of future pressures on water resources at national level are then used to indicate possible trends in catchment condition. These two factors are then evaluated together with fish diversity data in order to suggest levels of priority at global scale.

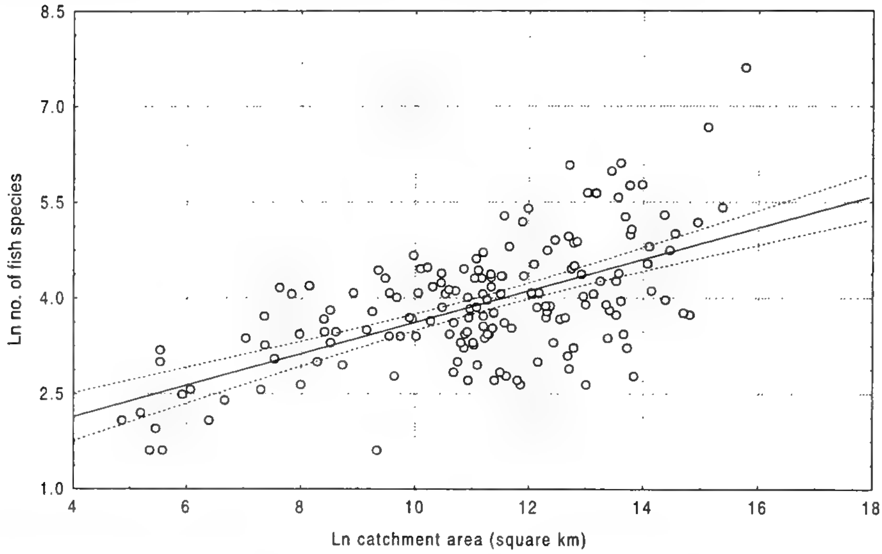
FRESHWATER FISHES: ANALYSIS OF GLOBAL DIVERSITY

A first step in planning for improved biodiversity management is to assess the biological resources present, and at local or national level it is important to consider this information in a continental or global context. With this in mind, we have assembled a database of estimates of the number of fish species in a large number of river basins.

The data have been gathered from a wide range of sources, including published literature and unpublished data supplied by colleagues (please refer to Acknowledgements, above). Figures are available for 166 basins, of which 107 are amongst the 151 mapped in the present analysis (Map 1, and Annex 1). Fish species included are those that spend a significant part of their life within river systems (including anadromous and catadromous species, that is those that migrate up or down rivers to breed); introduced species and marine species that enter estuarine waters only have been excluded where possible.

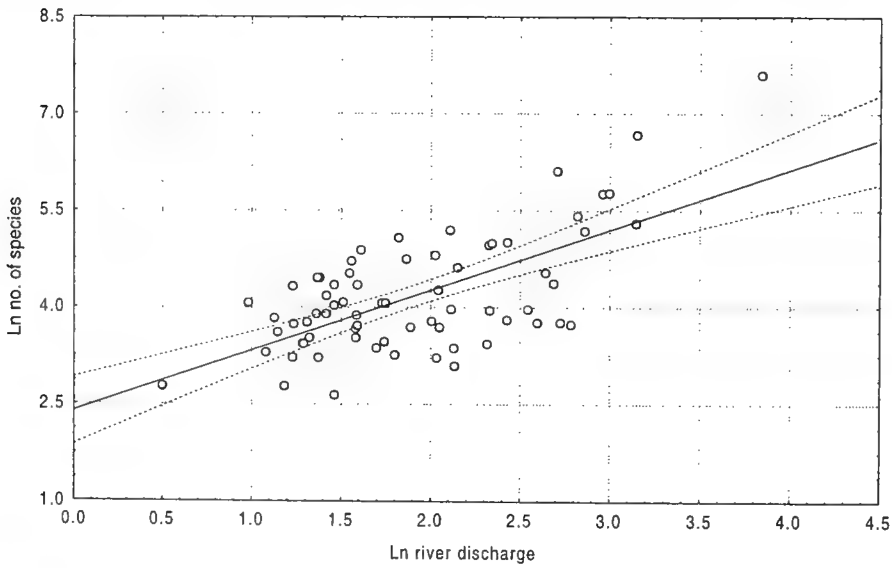
For most catchment basins actual counts of species are included; however in the case of a small number of very large tropical catchments (the Amazon, Mekong and Congo/Zaire) where it is known that species counts are very incomplete, expert assessments of likely overall numbers are included. The figures for the Mekong and Zaire are believed to be fairly reliable; for the Amazon the figure used (2,500) is certainly a very rough estimate. A number of rivers, particularly larger tropical ones, are incompletely known and the totals given are likely to under-represent the true figure somewhat. The number of native fish species per catchment ranges from 5 to an estimate of 2,500 for the Amazon system.

Figure 7. Relationship between species number and basin area



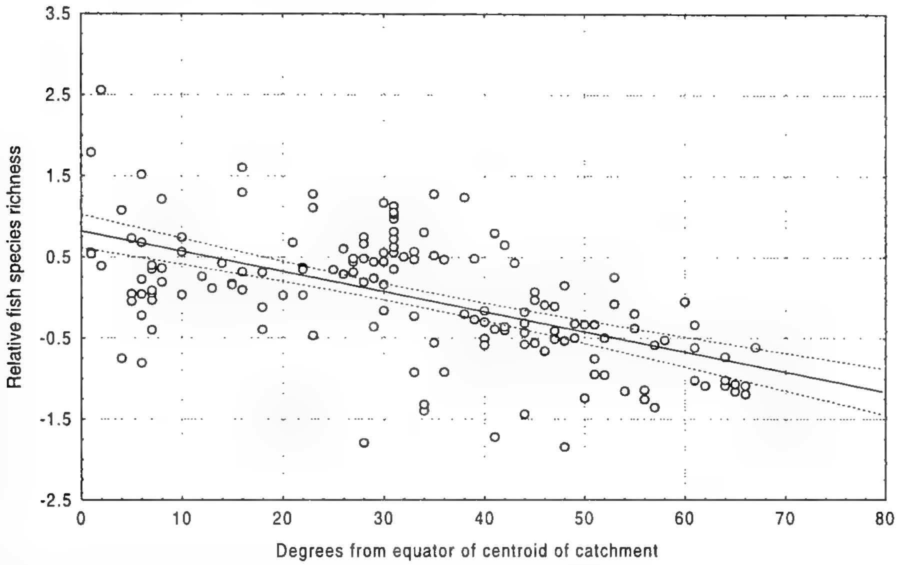
Notes: log-log plot, see Annex 2, dashed lines indicate 90% confidence limits.

Figure 8. Relationship between species number and basin discharge volume



Notes: log-log plot, see Annex 2, dashed lines indicate 90% confidence limits.

Figure 9. Species richness against basin latitude



Notes: this graph plots species richness relative to number of species expected on basis of basin size against latitude of centroid of basin (dashed lines indicate 90% confidence limits).

The readily available estimates of fish richness have resulted from studies made at various times and reflect different approaches to fish taxonomy, so the dataset is uneven in quality. However, both the low intensity of field survey work and the slow rate at which the few experienced systematists can deal with available specimens imply that the available global dataset is unlikely to be greatly improved in the near future.

The number of fish species in the 151 basins included in this analysis is shown in simplified form in Map 6, and fish species richness (in terms of actual number *versus* number expected on basis of basin area) in Map 7.

As might be expected from the classic species-area relationship (ie. that other things being equal, the number of species present increases with increasing area), there is overall a strong correlation between the size of a river and the number of fish species present (Figure 7). The 'size' of a river can be represented by the area of the basin, or by the volume of water flowing through the river system in any given period; the latter is a better predictor of fish species richness than is basin area (Figure 8). See Annex 3 for a note on methodology. Similar observations were reported in more detail by Oberdorff *et al.* (1995) and Guégan *et al.* (1998), including discussion of the rôle of energy availability.

By fitting a regression line through a log-transformed plot of species number against catchment area and measuring the distance from this line of each point (ie. the residual of each point), we estimate whether any given river is richer or poorer in species than would be expected on the basis of its size alone. A plot of these residuals (a measure of fish-species richness) against latitude (taken as the latitude of the centroid of each catchment) demonstrates overall a strong inverse correlation between latitude and species richness (Figure 9), so that in general the lower the latitude of the river, the richer in species it is. This is a clear manifestation of the most well known global diversity gradient, namely that species diversity increases with decreasing latitude. Analysis by Guégan *et al.* (1998) appears to indicate that latitude may be a surrogate measure for productivity within the basin.

Fish family diversity

In general, at any site there are certain to be far fewer families (or other higher taxa) present than individual species, and so it is usually quicker and easier during field collection at new sites, and subsequent museum study of samples, to determine how many families are present than how many different and perhaps undescribed species. So the question whether higher taxon richness is a valid surrogate of species richness is an important one in the context of biodiversity assessment. With this, and the incomplete and uneven nature of the fish diversity dataset in mind, we have examined family richness in fishes.

Distribution maps from Berra (1981) for the 142 fish families recognised by him with representatives in freshwater have been digitised. Although there have been some changes to the names and content of families mapped by Berra, and the maps themselves are coarse in scale, we have taken this source to represent a reasonable consensus view of fish families.

We have included all primary freshwater families and the inland areas of all those peripheral and secondary division families that extend significantly beyond estuarine waters into inland systems (primary families are strictly freshwater, secondary families are mainly freshwater but have some salt tolerance, peripheral groups occur mainly or partly in freshwater but are clearly derived from marine ancestors). From the digitised maps, a global density surface of numbers of freshwater fish families has been prepared (Map 8). By overlaying the outlines of the river catchments mapped in this analysis, the number of fish families in each of these basins has been estimated (Map 9).

The number of families per basin ranges from two in the Dra river in southern Morocco to 49 in the Amazon as a whole. This range is clearly far smaller than the range in fish species diversity (a 25-fold increase from least to most diverse, compared with a 250-fold for species). As with fish species, there is a clear, but less strong, relationship between the number of fish families in a catchment and the size of catchment. Again, as with fish species, the relationship with discharge is clearly better than that with catchment area. However, as data for discharge are incomplete, we have used catchment area in this analysis.

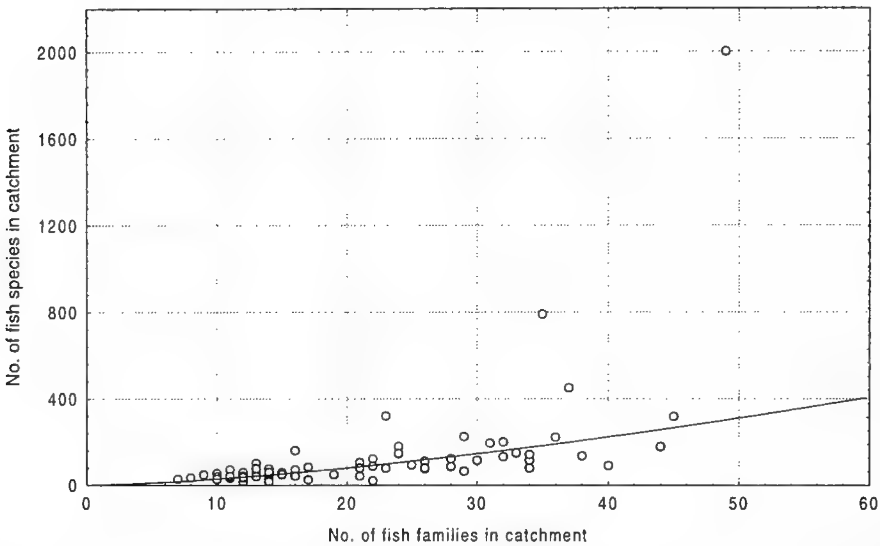
Map 10 shows the relative richness in families of the 151 river catchments mapped. The most obvious observation is that the richest rivers are all found in the tropics, most notably in northern and central south America. There are lesser centres of fish family diversity in western Africa and southeast Asia. This well reflects the density/contour map of fish family diversity. Of further note, by far the most diverse area outside the tropics or subtropics is eastern North America, where family richness calculated in this way is comparable to that in much of Africa and in the Indian sub-continent. This is reflected also in the species-richness of river catchments in this area (Map 7). It is likely that this effect is at least in part because catchment area has been used to calculate relative richness rather than discharge or runoff: rivers in much of Africa in particular have far lower runoff that would be expected from the size of their catchments, and therefore would be expected to have fewer fish species and families in them than predicted from the size of the catchment and its latitude.

Because of the relatively coarse level of resolution of the source data for fish family distribution, it is likely that the number of families in some smaller rivers, particularly in the tropics, has been overestimated. That is, it has not been confirmed that every catchment within the delimited range of a given family contains representatives of that family. Clearly this may alter results to some extent but is unlikely to have significantly distorted the overall picture.

How well does fish family richness indicate fish species richness?

A simple plot of number of fish species in a river catchment against estimated number of fish families demonstrates a correlation between the two (Figure 10). With the exception of a small number of catchments with a very large number of species (the Amazon, Congo/Zaire, Mekong and Yangtze, each with over 300 species), the relationship between fish species and fish numbers is a close one. At first inspection it appears to be roughly linear, with around five fish species for each family represented. In the four very species-rich rivers, there are over twice this number of fish species per family.

Figure 10. Relationship between number of fish species and fish families in catchment basins



Notes: species richness estimates derived from literature and personal communications; number of fish families per basin calculated from GIS overlay of fish family ranges on our sample catchment outlines. The outlying point is the Amazon basin.

Fitting a series of curves to the plot indicates that, in fact, the relationship between fish species and fish family richness is probably not strictly a linear one. The best fit of an exponential or power series curve is derived from a power series in which number of species is related to number of families to the power of 1.5 (Figure 10). Using this relationship, family number can explain over 80% of the variation in species number between river catchments. However, even then three of the most species rich rivers (in this case the Amazon, Zaire and Yangtze) deviate considerably from the relationship, with between from nearly three to nearly seven times the number of species predicted by family number (although the highest anomaly is for the Amazon, where the species estimate is very approximate). There is however,apparently no significant relationship between latitude and number of species per family, indicating that speciation at this level is similar in the tropics and in temperate regions.

There is still overall considerable variation in the relationship between number of species and number of families in different catchments. Because of uncertainties in some of the underlying data, it is difficult to tell how much of this is an artefact and how much reflects real differences. Of some note are the two catchments in New Guinea mapped in this study, the Fly and the Sepik. Both these are depauperate in fish families, as may be expected from the geographical position and geological history of the island, which is isolated from major continental centres of freshwater fish diversity. They are also apparently depauperate in number of species, compared with that to be expected of rivers of that size and at that latitude. However, both have considerably more numbers of species per family than predicted from the overall relationship set out above (130% and 80% more respectively), indicating that those families that have colonised these catchments have undergone a higher degree of speciation than normal.

It seems likely that as the data are refined, through more accurate counts of fish species and fish families and use of discharge rather than catchment area, the fit will improve somewhat and more interesting individual patterns will emerge.

Overall, however, it is clear that even with the variable quality of the existing data, at a global level fish family diversity is a good surrogate for fish species diversity, in that the general patterns in one are well reflected in the other.

INDICATORS OF HABITAT CONDITION IN RIVER CATCHMENTS.

Wilderness

A measure of wilderness in each of the catchments analysed has been derived, based on the Wilderness Index developed by the Australian Heritage Commission (R. Lesslie, *in litt.*, 30 May 1998). The wilderness value of any given point is essentially a measure of remoteness from human influence and is assessed on the basis of: remoteness from settlement (settled land or points of permanent occupation), from access (constructed vehicle access routes), and apparent naturalness (remoteness from permanent manmade structures) (Lesslie and Maslen, 1995). The analysis is carried out on a grid, using data from the Digital Chart of the World (DCW), and remoteness is measured as a distance from each grid point to the nearest feature of each class within a given radius (generally 30 km). Wilderness value is the sum of standardised values for each indicator class. The value used here is the mean wilderness value for all points within the catchment; this dataset is represented in simplified form in Map 11.

Water resource vulnerability

A measure of water resource vulnerability for each catchment has been calculated following Raskin *et al.* (1997). This team compiled a novel Water Resource Vulnerability Index (WRVI) for each country on the basis of three water resource stress indices: reliability; use-to-resource; and coping capacity.

"Reliability" incorporates three separate factors: storage-to-flow (national reservoir storage capacity in relation to average annual water supply; annual coefficient of variation of precipitation (ie. long-term predictability of rainfall); and import dependence (the percentage of a national water supply that flows from external sources). "Use-to-resource ratio" is a measure of annual water withdrawals divided by annual renewable water resources. "Coping capacity" is GDP per capita and serves as a proxy for a nation's capacity to cope with water problems and uncertainties, and to deliver basic water services to its citizens.

For each measure, including the three separate factors in "reliability", four classes (from "no stress" to "high stress") have been designated in Raskin (1997). A compound WRVI (model I) for each country is derived by giving equal weightings to each of the three stress indices (Model I).

We have calculated a measure of vulnerability for each catchment by measuring that proportion of each catchment which lies within any given country and weighting this proportion by the WRVI of that country. This analysis is represented in Map 12.

Water resource vulnerability and wilderness are both high-level measures of the state of water catchments and the pressures exerted on them. The extent to which they can provide actual insight into the state of riverine ecosystems in individual catchments is a matter of great interest.

In particular, the former is a measure of the extent to which water supply is or may be expected to become a problem to the human population in a country and is therefore only indirectly a measure of vulnerability of or degree of threat to riverine ecosystems. Further, being derived from country-level indices, it may be expected to provide only a limited insight into the state of individual catchments. Indeed, Raskin (1997) notes that "Ideally, the analysis would be conducted at the river catchment level where the relationship among water resources, human requirements and ecosystems is most direct. But a comprehensive global assessment that is built from numerous river catchments would be a problematic undertaking due to the sheer scale of effort and to the lack of a comprehensive water data-base organised by catchment."

Nevertheless, inspection of the map of water resource vulnerability shows good agreement with what may intuitively be expected at a global level, namely that the most vulnerable catchments overall are in South Asia, which has very high human population density, and in the northern half of Africa where rainfall is generally low and unpredictable. In contrast, the least vulnerable catchments are in high latitude countries with predictable rainfall and low population densities (Canada and

Finland). Some evident anomalies arise, of which perhaps the most noticeable are the two Alaskan catchments (the Yukon and the Kuskokwim). These may intuitively be expected to be of very low vulnerability, essentially in the same class as adjacent catchments such as the Mackenzie in Canada. However, because by this system the value for the USA as a whole has been applied, they are classified as of somewhat higher vulnerability.

The wilderness estimate is derived from data mapped by grid-squares rather than at country level, and is therefore of a much finer resolution and can be applied as a direct measure for each catchment. Again in general the map (Map 12) gives good overall agreement with what may be intuitively expected. Major apparent anomalies include the relatively low wilderness value ascribed to the Zaire catchment and the relatively high value ascribed to the Yangtze. The former is probably because the base data, taken from the Digital Chart of the World (DCW) are not completely standardised across the globe. Thus in parts of Central Africa several low-grade forms of access (tracks, trails and footpaths), and the settlements associated with them, that are not normally marked on DCW maps, are marked. This will tend to decrease the apparent wilderness value of the area compared with other regions (R. Lesslie, *in litt.*, 30 May 1998). In contrast, the Yangtze catchment, despite much of it lying in one of the most densely populated parts of the world, contains significant areas of montane regions with little marked access, so that the catchment as a whole has a higher wilderness value ascribed to it than might be expected.

Further refinements of the base-line information used to generate the wilderness index should resolve many of these apparent anomalies. However, the most important caveat to use of the wilderness index in this context is that it is a measure of the amount of wilderness in the land area of the catchment as a whole and does not directly reflect the condition of riverine ecosystems. Reasonably, other things being equal, it would be expected that there would be a good correspondence between the two, in that a catchment with a high wilderness rating should be relatively undisturbed and therefore have at least a proportion of its riverine ecosystems also relatively undisturbed. However, this may be expected not strictly to hold in arid and semi-arid areas (in this case most notably in northern Africa). Here, the wilderness measure for the catchment is often high because large areas of desert or subdesert hinterland are very sparsely inhabited, but the rivers themselves may be expected to be disproportionately affected by human activity (ie. should in fact have a low wilderness measure) because this is were the bulk of the human population in the catchment is settled.

Despite these problems, the measure does seem to provide a good starting point for assessing how disturbed or impacted the world's major catchments are overall.

A good overall impression of stress to or probable impact on riverine ecosystems can be gained by combining the water resource vulnerability index with the negative of the wilderness index (i.e. a measure of the absence of wilderness in a catchment). This has been done by normalising the two, so that all values for each lie between 0 and 1, and subtracting wilderness value from the water resource vulnerability index. Both indices have essentially the same spread of values (approximately four-fold increase from the lowest value to the highest), so that each contributes equally to an overall value for threat calculated in this way.

Map 13 shows an overall vulnerability or impact value for the river catchment as calculated in this way. Interestingly, combining these two independent measures appears to have the effect of mitigating some of the more obvious anomalies found for each of the measures separately (discussed above). Overall, the pattern mapped agrees well with what might intuitively be expected, with few evident anomalies. This is particularly noteworthy because neither of the two indices used to generate this measure includes direct measures of the state of the riverine ecosystems (although the use-to-resource ratio, used as part of the Water Resources Vulnerability Index provides some insight into this in that it estimates what proportion of river water is physically removed).

Using these measures, the most stressed catchments are to be found in South Asia (the Indian subcontinent), the Middle East and western and north-central Europe. The least stressed are those in the north-western part of North America.

Clearly, this methodology represents a preliminary assessment, at a coarse level, of likely major impacts on catchments. Further refinement of the system should take into account measurable impacts on individual catchments. Two major factors that should be considered in trying to obtain more direct measures of impacts on riverine ecosystems are dams and pollution.

Dams

Dams, particularly large dams, self-evidently have a major impact on the rivers they are built on. They affect flow regimes, often dramatically, and destroy large areas of existing habitat while creating new ones (eg. Dynesius and Nilsson, 1994). They have particularly significant impacts on catadromous and anadromous fishes (those that migrate down or up river systems to breed). Dams, particularly those used for generating hydroelectric power, may be, and indeed often are, built in areas that are not heavily populated or under major water stress. It may be expected therefore that their presence will not accurately be reflected in the indicators outlined above. Preliminary analysis of data on large dams shows that these are very unevenly distributed across the world's major catchments, with an enormous concentration in North America, particularly within the contiguous states of the USA, where at least eight catchments have over one hundred large dams in each. Clearly, such information should be incorporated into any further assessment of threats to catchments.

Pollution

The degree of pollution in a basin may be expected to be reflected to some extent both in the amount of wilderness in the basin and the measure of water resource vulnerability. However the connection is likely not to be straightforward. Point sources of pollution may have major impacts on river systems that are otherwise relatively undisturbed and therefore have a high wilderness value (as reportedly with the Fly River in New Guinea, which is affected by pollution from mining within its catchment). Furthermore catchments in areas of low water vulnerability (often in developed, temperate countries), may be expected to be particularly susceptible to pollution. This, however, is likely to be reflected in a low wilderness measure.

A FRAMEWORK FOR PRIORITISATION

Despite the various caveats, the measures for fish family richness and overall stress elaborated above do appear to be reasonable indicators respectively of biodiversity in riverine systems and the threats to it. Combining these can give some indication of global level priorities for the maintenance of riverine biodiversity. Figure 11 shows a scatter-plot of these two measures.

We suggest for this preliminary approach that highly diverse and highly stressed river systems (ie. those towards the top, right-hand part of the graph) should be accorded highest priority and systems with low diversity and low stress (ie. those towards the bottom left-hand part of the graph) should be accorded lowest priority.

There is no single *a priori* way of ranking the others, which may have high diversity and low stress, low stress and high diversity or moderate measures of both. However, simply allotting equal weight to richness and stress (i.e. normalising and averaging the two) allows a single measure to be derived for each catchment that can be used to identify three groups: high priority; intermediate priority; lower priority. The division between these three groups is arbitrary, particularly as there is very little numerical difference between many of the catchments of intermediate value.

The results are shown in Map 14. For clarity we have chosen to show the top thirty as high priority and the bottom thirty as lower priority, with the remaining 91 basins as intermediate. The 30 high priority basins are represented by a black marker in Figure 11 and named in Table 18.

This preliminary analysis of diversity and risk analysis could be further developed by *inter alia* the following steps:

1. Use discharge data, as a better predictor of fish richness than catchment area.

2. Verify and expand the dataset on fish species per catchment.

3. Revise fish family taxonomy and occurrence, and seek field data on fish richness per family, particularly for smaller river basins.

4. Most importantly, include system-specific information on river condition: dams; pollution; abstraction of water for irrigation; canalisation, etc.

Figure 11. Scatter diagram of fish family richness per basin against vulnerability

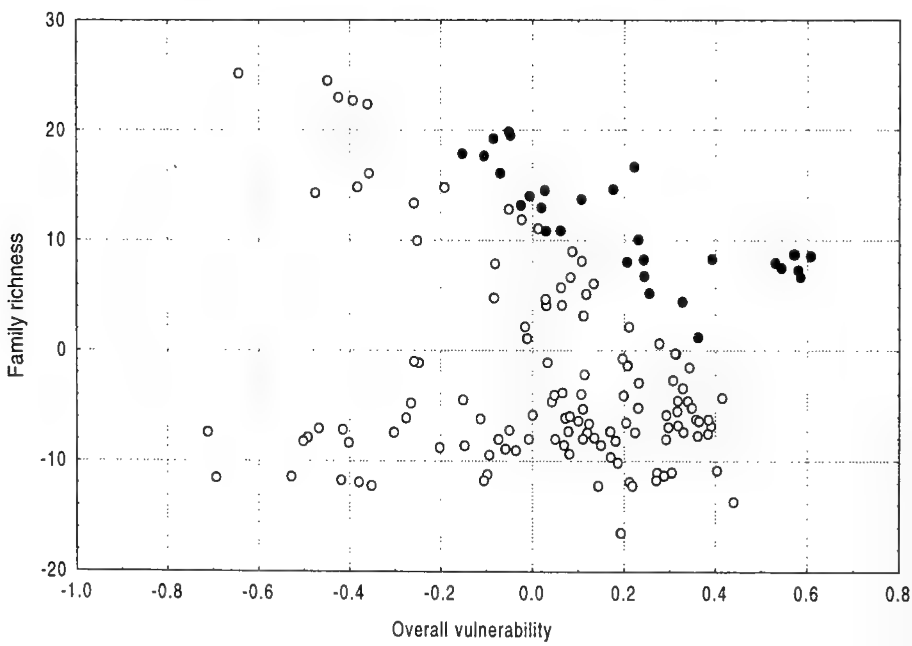


Table 18. Thirty high priority river basins

Ca	Magdalena	Perak
Cauvery	Mahanadi	Salween
Chao Phraya	Mekong	Sao Francisco
Gambia	Narmada	Senegal
Ganges-Brahmaputra	Niger	Sittang
Godavari	Nile	Song Hong (Red)
Indus	Pahang	Tapti
Irrawaddy	Parana	Tembesi-Hari
Krishna	Parnaiba	Uruguay
Ma	Penner	Volta

Notes. These are thirty river basins that support high biodiversity (assessed as fish family richness) and are most vulnerable to future pressures (have a low wilderness score, and high water resource vulnerability index). See text for further explanation. Basins are listed in alphabetical sequence.

REFERENCES

Abell, R., Olson, D., Dinerstein, E., Hurley, P., Eichbaum, W., Walters, S., Wettengel, W., Allnutt, T., and Loucks C. 1998. *A conservation assessment of the freshwater ecoregions of North America*. Final Report submited to the U.S. EPA, April 1998. World Wildlife Fund-US.

Abramovitz, J.N. 1996. *Imperiled Waters, Impoverished Future: The Decline of Freshwater Ecosystems*. Worldwatch Paper 128. Worldwatch Institute, Washington D.C.

Anon. 1978a (Centre for Natural Resources, Energy and Transport of the Department of Economic and Social Affairs, United Nations). 1978. Register of International Rivers. *Water Supply and Management*. 2: 1-58. (Special Issue). Pergamon Press.

Anon. 1978b. *World water balance and water resources of the Earth*. USSR Committee for the International Hydrological Decade. Studies and reports in hydrology N0. 25. UNESCO.

Belk, D. and Brtek, J. 1995. Checklist of the Anostraca. *Hydrobiologia* 298 (1-3): 315-353.

Berra, T.M. 1981. *An Atlas of Distribution of the Freshwater Fish Families of the World*. University of Nebraska Press, Lincoln and London.

Boon, P.J. Essential elements in the case for river conservation. Pp.11-33 in: Boon. P.J. *et al.* (1992) *River Conservation and Management*. John Wiley and Sons Ltd.

Borgström, R. 1994. Freshwater Ecology and Fisheries. Chapter 3, pp. 41-69, in Balakrishnan, M. Borgström, R. and Bie, S.W. *Tropical Ecosystems*. International Science Publisher. Oxford and IBH, New Delhi.

Coates, D. (1995) *Inland capture fisheries and enhancement: status, constraints and prospects for food security*. Paper presented at International conference on sustainable contribution of fisheries to food security. Kyoto, Japan 4-9 December 1995. FAO KC/FI/95/TECH/3.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., o'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Dai, A.Y. 1997. - A revision of freshwater crabs of the genus *Nanhaipotamon* Bott, 1968 from China (Crustacea: Decapoda: Brachyura: Potamidae). *Raffles Bulletin of Zoology*, 45(2): 209-235.

Dai, A.Y. and Türkay M. 1997. - Revision of the Chinese freshwater crabs previously placed in the genus *Isolapotamon* Bott, 1968 (Crustacea: Decapoda: Brachyura: Potamidae). *Raffles Bulletin of Zoology*, 45(2): 237-264.

Dai, Zhou, and Peng, 1995. Eight new species of the genus *Sinopotamon* from Jiangxi Province, China (Crustacea, Decapoda, Brachyura, Potamidae). *Beaufortia*, 45(5): 61-76.

Daget, J., Gosse, J.P., and Thys van den Audenaerde, D.F.E. (eds.). 1984. CLOFFA 1. *Checklist of the Freshwater Fishes of Africa*. ISNB, MRAC, ORSTOM. Volume 1.

Daget, J., Gosse, J.P., and Thys van den Audenaerde, D.F.E. (eds.). 1986*a*. CLOFFA 2. *Checklist of the Freshwater Fishes of Africa*. ISNB, MRAC, ORSTOM. Volume 2.

Daget, J., Gosse, J.P., and Thys van den Audenaerde, D.F.E. (eds.). 1986*b*. CLOFFA 3 *Checklist of the Freshwater Fishes of Africa*. ISNB, MRAC, ORSTOM. Volume 3.

Daget, J., Gosse, J.P., Teugels, G.G. and Thys van den Audenaerde, D.F.E. (eds.). 1991. CLOFFA 4. *Checklist of the Freshwater Fishes of Africa*. ISNB, MRAC, ORSTOM. Vol. 4.

Dodge, D.P. ed. 1989. Proceedings of the International Large River Symposium. *Can. Spec. Publ. Fish. Aquat. Sci.* 106.

Dynesius, M. and Nilsson, C. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. *Science* 266, 4 November, 753-762.

FAO. 1996a. *The state of world fisheries and aquaculture* (SOFIA). (available in .pdf from http://www.fao.org).

FAO. 1996b. *Food production: the critical role of water* Technical background document. World Food Summit. (available in .pdf from http://www.fao.org).

Goh, T.K. and Hyde, K.D. 1996. Biodiversity of freshwater fungi. *Journal of Industrial Microbiology*. 17: 328-345.

Gorthner, A. 1994. What is an ancient lake? Speciation in Ancient Lakes. Martens, K., Goddeeris, B. and Coulter, G. (eds). *Archiv für Hydrobiologie. Ergebnisse der Limnologie*. 44: 97-100.

Gray, J. 1988 Evolution of the freshwater ecosystem: the fossil record. In: *Palaeogeography, Palaeoclimatology, Palaeoecology* 62:1-214. Elsevier Science Publishers B.V., Amsterdam.

Guégan, J.-F, Lek, S. and Oberdorff, T. 1998. Energy availability and habitat heterogeneity predict global riverine fish diversity. *Nature* 391, 22 January, 382-384.

Hocutt, C.H. and Wiley, E.O. eds. 1986. *The Zoogeography of North American Freshwater Fishes*. John Wiley and Sons.

Hughes, R.H. and Hughes, J.S. 1992. *A Directory of African Wetlands*. IUCN, Gland, Switzerland and Cambridge, UK. UNEP, Nairobi, Kenya. WCMC, Cambridge, UK.

IUCN. 1996. *The 1996 IUCN Red List of Threatened Animals*. IUCN, Gland, Switzerland.

Kirchhofer, A. and Hefti, D. (eds) 1996. *Conservation of endangered freshwater fish in Europe*. Birkhäuser Verlag: Basel, Boston, Berlin. (Advances in Life Sciences).

Kornfield, I. L. and K. E. Carpenter. 1984. The cyprinids of lake Lanao, Philippines: taxonomic validity, evolutionary rates and speciation scenarios. Pp. 69-84 in A. A. Echelle and I. L. Kornfield (eds.), *Evolution of fish species flocks*. University of Maine at Orono Press, Orono.

Kottelat, M. 1985. Fresh-water fishes of Kampuchea. A provisory annotated check-list. *Hydrobiologia*, 121: 249-279.

Kottelat, M. 1986. Die Fischfauna des Inlé-Sees in Burma. *Aquar. Terrar. Ztschr.*, 39 (9): 403-406, (10): 452-453.

Kottelat, M. 1989. Zoogeography of the fishes from Indochinese inland waters with an annotated check-list. *Bull. Zool. Mus. Univ. Amsterdam*, 12 (1): 1-54.

Kottelat, M. 1990a. Synopsis of the endangered Buntingi (Osteichthyes: Adrianichthyidae and Oryziidae) of Lake Poso, Central Sulawesi, Indonesia, with a new reproductive guild and description of three new species. *Ichthyol. Explor. Freshwat.*, 1 (1): 49-67.

Kottelat, M. 1990b. The ricefishes (Oryziidae) of the Malili Lakes, Sulawesi, Indonesia, with description of a new species. *Ichthyol. Explor. Freshwat.*, 1 (2): 151-166.

Kottelat, M. 1990c. Sailfin silversides (Pisces: Telmatherinidae) of Lakes Towuti, Mahalona and Wawontoa (Sulawesi, Indonesia) with descriptions of two new genera and two new species. *Ichthyol. Explor. Freshwat.*, 1 (3): 227-246.

Kottelat, M. 1990d. *Indochinese nemacheilines. A revision of nemacheiline loaches (*Pisces: Cypriniformes*) of Thailand, Burma, Laos, Cambodia and southern Viet Nam.* Pfeil, München, 262 pp.

Kottelat, M. 1991. Sailfin silversides (Pisces: Telmatherinidae) of Lake Matano, Sulawesi, Indonesia, with descriptions of six new species. *Ichthyol. Explor. Freshwat.*, 1 (4): 321-344.

Kottelat, M. 1995. The fishes of the Mahakam River, East Borneo: an example of the limitations of zoogeographic analyses and the need for extensive fish surveys in Indonesia. *Trop.Biodiv.*, 2 (3): 401-426.

Kottelat, M. 1997. European freshwater fishes. An heuristic checklist of the freshwater fishes of Europe (exclusive of former USSR), with an introduction for non-systematists and comments on nomenclature and conservation. *Biologia, Bratislava, Sect. Zool.*, 52 (Suppl.5): 1-271.

Kottelat, M. and Chu X.-L. 1988. Revision of *Yunnanilus* with descriptions of a miniature species flock and six new species from China (*Cypriniformes: Homalopteridae*). *Env. Biol. Fish.*, 23 (1-2): 65-93.

Kottelat, M. and K. K. P. Lim. 1995. Freshwater fishes of Sarawak and Brunei Darussalam: a preliminary annotated check-list. *Sarawak Mus. J.*, 48 (69): 227-256.

Kottelat, M. and T. Whitten. 1996. *Freshwater Biodiversity in Asia with special reference to fish.* World Bank Technical Paper No. 343.

Kottelat, M., A. J. Whitten, S. N. Kartikasari and S. Wirjoatmodjo. 1993. *Freshwater fishes of Western Indonesia and Sulawesi.* Periplus Editions, Hong Kong, 259 pp., 84 pls.

Lake Database. At ILEC (International Lake Environment Committee Foundation) Internet home page. *http:.www.biwa.or.jp/ilec/database/database.html.*

Lelek, A. 1989. The Rhine River and some of its tributaries under human impact in the last two centuries. p. 469-487 *in* Dodge, D.P. ed. 1989. Proceedings of the International Large River Symposium. *Can. Spec. Publ. Fish. Aquat. Sci.* 106.

Lelek, A. 1996. General considerations regarding the decline of species, p. 1-7 in Kirchhofer, A. and Hefti, D. (eds) *Conservation of endangered freshwater fish in Europe.* Birkhäuser Verlag: Basel, Boston, Berlin.

Li S.-Z. 1982. [Fish fauna and its differentiation in the upland lakes of Yunnan]. *Acta Zool. Sinica*, 28 (2): 169-176. [Chinese, English abstract]

Luther, H. and Rzóska, J. 1971. *Project Aqua a source book of inland waters proposed for conservation.*IBP Handbook No 21. IUCN Occasional Paper No 2. International Biological Programme. Blackwell Scientific Publications, Oxford and Edinburgh.

L'Vovich, M.I. *et al.* 1990. Use and transformation of terrestrial water systems. In: Turner II, B.L. (1990) *The earth as transformed by human action. Global and regional changes in the biosphere over the past 300 years.* p.235-252. Cambridge Uniersity Press with Clark University.

Mabberley, D.J. 1997. *The Plant-Book. A portable dictionary of the vascular plants.* 2nd edition, revised. Cambridge University Press.

Magalhães C. and Türkay M. 1996a. - Taxonomy of the neotropical freshwater crab family Trichodactylidae I. The generic system with description of some new genera (Crustacea: Decapoda: Brachyura). *Senckenbergiana biologica*, 75 (1/2): 63-95.

Magalhães C. and Türkay M. 1996b. - Taxonomy of the neotropical freshwater crab family *Trichodactylidae II.* The genera *Forsteria, Melocarcinus, Sylviocarcinus* and *Zilchiopsis* (Crustacea: Decapoda: Brachyura). *Senckenbergiana biologica*, 75 (1/2): 97-130.

Magalhães C. and Türkay M. 1996c. - Taxonomy of the neotropical freshwater crab family *Trichodactylidae III.* The genera *Fredilocarcinus* and *Goyazana* (Crustacea: Decapoda: Brachyura). *Senckenbergiana biologica*, 75 (1/2): 131-142.

Martens, K., Goddeeris, B. and Coulter, G. (eds). 1994. Speciation in Ancient Lakes. *Archiv für Hydrobiologie. Ergebnisse der Limnologie.* 44.

Masuda, H., K. Amaoka, C. Araga, T. Uyeno and T. Yoshino. 1984. *The fishes of the Japanese archipelago.* Tokai University Press, Tokyo, 2 vols.

McAllister, D.E., Hamilton, A.L. and Harvey, B.H. 1997. Global Freshwater Biodiversity: striving for the integrity of freshwater ecosystems. *Sea Wind* 11(3). Special Issue. July-September 1997.

Meybeck, M. and Helmer, R. 1989 The quality of rivers: from pristine stage to global pollution. In: *Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change section)* 75:283-309. Elsevier Science Publishers, B.V., Amsterdam.

Moyle, P.B. 1996. Effects of invading species on freshwater and estuarine ecosystems. In: Sandlund, O.T. *et al.*(Eds) *Proceedings of the Norway/UN Conference on Alien Species*, Trondheim, 1-5 July 1996. Directorate for Nature Management and Norwegian Institute for Nature Research, Trondheim, Norway, p.86-92.

Moyle, P.B. and Leidy, R.A. 1992. Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. In: Fielder, P.L. *et al.* (Eds) *Conservation Biology, the theory and practice of nature conservation preservation and management.* p.129-169. Chapman and Hall, New York and London.

Munthali, S.M. 1997. Dwindling food-fish species and fishers' preference: problems of conserving Lake Malawi's biodiversity. *Biodiversity and Conservation* 6: 253-261.

Myers, G. S. 1960. The endemic fish fauna of Lake Lanao, and the evolution of higher taxonomic categories. *Evolution*, 14: 323-333.

Myers, N. 1988. Threatened biotas: 'hot spots' in tropical forests. *The Environmentalist* 8(3): 187-208.

Myers, N. 1990. The biodiversity challenge: expanded hot-spots analysis. *The Environmentalist* 10: 243-256..

Ng, P.K.L. 1988. *The freshwater crabs of peninsular Malaysia and Singapore.* Department of Zoology, University of Singapore, Shing Lee Publishers Pte. Ltd., Singapore, 156p.

Ng, P.K.L. 1994. Peat swamp fishes of Southeast Asia - Diversity under threat. *Wallaceana*, 73: 1-5.

Ng, P.K.L. 1995. A revision of the Sri Lankan montane crabs of the genus *Perbrinckia* Bott, 1969 (Crustacea: Decapoda: Brachyura: Parathelphusidae). *Journal of South Asian Natural History*, 1(1): 129-174.

Ng, P.K.L. and Dudgeon, D. 1991. The Potamidae and Parathelphusidae (Crustacea: Decapoda: Brachyura) of Hong Kong. *Invertebrate Taxonomy*, 6: 741-768.

Ng, P.K.L. and Naiyanetr, P. 1993. - New and recently described freshwater crabs (Crustacea: Decapoda: Brachyura: Potamidae, Gecarcinucidae and Parathelphusidae) from Thailand. *Zoologische Verhandelingen*, 284:1-117.

Ng, P.K.L., Tay, J.B., and Lim, K.K.P. 1994. Diversity and conservation of blackwater fishes in Peninsular Malaysia, particularly in the North Selangor peat swamp forest. *Hydrobiologia*, 285: 203-218.

Oberdorff, T., Guégan, J.-F. and Hugueny, B. 1995. Global scale patterns of fish species richness in rivers. *Ecography* 18: 345-352.

Olson, D.M., Chernoff, B., Burgess, G., Davidson, I., Canevari, P., Dinerstein, E., Castro, G., Morisset, V., Abell, R., and Toledo, E. (eds). 1997. *Freshwater biodiversity of Latin America and the Caribbean: a conservation assessment.* Proceedings of a workshop. World Wildlife Fund, Washington DC.

Palmer, M., Covich, A.P., Finlay, B.J., Gibert, J., Hyde, K.D., Johnson, R.K., Kairesalo, T., Lake, S., Lovell, C.R., Naiman, R.J., Ricci, C., Sabater, F. and Strayer, D. 1997. Biodiversity and ecosystem processes in freshwater sediments. *Ambio* 26(8): 571-577.

Parenti, L.R. 1984. A taxonomic revision of the Andean killifish genus *Orestias* (Cyprinodontiformes, Cypridontidae). *Bull.Amer.Mus.Nat.Hist*, 178 : 107-214

Pethiyagoda, R. 1991. *Freshwater fishes of Sri Lanka.* Wildlife Heritage Trust of Sri Lanka, Colombo, 362 pp.

Pethiyagoda, R. 1994. Threats to the indigenous freshwater fishes of Sri Lanka and remarks on their conservation. *Hydrobiologia*, 285: 189-201.

Pethiyagoda, R. and M. Kottelat. 1994. Three new species of fishes of the genera *Osteochilichthys* (Cyprinidae), *Travancoria* (Balitoridae)and *Horabagrus* (Bagridae) from the Chalakudy River, Kerala, India. J. South Asian Nat. Hist., 1 (1): 97-116.

Raskin, P., Gleick, P., Kirshen, P., Pontius, G. and Strzepek, K. 1997. *Water Futures: Assessment of Long-range Patterns and Problems.* Background Report #3 of *Comprehensive Assessment of the Freshwater Resources of the World.* Stockholm Environment Institute.

Reinthal, P.N. and Stiassny, M.L.J. 1991. The freshwater fishes of Madagascar: a study of an endangered fauna with recommendations for a conservation strategy. *Conservation Biology* 5(2): 231-243.

Richter, B.D., Braun, D.P., Mendelson, M.A. and Master, L.L. 1997. Threats to imperiled freshwater fauna. *Conservation Biology* 11(5): 1081-1093.

Rodriguez, G. 1982. *Les crabes d'eau douces d'Amérique.* Famille des Pseudothelphusidae. Faune Tropicale, 22, ORSTOM, Paris, 223p.

Rodriguez, G. 1986. Centers of radiation of fresh-water crabs in the neotropics. In: R. H. Gore and K. L. Heck, eds., Biogeography of the Crustacea. *Crustacean Issues*, 4: 51-67.

Rodriguez, G. 1992. *The freshwater crabs of America.* Family Trichodactylidae and supplement to the family Pseudothelphisidae. *Faune Tropicale*, 31, ORSTOM, Paris, 189p.

Rodriguez, G. and Campos, M.R. 1989. The cladistic relationships of the freshwater crabs of the Tribe Strengerianini (Crustacea, Decapoda, Pseudothelphusidae) from the northern Andes, with comments on their biogeography and descriptions of new species. *Journal of Crustacean Biology*, 9: 141-156.

Rodriguez, G. and Pereira, G. 1992. New species, cladistic relationships and biogeography of the genus *Fredius* (Decapoda: Brachyura: Pseudothelphusidae) from South America. *Journal of Crustacean Biology*, 12: 298-311.

Rodriguez, G. and von Sternberg, R. 1998. A revision of the freshwater crabs of the family Pseudothelphusidae (Decapoda: Brachyura) from Ecuador. *Proceedings of the Biological Society of Washington.* In press.

Scott, D.A. (ed) 1989. *A Directory of Asian Wetlands.* IUCN, Gland, Switzerland and Cambridge, UK.

Scott, D.A. and Carbonell, M. 1986. *A Directory of Neotropical Wetlands.* IUCN, Gland and Cambridge.

Scudder, T. and Conelly, T. 1985. *Management systems for riverine fisheries.* FAO Fisheries Technical Paper 263. FAO, Rome.

Sculthorpe, C.D. 1967. *The biology of aquatic vascular plants.* Edward Arnold, London.

Smith, G. R. and T. N. Todd. 1984. Evolution of species flocks of fishes in north temperate lakes. Pp. 45-68 in A. A. Echelle and I. L. Kornfield (eds.), *Evolution of fish species flocks.* University of Maine at Orono Press, Orono.

Stiassny, M. 1996. An overview of freshwater biodiversity, with some lessons learned from African fishes. *Fisheries* 21 (9): 7-13.

Talwar, P. K. and A. G. Jhingran. 1991. Inland fishes of India and adjacent countries. Oxford and IBH Publishing Company, New Delhi, 2 vols.

Tittley, I. 1992. Contribution to chapter 7, Lower plant diversity, in Groombridge, B. (ed) *Global Biodiversity.* Chapman and Hall.

Türkay, M. and Cumberlidge, N. 1998. Identification of freshwater crabs from Mount Nimba, West Africa (Brachyura: Potamoidea: Potamonautidae). *Senckenbergiana biologia.* In press.

Türkay, M. and Dai, A.Y. 1997. Review of the Chinese freshwater crabs previously placed in the genus *Malayopotamon* Bott, 1968 (Crustacea: Decapoda: Brachyura: Potamidae). *Raffles Bulletin of Zoology*, 45(2): 189-207.

UN (CSD). 1997. Comprehensive Assessment of the Freshwater Resources of the World. Economic and Social Council. Fifth Session, 5-25 April. E/CN.17/1997/9. Available online through http://www.un.org/esa/sustdev/csd.htm.

UNEP (United Nations Environment Programme). 1991. *Freshwater Pollution.* UNEP/GEMS Environmental Library No 6.

UNEP (United Nations Environment Programme). 1995. *Water Quality of World River Basins.* UNEP/GEMS Environmental Library No 6.

Watter, G.T. 1992. Unionids, fishes, and the species-area curve. *Journal of Biogeography* 19: 481-490.

Welcomme, R. L (comp). 1988. International introductions of inland aquatic species. *FAO Fish.Tech.Pap.* (294) 318pp.

WWF. 1997. *Living Planet Report.* Unpublished draft, December.

Wu Y.-F. and Wu C.-Z. 1992. [*The fishes of the Qinghai-Xizang Plateau*]. Sichuan Publishing House of Science and Technology, Chengdu , 599 pp. [Chinese, English summary]

Yang J.-X. and Chen Y.-R. 1995. [*The biology and resource utilization on the fishes of Fuxian Lake, Yunnan*]. Yunnan Science and Technology Press, Kunming, 224 pp. [Chinese, English summary]

ANNEX 1

LARGER RIVERS OF THE WORLD, INCLUDING A LIST OF BASINS ANALYSED IN THIS REPORT AND A PRELIMINARY REVISED LIST OF INTERNATIONAL BASINS

Part 1: basins included in the analytic phase of this report (sorted by approximate area of basin).
Part 2: other larger basins, not yet included in the analysis (sorted by approximate area of basin).
NB: international basins have more than one country listed in the 'Countries' column.

Part 1. Basins included in the analytic phase of this report.

Continent	River	Countries	area (sq. km)
South America	Amazon (with Ucayali)	Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Venezuela	5,870,000
Africa	Congo	Angola, Burundi, Cameroon, Central African Republic, Congo, Congo (DR), Rwanda, Tanzania, Zambia,	3,720,000
N+C America	Mississippi (with Missouri)	Canada, USA	3,250,000
South America	La Plata (with Parana and Uruguay)	Argentina, Bolivia, Brazil, Paraguay, Uruguay	3,200,000
Africa	Nile (with Kagera)	Burundi, Congo (DR), Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda	3,030,700
Asia	Ob (with Irtysh)	China, Kazakhstan, Russia	3,010,000
Asia	Yenisey (Yenesei)	Mongolia, Russia	2,530,000
Asia	Lena	Russia	2,490,000
Africa	Niger	Algeria, Benin, Burkino Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Nigeria, Niger	2,200,000
Asia	Amur	China, Mongolia, Russia	1,900,000
Asia	Yangtze	China	1,800,000
N+C America	Mackenzie (with Athabaska)	Canada	1,800,000
Asia	Ganges-Brahmaputra	Bangladesh, Bhutan, China, India, Nepal	1,600,400
Africa	Zambezi	Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe	1,419,960
Europe	Volga	Russia	1,360,000
N+C America	St. Lawrence	Canada, USA	1,280,000
Australia & NZ	Murray-Darling	Australia	1,060,000
N+C America	Nelson (with Saskatchewan)	Canada, USA	990,000
Asia	Indus	Afghanistan, China, India, Pakistan	980,000

Continent	River	Countries	area (sq. km)
South America	Orinoco	Colombia, Venezuela	966,000
Africa	Orange	Botswana, Lesotho, Namibia, South Africa	950,000
Asia	Shatt-al-Arab (Tigris and Euphrates)	Iran, Iraq, Syria, Turkey	884,000
Africa	Chari	Cameroon, Chad, Central African Republic	880,000
Europe	Danube	Albania, Austria, Bulgaria, Czech Republic, Germany, Hungary, Italy, Moldova, Poland, Romania, Slovakia, Switzerland, Ukraine, Yugoslavia,	796,250
Asia	Mekong	Cambodia, China, Laos, Myanmar, Thailand, Viet Nam,	786,000
Africa	Juba (with Shaballe)	Ethiopia, Kenya, Somalia	766,500
N+C America	Yukon	Canada, USA	765,000
Asia	Hwang Ho	China	745,000
Asia	Amu Darya	Afghanistan, Kyrgystan, Tajikistan, Turkmenistan, Uzbekistan	653,000
Asia	Kolyma	Russia	647,000
N+C America	Colorado (State of Arizona)	Mexico, USA	615,000
N+C America	Columbia	Canada, USA	610,000
South America	Sao Francisco	Brazil	600,000
N+C America	Bravo del Norte (Rio Grande)	Mexico, USA	550,000
Europe	Dnepr	Belarus, Russia, Ukraine	504,000
Asia	Syr Darya	Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan	429,134
Europe	Don	Russia, Ukraine	422,000
Asia	Irrawaddy	China, India, Myanmar	396,000
Asia	Helmand	Afghanistan, Iran, Pakistan	386,000
Africa	Limpopo	Botswana, Mozambique, South Africa, Zimbabwe	385,000
Africa	Volta	Benin, Burkino Faso, Côte d'Ivoire, Ghana, Mali, Togo	379,000
Asia	Indigirka	Russia	360,000
Europe	Northern Dvina	Russia	357,000
Africa	Senegal	Guinea, Mali, Mauritania, Senegal	353,000
South America	Parnaiba	Brazil	325,000
Asia	Godavari	India	314,000
Asia	Salween	China, Myanmar, Thailand	270,000
N+C America	Fraser	Canada, USA	260,000
Asia	Krishna	India	256,000
South America	Magdalena	Colombia	240,000
Europe	Ural	Kazakhstan, Russia	237,000
Asia	Liao Ho	China	231,000
Asia	Kura-Araks	Armenia, Azerbaijan, Georgia, Iran, Turkey	225,000
Africa	Ogooue/Ogowe	Cameroon, Congo, Equatorial Guinea Gabon	220,700

Continent	River	Countries	area (sq. km)
Europe	Wisla/Vistula	Belarus, Poland, Slovakia, Ukraine	193,000
Africa	Rufiji	Tanzania	178,000
Asia	Hong Ha (Red River)	China, Laos, Viet Nam	169,600
Europe	Rhine	Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Netherlands, Switzerland	168,757
Asia	Chao Phraya/Menam	Thailand	160,000
South America	Essequibo	Guyana, Venezuela	147,000
Europe	Elbe	Austria, Czech Republic, Germany, Poland	144,500
South America	Chubut	Argentina	138,000
Africa	Sanaga	Cameroon, Central African Republic	135,000
Asia	Mahanadi	India	133,000
Europe	Oder	Czech Republic, Germany, Poland	126,000
N+C America	Rio Grande de Santiago	Mexico	125,000
Europe	Loire	France	120,000
N+C America	Grijalva (with Usumacinta)	Guatemala, Mexico	120,000
N+C America	Mobile (Alabama)	USA	115,000
N+C America	Brazos	USA	114,000
South America	Lakes Titicaca – Poopo system	Bolvia, Chile, Peru	114,000
Africa	Cunene/Kunene	Angola, Namibia	112,000
N+C America	Balsas	Mexico	106,000
Africa	Save (Sabi)	Mozambique, Zimbabwe	103,000
Asia	Narmada	India	102,000
N+C America	Colorado (State of Texas)	USA	100,000
Europe	Rhone	France, Switzerland	95,300
Europe	Douro/Duero	Portugal, Spain	94,500
Africa	Tana	Kenya	91,000
Europe	Western Dvina	Belarus, Latvia, Russia	87,900
Europe	Ebro	Andorra, France, Spain	84,440
N+C America	Panuco	Mexico	84,000
Europe	Tejo/Tagus	Portugal, Spain	82,000
Africa	Dra	Algeria, Morocco	80,500
Europe	Seine	France	78,600
Africa	Sassandra	Côte d'Ivoire, Guinea	77,500
Asia	Kyzyl Irmak/Kizil Irmack	Turkey	75,800
Africa	Gambia	Gambia, Guinea, Senegal	75,760
Europe	Po	Italy, Switzerland	74,300
Asia	Murgab	Afghanistan, Turkmenistan	73,000
N+C America	Sacramento	USA	73,000
N+C America	Susquehanna	USA	72,500
Europe	Dnestr	Moldova, Ukraine	72,100
Asia	Sepik	Indonesia, Papua New Guinea	71,000
Asia	Hari Rud/Tedzhen	Afghanistan, Iran, Turkmenistan	70,600
N+C America	Yaqui	Mexico, USA	70,000
Asia	Fly	Indonesia, Papua New Guinea	67,000

Continent	River	Countries	area (sq. km)
South America	Maroni	French Guiana, Surinam	66,000
South America	Colorado	Argentina	65,000
Asia	Yalu	China, Korea (PDR)	64,500
Europe	Guadiana	Portugal, Spain	61,400
Africa	Lurio	Mozambique	57,600
Europe	Guadalquivir	Spain	57,100
N+C America	Stikine	Canada, USA	56,700
N+C America	Skeena	Canada	54,900
Europe	Garonne	Andorra, France, Spain	53,425
Europe	Weser	Germany	52,800
Europe	Kemi/Kemijoki	Finland, Russia	51,500
Africa	Omo	Ethiopia	46,700
Europe	Terek	Georgia, Russia	43,200
Europe	Glama	Norway	40,500
N+C America	Papaloapan	Mexico	37,400
Asia	Ma	Laos, Viet Nam	36,000
N+C America	Hudson	USA	35,000
South America	Atrato	Colombia	32,200
Europe	Dal	Sweden	29,000
Asia	Ca	Laos, Viet Nam	28,500
N+C America	Savannah	USA	27,200

Part 2. Larger basins not analysed in this report.

Africa	Lake Chad basin	Cameroon , Central African Republic, Chad, Niger, Nigeria, Sudan	1,910,000
Asia	Tarim (Yarkend)	China, Kyrgyzstan	980,000
Africa	Kavango (Cubango)	Angola, Botswana, Namibia	785,000
Asia	Chutsyan		437,000
Asia	His	China, Viet Nam	436,000
Asia	Khatanga	Russia	364,000
Europe	Pechora	Russia	322,000
Australia & NZ	Coopers Creek	Australia	285,000
Europe	Neva	Russia	281,000
N+C America	Churchill	Canada	281,000
Asia	Yana	Russia	238,000
Asia	Hwai Ho	China	220,000
Asia	Olenek	Russia	219,000
Africa	Lake Turkana	Ethiopia, Kenya, Sudan, Uganda	203,300
Asia	Anadyr	Russia	191,000
Asia	Pyasina	Russia	182,000
Asia	Ili	China, Kazakhstan	176,000
Africa	Ruvuma	Malawi, Mozambique, Tanzania	166,500
Australia & NZ	Diamantina	Australia	156,000
Asia	Taz	Russia	150,000
Africa	Cuanza	Angola	149,000
Australia & NZ	Fitzroy (Qld)	Australia	143,000
N+C America	Thelon	Canada	142,000
N+C America	Albany	Canada	134,000
N+C America	Koksoak	Canada	133,000
Australia & NZ	Burdekin	Australia	131,000

Continent	River	Countries	area (sq. km)
South America	Rio Negro	Brazil, Colombia, Venezuela	130,000
Africa	Cuvelai-Etosha	Angola, Namibia	126,000
Asia	Taimyr	Russia	124,000
Asia	Kerulen	Mongolia	120,000
Africa	Awash	Djibouti, Ethiopia	118,500
Asia	Pur	Russia	112,000
N+C America	Moose	Canada	108,000
N+C America	Hayes	Canada	108,000
Australia & NZ	Flinders	Australia	108,000
N+C America	Back	Canada	107,000
N+C America	Severn	Canada	101,000
Asia	Anabar	Russia	100,000
Africa	Guir	Algeria, Morocco	98,500
N+C America	Fort George	Canada	97,700
Africa	Bandama	Côte d'Ivoire	97,000
N+C America	Saguenay	Canada	90,100
South America	Mearim	Brazil	89,700
Australia & NZ	Fitzroy (WA)	Australia	86,500
Europe	Neman	Belarus, Lithuania, Poland, Russia	86,300
Asia	Hari	Afghanistan, Iran, Turkmenistan	84,000
Australia & NZ	Ashburton	Australia	82,000
Asia	Sarysu	Kazakhstan	81,600
South America	Doce	Brazil	81,300
N+C America	San Joaquin	USA	80,100
N+C America	Churchill (Hamilton)		79,800
Australia & NZ	Gascoyne	Australia	79,000
Europe	Mezen	Russia	78,000
Australia & NZ	Victoria	Australia	77,500
Africa	Kam	Nigeria	76,500
Europe	Vuoksa	Finland, Russia	76,000
Africa	Komoe	Burkino Faso, Côte d'Ivoire	75,000
Asia	Penzhina	Russia	73,500
South America	Courantyne	Guyana, Surinam	72,100
N+C America	Kazan	Canada	71,500
Australia & NZ	Mitchell	Australia	69,300
Australia & NZ	Murchison	Australia	68,300
N+C America	Winisk	Canada	67,300
Asia	Lake Ubsa	Mongolia, Russia	67,000
Africa	Baraka	Ethiopia, Sudan	66,200
Africa	Daoura	Algeria, Morocco	65,700
N+C America	Nottaway	Canada	65,000
Asia	Alazea/Alazeya	Russia	64,700
Asia	Nadym	Russia	64,000
Africa	Kouilou	Congo	62,000
N+C America	Copper	Canada	61,800
Asia	Uda	Russia	61,300
Asia	Atrek	Iran, Turkmenistan	61,000
Asia	Chu	Laos, Viet Nam	60,800
South America	Paraiba	Brazil	59,000
Europe	Kuban	Russia	57,900
Africa	Cross	Cameroon, Nigeria	57,000
Europe	Onega	Russia	56,900

Continent	River	Countries	area (sq. km)
Asia	Sakarya	Turkey	56,500
Europe	Narva	Estonia, Russia	56,200
Europe	Maritsa	Bulgaria, Greece, Turkey	56,000
Asia	Kamchatka	Russia	55,900
South America	Lagoon Mirim	Brazil, Uruguay	55,700
Australia & NZ	Fortescue	Australia	55,000
Africa	Moulouya	Morocco	52,000
N+C America	Saint John	Canada, USA	51,800
N+C America	Apalachicola	USA	51,800
N+C America	Attawapiskat	Canada	50,200
Europe	Klaralven	Norway, Sweden	47,000
N+C America	Eastmain	Canada	46,400
N+C America	Manicouagan	Canada	45,600
Africa	Oueme	Benin, Nigeria, Togo	45,500
N+C America	George	Canada	44,800
Asia	Saigon	Cambodia, Viet Nam	44,000
Africa	Gourits	South Africa	44,000
N+C America	Humboldt	USA	43,900
N+C America	Rupert	Canada	43,200
N+C America	Great Whale	Canada	43,200
N+C America	Leaf	USA	43,000
N+C America	St. Maurice	Canada	42,700
Asia	Kaladan	India, Myanmar	40,000
Africa	Sebu		40,000
N+C America	San Juan	Costa Rica, Nicaragua	39,350
Europe	Kiumi		37,800
Asia	Dasht	Iran, Pakistan	36,000
Africa	Medjerda	Algeria, Tunisia	36,000
Africa	Chelif	Algeria	35,000
Asia	Han	Korea (PDR), Korea (R)	34,700
South America	Catatumbo	Colombia, Venezuela	34,480
Asia	Tumen	China, Korea (PDR), Russia	34,400
Africa	Oum-er-Rbia	Morocco	34,400
Africa	Maputo	Mozambique, South Africa, Swaziland	33,963
Africa	Pangani	Tanzania	33,800
Africa	Niem	Cameroon, Gabon, Equatorial Guinea	33,000
Europe	Torne/Tornio	Finland, Sweden	32,400
Africa	Gash	Ethiopia, Sudan	32,000
N+C America	Weiss		31,300
South America	Oyapock	Brazil, French Guiana	30,270
N+C America	Penobscot	USA	30,000
N+C America	Potomac	USA	30,000
Africa	Buzi	Mozambique, Zimbabwe	29,500
N+C America	Harricanaw	Canada	29,300
N+C America	Connecticut	Canada, USA	29,000
Africa	Kovali/Cavally	Côte d'Ivoire, Guinea, Liberia	28,800
Africa	Lake Natron	Kenya, Tanzania	28,500
Europe	Kem	Russia	27,700
Africa	Nyanga	Congo, Gabon	26,000
South America	Baker	Argentina, Chile	25,700
Africa	Mono	Benin, Togo	25,600
Europe	Oulu	Finland, Russia	25,000

Continent	River	Countries	area (sq. km)
N+C America	Coco (Segovia)	Honduras, Nicaragua	24,800
South America	Bio Bio	Argentina, Chile	24,300
Europe	Vardar	Greece, Macedonia FYR	24,000
Europe	Tuloma	Finland, Russia	23,600
Africa	Cavally	Côte d'Ivoire, Guinea, Liberia	23,500
South America	Lauca	Bolivia, Chile	23,500
South America	Patia	Colombia, Ecuador	22,540
Europe	Jucar	Spain	22,400
Africa	Corubal	Guinea, Guinea-Bisseau	22,000
Australia & NZ	Ciutha	New Zealand	22,000
Europe	Severn	UK	21,000
Asia	Coruh	Georgia, Turkey	21,000
Europe	Olanga	Finland, Russia	20,700
Africa	Moa	Guinea, Liberia, Sierra Leone	20,000
Europe	Pregel	Poland, Russia	19,700
Africa	Atui	Mauritania, Western Sahara	19,500
Europe	Pasvik	Finland, Norway, Russia	19,300
Africa	St Paul	Guinea, Liberia	18,000
Europe	Minko/Mino	Portugal, Spain	17,700
Europe	Tiber	Italy	17,200
Europe	Drin	Albania, Macedonia FYR	17,100
Europe	Schelde	Belgium, France, Netherlands	16,500
Asia	Suyfun	China, Russia	16,500
South America	Chira	Ecuador, Peru	16,220
Europe	Segura	Spain	16,100
Africa	Benito	Equatorial Guinea, Gabon	15,900
Europe	Shannon	Ireland	15,700
Europe	Thames	UK	15,300
South America	Aysen	Argentina, Chile	15,300
Africa	Little Scarcies	Guinea, Sierra Leone	15,000
Europe	Struma	Bulgaria, Greece, Macedonia FYR, Federal Republic of Yugoslavia	14,500
Africa	Tano	Côte d'Ivoire, Ghana	14,000
South America	Pascua	Argentina, Chile	13,840
Africa	Geba	Guinea, Guinea-Bissau, Senegal	13,700
Europe	Minho	Portugal, Spain	13,500
Africa	St John	Guinea, Liberia	13,500
Asia	Asi (Orontes)	Lebanon, Syria, Turkey	13,300
Africa	Bia	Ghana, Cote d'Ivoire	13,100
Europe	Tana	Finland, Norway	13,000
South America	Palena	Argentina, Chile	13,000
Africa	Utamboni	Equatorial Guinea, Gabon	12,800
N+C America	Motagua	Guatemala, Honduras	12,570
Africa	Cestos	Liberia, Cote d'Ivoire, Guinea	12,500
South America	Gallegos-Chico	Argentina, Chile	12,240
Africa	Lofa	Guinea, Liberia	12,000
Asia	Jordan	Israel, Jordan, Lebanon, Syria	11,500
South America	Valdivia	Argentina, Chile	11,280
South America	Mira	Colombia, Ecuador	11,200
South America	Yelcho	Argentina, Chile	11,145
Asia	Sembakung	Indonesia, Malaysia	11,000
Africa	Chiloango	Angola, Congo, Congo (DR)	11,000

Continent	River	Countries	area (sq. km)
N+C America	Candelaria	Guatemala, Mexico	10,800
Asia	Karnafuli	Bangladesh, India	10,500
South America	Amacuro	Guyana, Venezuela	10,260
Africa	Mano-Morro	Liberia, Sierra Leone	10,000
N+C America	Lempa	El Salvador, Guatemala, Honduras	9,870
South America	Serrano	Chile, Argentina	9,100
Africa	Tafna	Algeria, Morocco	8,800
South America	Puelo	Argentina, Chile	8,800
Africa	Great Scarcies	Guinea, Sierra Leone	8,500
South America	Barima	Guyana, Venezuela	8,400
N+C America	St. Croix	Canada, USA,	8,100
Africa	Umbeluzi	Mozambique, South Africa, Swaziland	8,000
N+C America	Artibonite	Dominican Republic, Haiti	7,900
N+C America	Belize	Belize, Guatemala	6,960
Europe	Vijose	Albania, Greece	6,900
N+C America	Choluteca	Honduras, Nicaragua	6,260
Asia	Tiban	Yemen	6,200
Europe	Bann	Ireland, UK (Northern Ireland)	5,800
N+C America	Hondo	Belize, Guatemala, Mexico	5,600
South America	Rio Grande	Argentina, Chile	4,830
South America	Lake Gagnano	Argentina, Chile	4,820
Europe	Erne	Ireland, UK (Northern Ireland)	4,750
South America	Tumbes	Ecuador, Peru	4,655
Asia	Tami	Indonesia, Papua New Guinea	4,600
Europe	Foyle	Ireland, UK (Northern Ireland)	4,000
Europe	Naatamo	Finland, Norway	3,700
Europe	Lima	Portugal, Spain	3,400
N+C America	Sixaola	Costa Rica, Panama	3,300
Asia	Pakchan	Myanmar, Thailand	3,100
N+C America	Changuinola	Costa Rica, Panama	3,060
N+C America	Negro	Honduras, Nicaragua	2,830
Europe	Isonzo	Italy, Slovenia	2,800
N+C America	Goascoran	El Salvador, Honduras	2,500
Africa	Akpa	Cameroon, Nigeria	2,150
N+C America	Suchiate	Guatemala, Mexico	1,840
N+C America	Sarstun	Belize, Guatemala	1,800
Europe	Yser	Belgium, France	1,700
N+C America	Paz	El Salvador, Guatemala	1,650
N+C America	Tijuana	Mexico, USA	1,635
South America	Carmen Silva	Argentina, Chile	1,620
South America	Zarumilla	Ecuador, Peru	1,570
South America	Zapaleri	Argentina, Bolivia, Chile	1,565
Asia	Golok	Malaysia, Thailand	1,500
Europe	Lake Prespa	Albania, Greece, Macedonia FYR	1,400
Europe	Muga	France, Spain	1,300
N+C America	Coatan-Achute	Guatemala, Mexico	1,250
Europe	Rezvaya	Turkey, Bulgaria	1,100
Europe	Veleka	Bulgaria, Turkey	1,000
South America	Mataje	Colombia, Ecuador	870
Europe	Bidasoa	France, Spain	820
Europe	Roia	France, Italy	750
South America	Cullen	Argentina, Chile	735

Continent	River	Countries	area (sq. km)
N+C America	Jurado	Colombia, Panama	620
South America	Chuy	Brazil, Uruguay	500
N+C America	Massacre	Dominican Republic, Haiti	480
N+C America	Pedemales	Dominican Republic, Haiti	450
South America	San Martin	Argentina, Chile	370
Europe	Jacobs	Norway, Russia	240
Europe	Fane	Ireland, UK (Northern Ireland)	190
Europe	Meuse	Belgium, France, Germany, Netherlands	

Notes: the estimates of basin area are from two different sources, sometimes with significant differences for the same system; the country information is preliminary and entirely unofficial and implies no expression of opinion on the part of WCMC, UNEP or any collaborating organisation about the legal status of any country, territory or area concerning the delimitation of boundaries of nations or catchment basins.

Sources: expanded from:

Anon. 1978a (Centre for Natural Resources, Energy and Transport of the Department of Economic and Social Affairs, United Nations). 1978. Register of International Rivers. *Water Supply and Management*. 2: 1-58. (Special Issue). Pergamon Press.

Anon. 1978b. *World water balance and water resources of the Earth*. USSR Committee for the International Hydrological Decade. Studies and reports in hydrology N0. 25. UNESCO.

ANNEX 2

RIVER BASIN ANALYSIS: SELECT DATA FROM WCMC FRESHWATER BIODIVERSITY DATABASE

River basins are listed in numerical sequence within each main column, the basin with the highest value for each parameter being listed first. In columns 3 and 5-8, the relative values of the figures are of significance not their actual magnitude.

1 Area sq km (approx)		2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Amazon	6063681	Amazon	2500	Amazon	2.85	Amazon	49	Maroni	25.11	Mamberamo	2989	Tana	640	Cauvery	0.61
Congo/Zaire	3692062	Congo/Zaire	690	Zaire	1.68	Orinoco	45	Essequibo	24.49	Kuskokwim	2965	Narmada	639	Mahanadi	0.59
Mississippi	3225218	Mekong	450	Mekong	1.62	Tocantins	45	Amazon	22.97	Atrato	2905	Penner	639	Godavari	0.58
Nile	3071306	Yangtze	320	Cauvery	1.62	Parana	44	Tocantins	22.68	Stikine	2888	Krishna	639	Krishna	0.57
Ob	3070962	Orinoco	318	Sittang	1.59	Essequibo	44	Orinoco	22.35	Amazon	2880	Godavari	639	Penner	0.57
Parana	2571187	Cauvery	265	Kapuas	1.53	Maroni	43	Perak	19.86	Essequibo	2830	Mahanadi	639	Narmada	0.54
Lena	2404487	Kapuas	250	Sinu	1.50	Parnaiba	40	Parana	19.52	Mackenzie	2816	Cauvery	639	Tapti	0.53
Amur	2207981	Mississippi	225	Chao Phraya	1.32	Magdalena	38	Parnaiba	19.24	Maroni	2783	Tapti	638	Helmand	0.44
Niger	2112774	Chao Phraya	222	Orinoco	1.24	S. Francisco	38	Magdalena	17.87	Yukon	2779	Helmand	637	Weser	0.41
Yenisey	1916400	Sittang	200	Mahakam	1.23	Mekong	37	Pahang	17.64	Indigirka	2740	Dra	611	Tigris-Euphrates	0.40
Yangtze	1711156	Krishna	187	Yangtze	1.10	Chao Phraya	36	Chao Phraya	16.64	Lena	2690	Indus	604	Ganges-Brahmaputra	0.39
Ganges-Brahmaputra	1684918	Ogooue	184	Song Hong	1.08	Niger	35	S. Francisco	16.09	Tocantins	2663	Nile	596	Loire	0.39
Mackenzie	1529031	Song Hong	180	Ogooue	1.04	Perak	35	Sinu	16.07	Rajang	2634	Tigris-Euphrates	581	Seine	0.38
Volga	1387306	Mahakam	174	Pearl	1.04	Salween	34	Rajang	14.81	Yenisey	2622	Ganges-Brahmaputra	574	Oder	0.38
Zambezi	1384999	Parana	170	Krishna	1.02	Uruguay	34	Mahakam	14.79	Orinoco	2567	Jubba-Shebelle	566	Kura-Araks	0.36
Saskatchewan-Nelson	1134018	Hwang Ho	160	Sanaga	0.85	Irrawaddy	34	Mekong	14.63	Sinu	2558	Murghab	551	Indus	0.36
St. Lawrence	1052181	Niger	149	Susquehanna	0.82	Pahang	34	Sittang	14.52	Kolyma	2540	Senegal	549	Vistula	0.36
Murray-Darling	1049806	Sinu	148	Savannah	0.80	Congo/Zaire	33	Atrato	14.28	Fly	2309	Hari Rud	526	Garonne	0.36
Indus	1031425	Indus	147	Alabama	0.79	Mahakam	33	Tembesi-Hari	14.01	Cunene	2286	Amu Darya	517	Sevan Lake	0.35

1 Area sq km (approx)		2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Orinoco	938481	Salween	143	Salween	0.76	Kapuas	32	Salween	13.75	Dra	2276	Kura-Araks	509	Tana	0.34
Hwang Ho	880881	Magdalena	135	Magdalena	0.72	Volta	32	Kapuas	13.35	Rufiji	2275	Sevan Lake	487	Panuco	0.34
Yukon	829506	Sanaga	135	Hudson	0.62	Rajang	32	Uruguay	13.17	Kapuas	2264	Rufiji	480	Kizil	0 33
Danube	807881	Volta	132	Mississippi	0.59	Ganges-Brahmaputra	32	Irrawaddy	12.95	Okavango	2258	Omo Wenz	480	Liao	0.33
Mekong	804381	Chari	130	Hwang Ho	0.56	Sittang	31	Comoe	12.83	Ogooue	2246	Olifants	480	Song Hong	0.33
Jubba-Shebelle	803212	Alabama	122	Fly	0.56	Sinu	31	Sanaga	11 86	Omo Wenz	2151	Groot	480	Rhine	0.32
Tocantins	779874	Zambezi	122	Volta	0.55	Sanaga	31	Sassandra	11.06	Skeena	2145	Yangtze	480	Po	0.32
Kolyma	746043	Amur	120	Yalu Jiang	0.50	Chari	31	Niger	10.88	Lurio	2137	Save	480	Rhone	0.32
Okavango	694456	Nile	115	Gambia	0.47	Tembesi-Hari	31	Volta	10.83	Baikal	2098	Syr Darya	480	Ting	0.31
Chari	669706	Uruguay	115	Uruguay	0.46	Comoe	31	Ca	10.06	Mahakam	2057	Tsiribihina	480	Yalu Jiang	0.31
Colorado	669056	Susquehanna	111	Indus	0.44	Atrato	31	Ogooue	9.96	Jubba-Shebelle	2021	Mangoky	480	Min	0.31
Columbia	668587	Pearl	106	Chari	0.42	Ogooue	30	Chari	8.96	Nile	2020	Betsiboka	480	Hari Rud	0.30
Rio Grande	642343	Fly	101	Narmada	0.37	Nile	30	Krishna	8.72	Zambezi	1996	Santiago-Lerma-Chapala	480	Balsas	0.30
S. Francisco	623856	St. Lawrence	93	Parana	0.37	Mississippi	29	Penner	8.71	Fraser	1988	Seine	480	Elbe	0.29
Orange	621224	Parnaiba	90	Usumacinta	0.34	Krishna	29	Cauvery	8.56	Ob	1973	Loire	480	Santiago-Lerma-Chapala	0.29
Amu Darya	611525	Savannah	88	Panuco	0.33	Sassandra	29	Ganges-Brahmaputra	8.29	Tana	1964	Lurio	479	Murghab	0.29
Tigris-Euphrates	600356	Senegal	86	Elbe	0.33	Zambezi	28	Ma	8.22	Amur	1956	Hwang Ho	479	Betsiboka	0.28
Baikal	586799	Hudson	80	Niger	0.28	Senegal	28	Susquehanna	8.10	Niger	1949	Papaloapan	479	Si	0.28
Dnieper	532756	Usumacinta	80	Rajang	0.28	Godavari	28	Gambia	8.05	Magdalena	1948	Si	479	Mangoky	0.27
Don	485837	Gambia	79	Sassandra	0.28	Cauvery	27	Tapti	7.95	Sepik	1930	Balsas	479	Tsiribihina	0.27
Si	460243	Irrawaddy	79	Papaloapan	0.26	Susquehanna	26	Zaire	7.87	Congo/Zaire	1869	Min	479	Nile	0.26

1 Area sq km (approx)		2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Senegal	435981	Okavango	79	Parnaiba	0.23	Gambia	26	Narmada	7.47	Senegal	1835	Yalu Jiang	479	Senegal	0.24
Syr Darya	429118	Narmada	77	Zambezi	0.18	Narmada	26	Godavari	7.29	Rio Colorado	1828	Ting	479	Ma	0.24
Rio Colorado	419081	Elbe	77	Senegal	0.11	Penner	26	Senegal	6.74	Olifants	1811	Liao	479	Thames	0.23
Limpopo	414524	Panuco	75	Rhone	0.09	Mahanadi	26	Mahanadi	6.67	Usumacinta	1808	Kizil	479	Papaloapan	0.23
Volta	414243	Yalu Jiang	74	Irrawaddy	0.06	Tapti	26	Titicaca	6.62	Pahang	1806	Panuco	479	Ca	0.23
Irrawaddy	387631	Tigris-Euphrates	71	Amur	0.06	Ca	26	Hudson	6.09	Chobut	1783	Weser	479	Danube	0.22
N. Dvina	359412	Rio Grande	71	Dniester	0.04	St. Lawrence	25	Savannah	5.69	Amu Darya	1780	Chao Phraya	478	Chao Phraya	0.22
Uruguay	343618	Sassandra	65	Sepik	-0.02	Ma	25	Nile	5.20	Chari	1776	Song Hong	478	Syr Darya	0.22
Parnaiba	330750	Volga	61	St. Lawrence	-0.02	Titicaca	25	Pearl	5.10	Negro	1770	Garonne	477	Amu Darya	0.21
Indigirka	328118	Rajang	59	Brazos	-0.03	Song Hong	24	Kwanza	4.77	Limpopo	1752	Oder	469	Save	0.21
Godavari	320937	Rhone	58	Dalalven	-0.06	Indus	24	Zambezi	4.64	Parnaiba	1744	Vistula	464	Jubba-Shebelle	0.21
Helmand	317481	Papaloapan	58	Nile	-0.07	Kwanza	24	Song Hong	4.41	Kwanza	1744	Yaqui	463	Gambia	0.21
Liao	274124	Dnieper	58	Okavango	-0.08	Yangtze	23	Mississippi	4.11	Indus	1739	Rhone	460	Hwang Ho	0.21
Ural	261718	Brazos	55	Weser	-0.10	Hudson	23	Omo Wenz	4.07	Groot	1731	Niger	457	Dniester	0.20
Krishna	252443	Sepik	53	Tigris-Euphrates	-0.16	Alabama	22	Alabama	3.17	Murghab	1713	Po	452	Yangtze	0.20
Salween	249481	Mackenzie	53	W. Dvina	-0.16	Savannah	22	Save	2.15	S. Francisco	1700	Gambia	449	Dra	0.19
Fraser	239943	Dniester	52	Rio Grande	-0.17	Saskatchewan-Nelson	22	St. Lawrence	2.14	Kemijoki	1673	Limpopo	448	Yaqui	0.19
Magdalena	233343	Danube	52	Terek	-0.21	Si	22	Indus	1.18	N. Dvina	1665	Zambezi	446	Tagus	0.18
Ogooue	221968	Ural	48	Kura-Araks	-0.24	Omo Wenz	22	Rufiji	1.11	Helmand	1660	Orange	440	Mekong	0.18
Rufiji	204050	Syr Darya	48	Vistula	-0.30	Pearl	21	Si	0.64	Titicaca	1657	Chari	436	Groot	0.17
Rhine	192887	Kura-Araks	47	Skeena	-0.32	Okavango	21	Yalu Jiang	-0.27	Yangtze	1653	Mekong	436	Ural	0.17
Vistula	183249	Limpopo	47	Sacramento	-0.33	Jubba-Shebelle	21	Ting	-0.32	Perak	1652	Ca	425	Douro-Duero	0.15

1 Area sq km (approx)		2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Song Hong	172462	Don	47	Dnieper	-0.33	Save	21	Yangtze	-0.74	Comoe	1651	Ma	424	Olifants	0.14
Essequibo	165712	Vistula	46	Ural	-0.35	Rufiji	21	Saskatchewan-Nelson	-0.99	Orange	1651	Usumacinta	418	Orange	0.14
Oder	165156	Columbia	45	Glama	-0.35	Limpopo	19	Lurio	-1.09	Parana	1635	Rhine	417	Hudson	0.13
Negro	160287	Rhine	44	Rhine	-0.36	Amur	17	Okavango	-1.11	Hwang Ho	1624	Elbe	413	Dnieper	0.12
Kura-Araks	154312	W. Dvina	44	Yaqui	-0.37	Yalu Jiang	17	Jubba-Shebelle	-1.37	Saskatchewan-Nelson	1622	Titicaca	408	Don	0.12
Chao Phraya	151868	Saskatchewan-Nelson	44	Klamath	-0.41	Murray-Darling	17	Tana	-1.52	Rio Grande	1615	Ural	408	Pearl	0.12
Mahanadi	149500	Ob	43	Garonne	-0.41	Tana	17	Limpopo	-2.17	Save	1612	Salween	406	Limpopo	0.11
Kwanza	141437	Lena	43	Balsas	-0.42	Liao	17	Min	-2.71	Colorado	1610	Rio Grande	398	Alabama	0.11
Chobut	140881	Jubba-Shebelle	42	Syr Darya	-0.47	Lurio	17	Thames	-2.90	Yaqui	1604	Danube	388	Guadiana	0.11
Sanaga	134456	Yenisey	42	Limpopo	-0.48	Hwang Ho	16	Liao	-3.42	Columbia	1598	Amur	387	W. Dvina	0.11
Fly	133687	Weser	41	Loire	-0.49	Rio Grande	16	Colorado River	-3.81	Syr Darya	1590	Tagus	371	Susquehanna	0.11
Usumacinta	126806	Sacramento	41	Tagus	-0.50	Lena	16	Brazos	-3.95	Salween	1577	Dniester	362	Salween	0.11
Santiago-Lerma-Chapala	126412	Amu Darya	40	Seine	-0.50	Ting	16	Usumacinta	-4.03	Chao Phraya	1567	Ob	355	Brazos	0.11
Hari Rud	126293	Fraser	40	Fraser	-0.51	Usumacinta	15	Dniester	-4.07	Uruguay	1565	Douro-Duero	353	Terek	0.10
Sacramento	125243	Dalalven	38	Volga	-0.51	Dnieper	15	Weser	-4.29	Sanaga	1564	Congo/Zaire	348	Chari	0.09
Brazos	121281	Balsas	37	Don	-0.52	Brazos	15	Dalalven	-4.47	Papaloapan	1547	Guadiana	347	Titicaca	0.08
Balsas	119393	Terek	37	Stikine	-0.53	Danube	15	Po	-4.54	Hari Rud	1546	Amazon	345	Rio Grande	0.08
Kuskokwim	117843	Oder	35	Kemijoki	-0.53	Min	15	Panuco	-4.58	Irrawaddy	1529	Volta	343	Volga	0.08
Elbe	114643	Yaqui	35	Danube	-0.54	Colorado River	15	Rio Salado	-4.64	Klamath	1517	Irrawaddy	340	Ebro	0.08
Save	114643	Loire	34	Oder	-0.55	Rio Colorado	15	Cunene	-4.77	Volta	1513	Okavango	325	Glama	0.07
Loire	114249	Garonne	34	Po	-0.61	Panuco	14	Sevan Lake	-5.17	Mekong	1508	Colorado	322	Guadalquivir	0.07

1 Area sq km (approx)		2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Alabama	113887	N. Dvina	33	Columbia	-0.64	Volga	14	Papaloapan	-5.19	Ganges-Brahmaputra	1508	W. Dvina	322	Colorado River	0.07
Colorado River	112299	Skeena	32	Mackenzie	-0.67	Dniester	14	W. Dvina	-5.27	Tembesi-Hari	1507	Perak	321	Mississippi	0.06
Cunene	110024	Seine	31	Guadalquivir	-0.71	Don	14	Rhone	-5.50	Tigris-Euphrates	1506	Comoe	321	Savannah	0.06
Kapuas	102874	Tagus	31	Thames	-0.72	Columbia	14	Elbe	-5.85	Murray-Darling	1492	Kuskokwim	320	Niger	0.06
Rio Salado	102018	Glama	31	Kuskokwim	-0.73	Po	14	Murray-Darling	-5.86	Gambia	1478	Cunene	320	Sacramento	0.05
Sepik	100243	Yukon	31	Ebro	-0.73	Orange	14	Rio Grande	-5.97	Sassandra	1451	Ogooue	320	Usumacinta	0.05
Panuco	99074	Po	29	Amu Darya	-0.73	Rio Salado	14	Glama	-6.11	Tsiribihina	1432	Baikal	320	Rio Salado	0.04
Douro-Duero	97343	Klamath	29	Jubba-Shebelle	-0.75	Cunene	14	Fly	-6.12	Mangoky	1425	Kwanza	320	Lurio	0.03
Po	96875	Kolyma	29	Saskatchewan-Nelson	-0.79	Fly	13	Rio Colorado	-6.19	Si	1410	Sanaga	320	Omo Wenz	0 03
Narmada	96062	Helmand	27	N. Dvina	-0.80	Elbe	13	Garonne	-6.23	Sittang	1408	Klamath	320	Volta	0.03
Tana	95468	Kemijoki	27	Yenisey	-0.96	Rhone	13	Seine	-6.24	Betsiboka	1401	Murray-Darling	320	Zambezi	0.03
Rhone	94475	Kuskokwim	27	Helmand	-0.97	Ural	13	Terek	-6.36	Ural	1397	Rio Salado	320	Sittang	0.03
Dra	93199	Stikine	27	Lena	-0.99	Kura-Araks	13	Kura-Araks	-6.38	Tapti	1394	Sacramento	320	Irrawaddy	0.02
Cauvery	91375	Ebro	25	Ob	-1.05	Rhine	13	Hwang Ho	-6.54	Santiago-Lerma-Chapala	1370	Volga	320	Sassandra	0.01
Titicaca	88506	Murray-Darling	25	Yukon	-1.06	W. Dvina	13	Dnieper	-6.63	Rio Salado	1367	Dnieper	320	Murray-Darling	0.00
Murghab	86049	Guadalquivir	23	Mangoky	-1.07	Ob	13	Rhine	-6.79	Narmada	1357	Hudson	320	Tembesi-Hari	-0.01
Ebro	85931	Thames	16	Kolyma	-1.10	Weser	13	Loire	-6.84	Balsas	1348	Thames	320	Klamath	-0.01
W. Dvina	83499	Orange	16	Murghab	-1.24	Fraser	13	Balsas	-6.92	Sacramento	1345	Mamberamo	319	Rufiji	-0.01
Seine	81975	Murghab	15	Murray-Darling	-1.33	Colorado	13	Skeena	-7.06	Min	1318	Essequibo	319	St. Lawrence	-0.02
Mamberamo	81806	Mangoky	15	Guadiana	-1.34	Baikal	13	Fraser	-7.18	Savannah	1304	Indigirka	319	Sanaga	-0.02
Garonne	81324	Guadiana	13	Olifants	-1.50	Papaloapan	12	Amur	-7.20	Yalu Jiang	1304	Lena	319	Uruguay	-0.03

1 Area sq km (approx)		2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Mahakam	80550	Hari Rud	12	Hari Rud	-1.56	Mackenzie	12	Ebro	-7.33	Ting	1301	Tocantins	319	Colorado	-0.04
Comoe	79087	Olifants	10	Orange	-1.65	Vistula	12	Ural	-7.34	Ca	1295	Rajang	319	Parana	-0.05
Tagus	79024	Douro-Duero	9	Douro-Duero	-1.78	Yenisey	12	Kizil	-7.38	Colorado River	1293	Yenisey	319	Amur	-0.05
Yaqui	78956	Penner	-	Atrato	-	Dalalven	12	Danube	-7.38	Mississippi	1292	Orinoco	319	Comoe	-0.05
Lurio	75618	Godavari	-	Baikal	-	Balsas	12	Stikine	-7.42	Kura-Araks	1288	Sinu	319	Perak	-0.05
Dniester	74762	Mahanadi	-	Betsiboka	-	Oder	12	Kemijoki	-7.43	Guadiana	1288	Kolyma	319	N. Dvina	-0.06
Tapti	73918	Tapti	-	Ca	-	Loire	12	Don	-7.46	Guadalquivir	1282	Kapuas	319	S. Francisco	-0.07
Guadiana	71074	Ganges-Brahmaputra	-	Chobut	-	Garonne	12	Oder	-7.51	Penner	1279	Magdalena	319	Columbia	-0.07
Gambia	69931	Perak	-	Colorado	-	N. Dvina	12	Vistula	-7.70	Krishna	1271	Sepik	319	Congo/Zaire	-0.08
Sassandra	69549	Ca	-	Colorado River	-	Seine	12	Kuskokwim	-7.90	Glama	1269	Rio Colorado	319	Kwanza	-0.08
Omo Wenz	69056	Ma	-	Comoe	-	Thames	12	Orange	-7.91	Liao	1254	Pahang	319	Parnaiba	-0.09
Susquehanna	67906	Pahang	-	Cunene	-	Tigris-Euphrates	11	Guadiana	-7.98	Ebro	1254	Chobut	319	Negro	-0.09
Maroni	67731	S. Francisco	-	Dra	-	Sacramento	11	Klamath	-8.01	Ma	1253	Negro	319	Chobut	-0.10
Tsiribihina	61800	Tembesi-Hari	-	Essequibo	-	Terek	11	Sacramento	-8.01	Song Hong	1253	Parnaiba	319	Ob	-0.11
Min	61206	Comoe	-	Ganges-Brahmaputra	-	Glama	11	Santiago-Lerma-Chapala	-8.02	Volga	1252	S. Francisco	319	Pahang	-0.11
Guadalquivir	55843	Essequibo	-	Godavari	-	Yukon	11	Columbia	-8.04	Kizil	1250	N. Dvina	319	Rio Colorado	-0.11
Kemijoki	52318	Tocantins	-	Groot	-	Kuskokwim	11	Tagus	-8.17	Godavari	1248	Parana	319	Sepik	-0.15
Stikine	52162	Ting	-	Indigirka	-	Ebro	11	Mamberamo	-8.24	Mahanadi	1234	Uruguay	319	Dalalven	-0.15
Kizil	50968	Si	-	Kizil	-	Santiago-Lerma-Chapala	11	Lena	-8.36	Sevan Lake	1232	Tembesi-Hari	319	Magdalena	-0.15
Terek	50456	Tana	-	Kwanza	-	Sepik	10	Guadalquivir	-8.54	Dalalven	1226	Sassandra	319	Mahakam	-0.19
Weser	48618	Titicaca	-	Liao	-	Amu Darya	10	Douro-Duero	-8.55	Panuco	1221	Sittang	319	Baikal	-0.20

1 Area	sq km (approx)	2 Number of fish species		3 Fish species richness for area		4 Number of fish families		5 Fish family richness for area		6 Wilderness value		7 Water Resources Vulnerability Index – I		8 Overall vulnerability	
Penner	48593	Save	-	Lurio	-	Skeena	10	Sepik	-8.60	Rhone	1202	Savannah	319	Okavango	-0.25
Betsiboka	48462	Min	-	Ma	-	Tagus	10	Baikal	-8.80	Douro-Duero	1201	Colorado River	319	Ogooue	-0.25
Yalu Jiang	47918	Liao	-	Mahanadi	-	Kolyma	10	N. Dvina	-8.91	Tagus	1189	Guadalquivir	319	Saskatchewan-Nelson	-0.26
Olifants	47106	Sevan Lake	-	Mamberamo	-	Kemijoki	10	Colorado	-9.04	Terek	1188	Ebro	319	Kapuas	-0.26
Rajang	46018	Omo Wenz	-	Maroni	-	Stikine	10	Volga	-9.36	W. Dvina	1172	Terek	319	Cunene	-0 26
Papaloapan	45962	Maroni	-	Min	-	Guadiana	10	Negro	-9.45	Brazos	1171	Brazos	319	Fly	-0.28
Glama	43993	Kizil	-	Negro	-	Douro-Duero	10	Groot	-9.63	Susquehanna	1169	Susquehanna	319	Kemijoki	-0.30
Mangoky	43093	Kwanza	-	Omo Wenz	-	Kizil	10	Yaqui	-10.17	Cauvery	1167	Alabama	319	Kolyma	-0.35
Skeena	42731	Santiago-Lerma-Chapala	-	Pahang	-	Negro	10	Tigris-Euphrates	-10.84	Po	1163	Pearl	319	Sinu	-0.36
Klamath	41443	Rufiji	-	Penner	-	Mamberamo	10	Hari Rud	-11.02	Garonne	1160	Don	319	Orinoco	-0.36
Tembesi-Hari	41043	Lurio	-	Perak	-	Syr Darya	9	Mangoky	-11.08	Alabama	1157	Atrato	318	Yenisey	-0.38
Hudson	39387	Atrato	-	Rio Colorado	-	Klamath	9	Chobut	-11.22	Danube	1142	Fly	318	Rajang	-0.38
Ma	36550	Colorado River	-	Rio Salado	-	Guadalquivir	9	Betsiboka	-11.29	St. Lawrence	1140	Mahakam	318	Tocantins	-0.39
Atrato	35462	Betsiboka	-	Rufiji	-	Indigirka	9	Murghab	-11.33	Pearl	1137	Mississippi	318	Lena	-0.40
Groot	33743	Tsiribihina	-	Santiago-Lerma-Chap.	-	Yaqui	8	Yukon	-11.43	Don	1132	Glama	318	Fraser	-0.42
Sittang	31043	Rio Salado	-	S. Francisco	-	Hari Rud	8	Mackenzie	-11.54	Dnieper	1125	Columbia	295	Indigirka	-0.42
Dalalven	30781	Groot	-	Save	-	Sevan Lake	8	Tsiribihina	-11.73	Hudson	1095	Yukon	257	Amazon	-0.42
Pahang	29012	Rio Colorado	-	Sevan Lake	-	Chobut	8	Indigirka	-11.75	Dniester	1095	St. Lawrence	234	Essequibo	-0.45
Ting	28306	Colorado	-	Si	-	Helmand	7	Ob	-11.80	Seine	1092	Maroni	184	Skeena	-0.47
Savannah	28162	Dra	-	Tana	-	Murghab	7	Amu Darya	-11.88	Vistula	1086	Saskatchewan-Nelson	182	Atrato	-0.48
Ca	22975	Negro	-	Tapti	-	Groot	7	Yenisey	-11.94	Loire	1076	Dalalven	166	Kuskokwim	-0.49

1 **Area** sq km (approx)		2 **Number of fish species**		3 **Fish species richness for area**		4 **Number of fish families**		5 **Fish family richness for area**		6 **Wilderness value**		7 **Water Resources Vulnerability Index – I**		8 **Overall vulnerability**	
Pearl	22537	Cunene	-	Tembesi-Hari	-	Mangoky	6	Syr Darya	-12.24	Elbe	1054	Kemijoki	165	Mamberamo	-0.50
Perak	14750	Chobut	-	Ting	-	Betsiboka	6	Kolyma	-12.24	Oder	1044	Stikine	163	Yukon	-0.53
Sinu	13200	Baikal	-	Titicaca	-	Tsiribihina	6	Olifants	-12.24	Rhine	997	Skeena	160	Maroni	-0.64
Thames	12968	Mamberamo	-	Tocantins	-	Olifants	5	Helmand	-13.69	Weser	997	Fraser	160	Mackenzie	-0.69
Sevan Lake	4993	Indigirka	-	Tsiribihina	-	Dra	2	Dra	-16.47	Thames	799	Mackenzie	159	Stikine	-0.71

Notes. Column 1 includes area as measured by superimposing a grid on catchment boundaries. Column 2 includes estimates of the total number of fish species present in each basin, excluding introduced species where relevant information was available; there is a significant error margin associated with these data, reflecting different survey and reporting methods, different taxonomies, date and completeness of surveys, etc. Much of this information was first compiled for the World Resources Institute (WRI). A dash (-) indicates no data available. Column 3 includes results of regression analysis of fish species number against basin area; basins with no sign shown have more species than expected according to basin area, basins with a negative sign to the value shown have fewer species than expected. A dash (-) indicates no fish species number available. Column 4 includes a coarse estimate of the number of fish families present, derived by GIS analysis of generalised family distribution maps digitised from Berra (1981). Column 5, similar to Column 3 but using the family number estimates instead of fish species. Column 6 presents an estimate of 'wilderness', in terms of presence or absence of gross human impact, derived from a global wilderness analysis by R. Lesslie (ANU) and assessed by measuring the distance of each point in the basin to the nearest roads, settlements and similar infrastructure; the value shown is the mean value for the basin overall. Column 7 is an estimate of probable pressures on water resources, derived from the Water Resources Vulnerability Index (WRVI) analysis of Raskin *et al.* (1997), taking into account reliability and availability of water resources, and capacity to manage resources; the index gives a value at national level, the data here are derived by calculating the mean value for the basin taking into account the relative extent of different countries within each basin. Column 8 indicates the overall 'vulnerability' of river basins, taking into account both the wilderness value or relative naturalness, and the probable susceptibility to future pressures, estimated by the WRVI. See text for application of this measure, with estimates of fish biodiversity, in a preliminary framework for prioritisation.

ANNEX 3

TECHNICAL NOTES

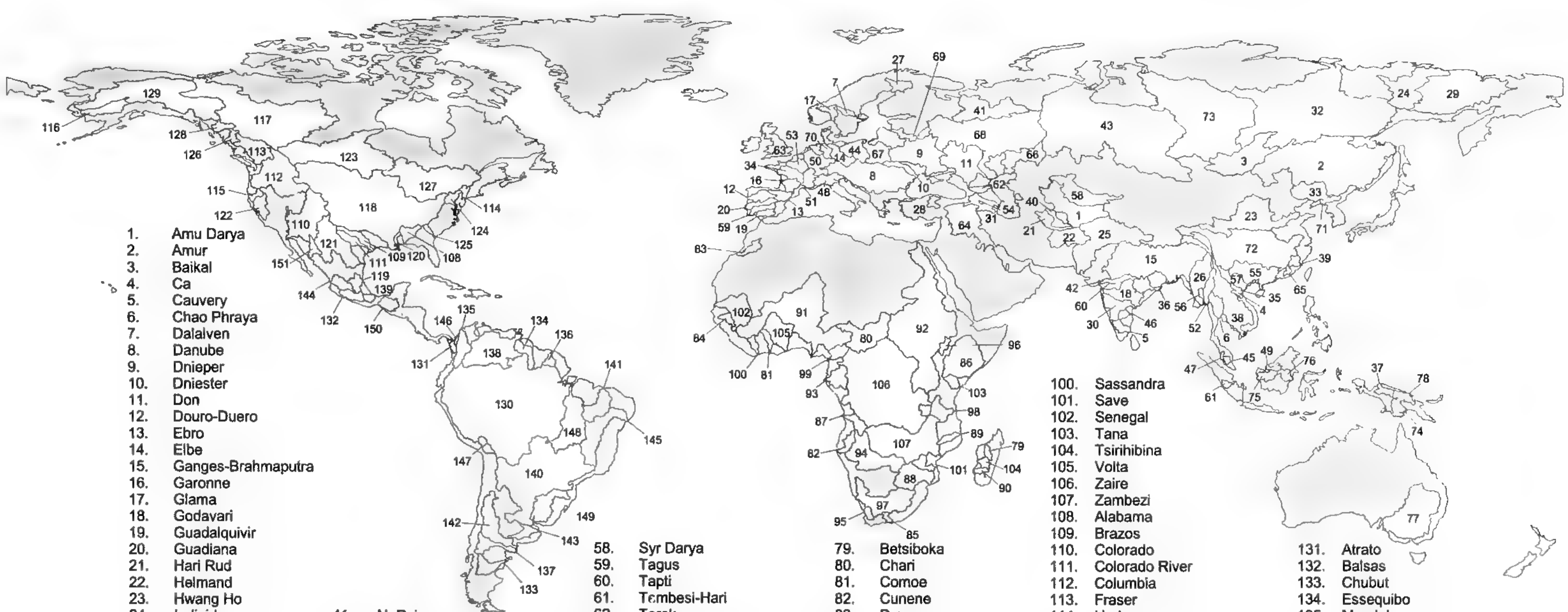
Catchment basin boundaries

The catchment basin boundaries used were based initially on the global dataset on the GlobalARC CR-ROM made available by CERL (the US Army Corps of Engineers Construction Engineering Research Laboratories). This is generated from a relatively coarse elevation model. Data for North America and Africa were replaced with improved boundaries generated by the United States Geological Survey (USGS). The most inclusive basin boundaries, ie. the entire drainage system passing through one river mouth (or delta region) to the sea were used in the analysis, selected to provide a reasonable sample from each continent. A very few internally draining systems were also included. In addition, and particularly outside N America and Africa, the major catchment boundaries were inspected by eye against appropriate paper maps, and adjustments made. USGS hydrological data are available from:
http://edcwww.cr.usgs.gov/landdaac/gtopo30/hydro/index.html.

Fish diversity analysis

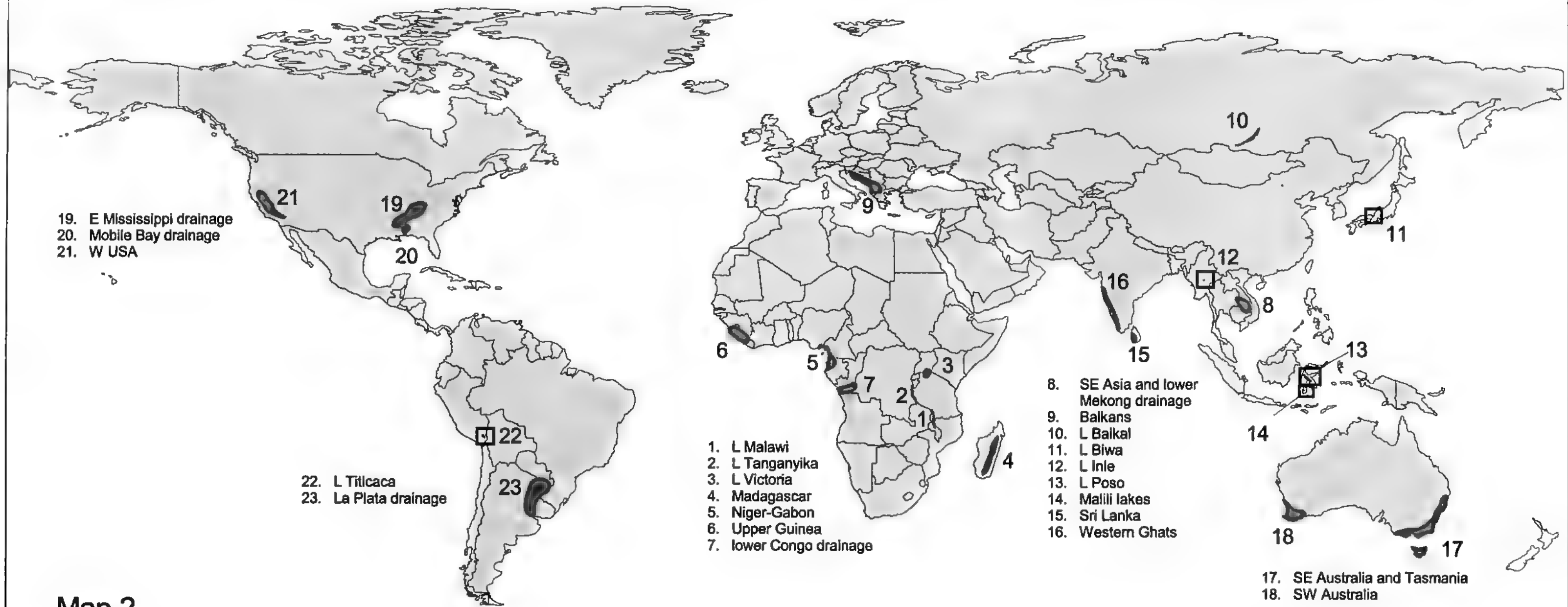
The number of native fish species per catchment ranges from 5 to an estimate of 2500 for the Amazon system. Because of this very wide range in numbers, the data are easier to manage when log-transformed; that is, the natural logs of both the species number and the measure of river size are used. The size of the river can be expressed both in terms of the size of the catchment and of the mean annual discharge (essentially a measure of the volume of water in the river). As confirmed by Guégan *et al.* (1998) where data for both these are available, the latter is a considerably better predictor of fish species number than the former ($r=0.49$ in the case of catchment area, $r=0.67$ in the case of discharge for log-transformed data, $n=69$, $p<0.0001$ in both cases). As might be expected, discharge and catchment area themselves are strongly correlated ($r=0.74$, $n=69$, $p<0.0001$), with the major deviations being large rivers (e.g. the Niger and Nile) whose catchments lie mainly in arid regions and which thus have less discharge than expected from the size of the catchment. However, because we have data for catchment area for considerably more rivers than we have data for discharge (data on species number and catchment size available for 166 rivers, compared with data on species number and discharge for 69 rivers), we have used the former as an imperfect surrogate for the latter, in order to maximise our use of information.

Because the range of values for fish families is much smaller than for fish species, these data can be analysed without log-transforming them (although, as in all species-area relationships, the log of the area concerned is used, rather than the absolute value). A comparison of the logged and unlogged data shows that the two yield similar results. For this reason, and because unlogged data are intuitively easier to understand, we have used these.



1. Amu Darya
2. Amur
3. Baikal
4. Ca
5. Cauvery
6. Chao Phraya
7. Dalalven
8. Danube
9. Dnieper
10. Dniester
11. Don
12. Douro-Duero
13. Ebro
14. Elbe
15. Ganges-Brahmaputra
16. Garonne
17. Glama
18. Godavari
19. Guadalquivir
20. Guadiana
21. Hari Rud
22. Helmand
23. Hwang Ho
24. Indigirka
25. Indus
26. Irrawady
27. Kemijoki
28. Kizil
29. Kolyma
30. Krishna
31. Kura-Araks
32. Lena
33. Liao
34. Loire
35. Ma
36. Mahanadi
37. Mamberamo
38. Mekong
39. Min
40. Murghab
41. N. Dvina
42. Narmada
43. Ob
44. Oder
45. Pahang
46. Penner
47. Perak
48. Po
49. Rajang
50. Rhine
51. Rhone
52. Salween
53. Seine
54. Sevan Lake
55. Xi
56. Sittang
57. Song Hong (Red)
58. Syr Darya
59. Tagus
60. Tapti
61. Tembesi-Hari
62. Terek
63. Thames
64. Tigris-Euphrates
65. Ting
66. Ural
67. Vistula
68. Volga
69. W. Dvina
70. Weser
71. Yalu Jiang
72. Yangtze
73. Yenisey
74. Fly
75. Kapuas
76. Mahakam
77. Murray-Darling
78. Sepik
79. Betsiboka
80. Chari
81. Comoe
82. Cunene
83. Dra
84. Gambia
85. Groot
86. Jubba-Shebelle
87. Kwanza
88. Limpopo
89. Lurio
90. Mangoky
91. Niger
92. Nile
93. Ogooue
94. Okavango
95. Olifants
96. Omo Wenz
97. Orange
98. Rufiji
99. Sanaga
100. Sassandra
101. Save
102. Senegal
103. Tana
104. Tsirihibina
105. Volta
106. Zaire
107. Zambezi
108. Alabama
109. Brazos
110. Colorado
111. Colorado River
112. Columbia
113. Fraser
114. Hudson
115. Klamath
116. Kuskokwim
117. Mackenzie
118. Mississippi
119. Panuco
120. Pearl
121. Rio Grande
122. Sacramento
123. Saskatchewan-Nelson
124. Susquehanna
125. Savannah
126. Skeena
127. St. Lawrence
128. Stikine
129. Yukon
130. Amazon
131. Atrato
132. Balsas
133. Chubut
134. Essequibo
135. Magdalena
136. Maroni
137. Negro
138. Orinoco
139. Papaloapan
140. Parana
141. Parnaiba
142. Rio Colorado
143. Rio Salado
144. Santiago-Lerma-Chapala
145. Sao Francisco
146. Sinu
147. Titicaca
148. Tocantins
149. Uruguay
150. Usumacinta
151. Yaqui

Map 1.

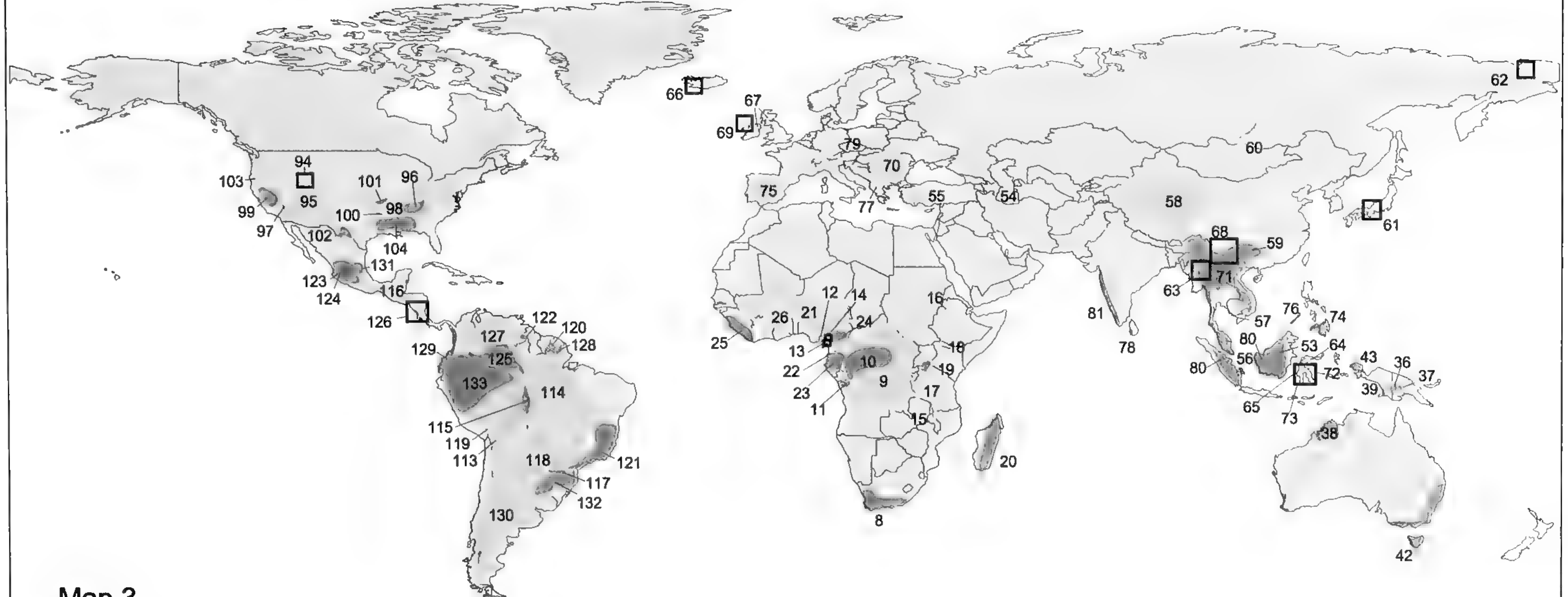


Map 2.

Global hotspots of freshwater biodiversity: a preliminary selection.

This map shows the general location of areas that have been identified in this document as of special importance for more than one of the five groups of species discussed. See relevant text and Table 16.

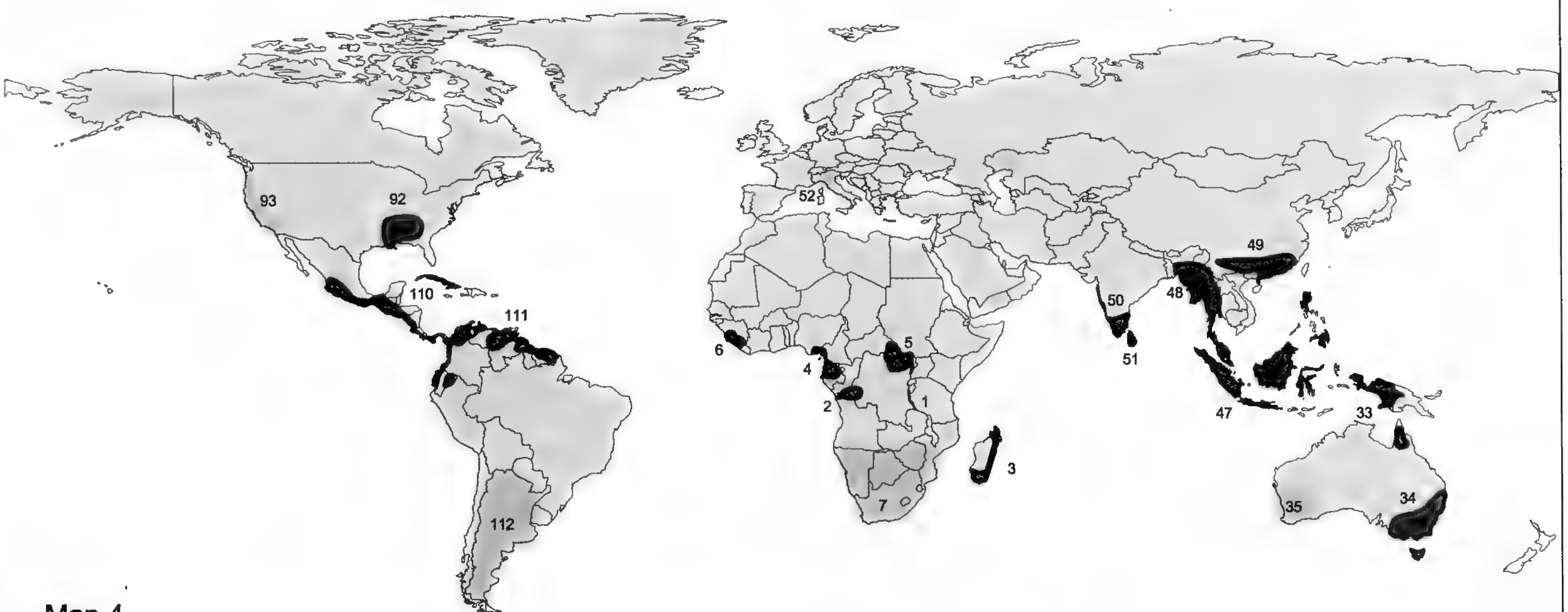
WORLD CONSERVATION MONITORING CENTRE



Map 3.

Areas of special importance for freshwater fish diversity.

This map shows the approximate location of areas known to be of special importance for fish diversity. The blue colour represents general regions of high richness or endemism; the orange colour represents more restricted areas of high diversity. See Table 17 for details. Based on data provided by M. Kottelat, S. Kullander, G. Allen, C. Leveque, G. Teugels and WCMC.

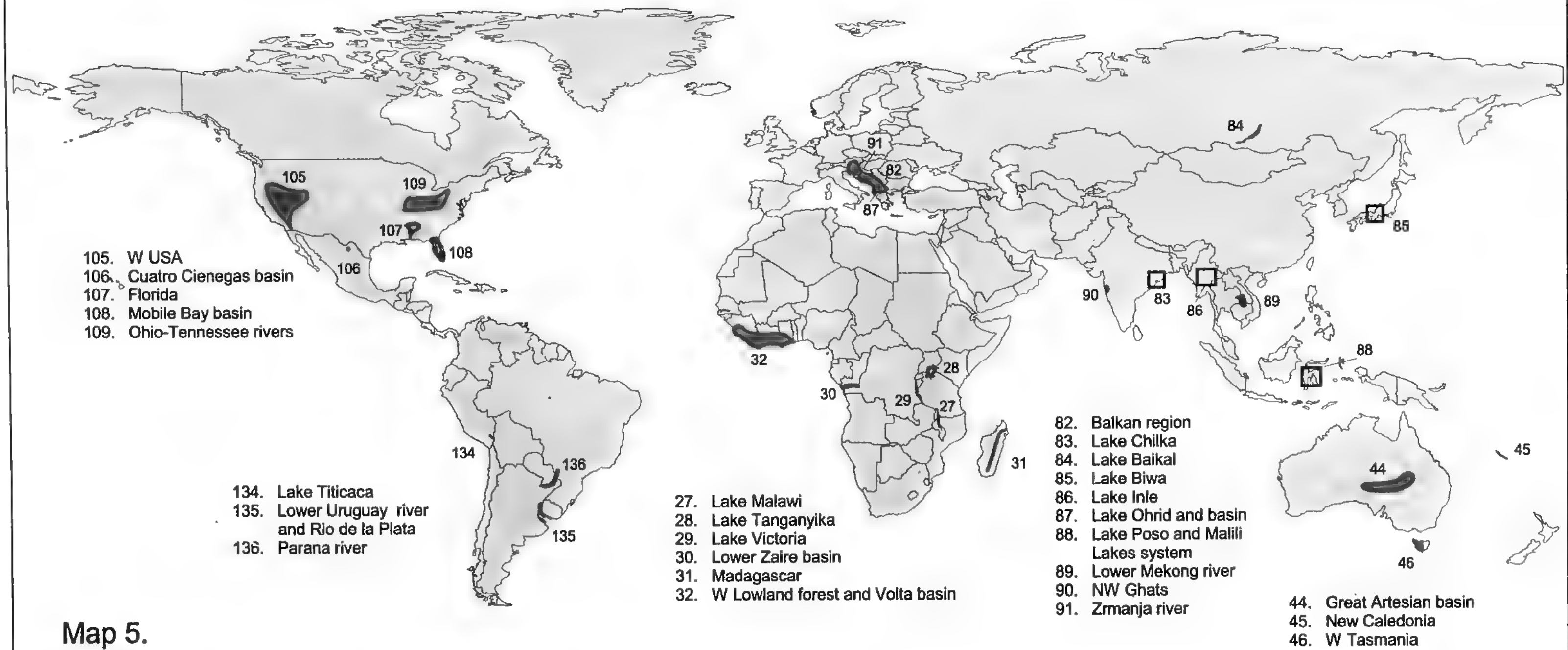


Map 4.

Areas of special importance for inland water crustacean diversity.

This map shows the general location of areas that have been identified in this document as of special importance for inland water molluscs. See Table 17 for details. Based on data provided by K. Crandall, N. Cumberlidge, R. von Sternberg and D. Belk, all of the IUCN/SSC Inland Water Crustacean Specialist Group.

WORLD CONSERVATION MONITORING CENTRE



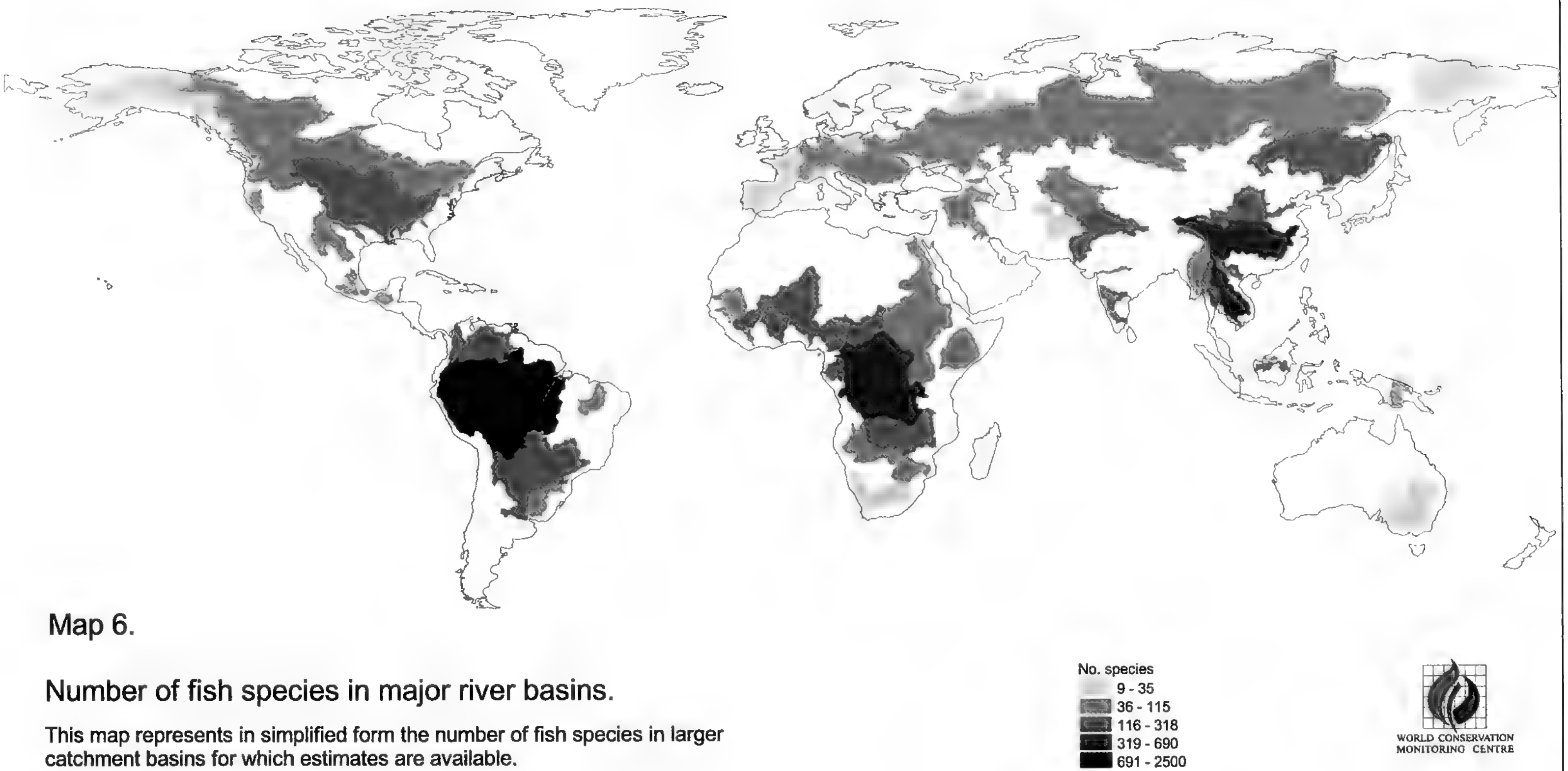
Map 5.

Areas of special importance for freshwater mollusc diversity.

This map shows the location of areas that have been identified in the document as of special importance for molluscs. See Table 17. Based on data provided by P. Bouchet, O. Gargominy, A. Bogan and W. Ponder, all of the IUCN/SSC Mollusc Specialist Group.

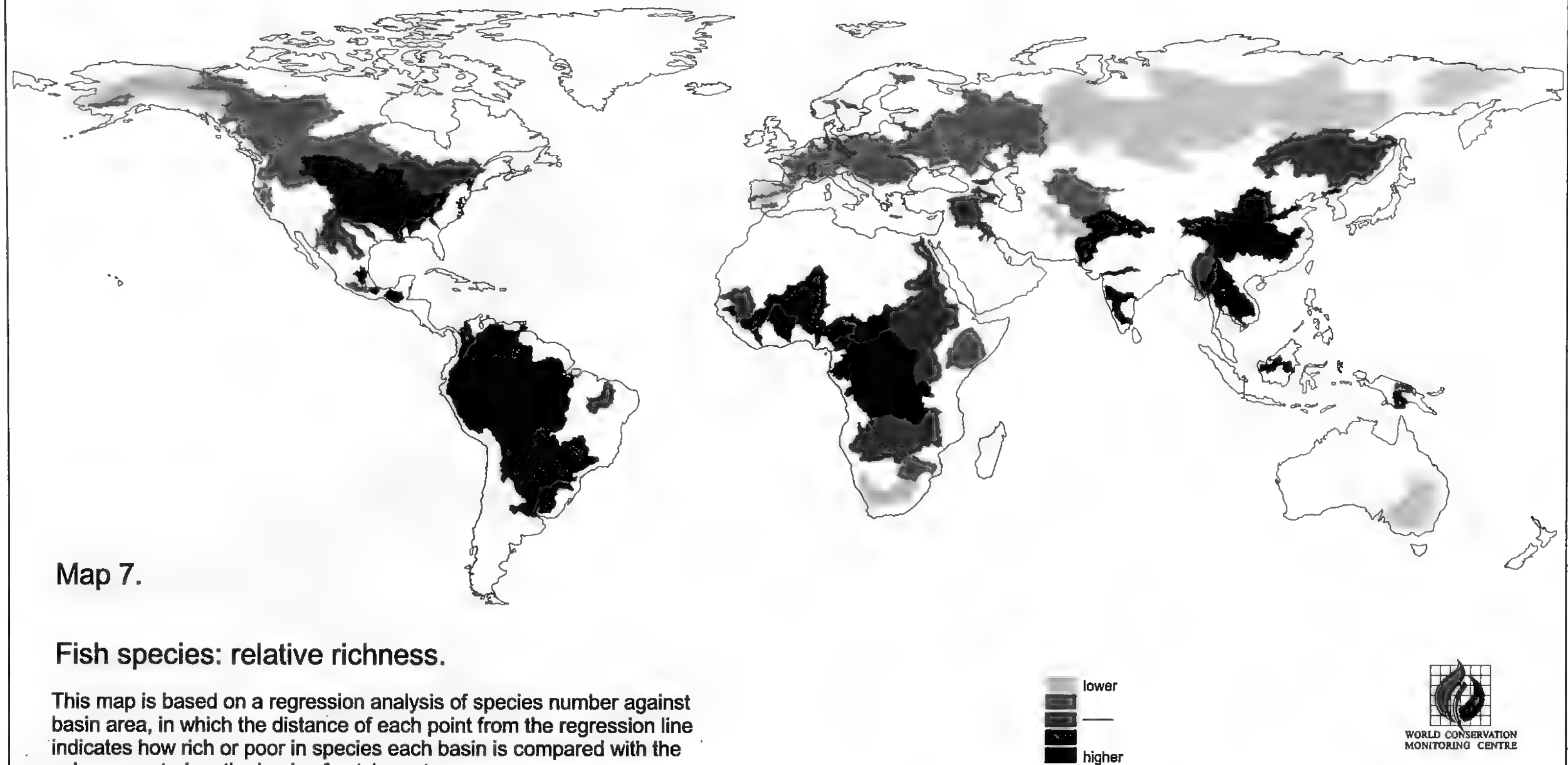
WORLD CONSERVATION MONITORING CENTRE

Map 6.



Number of fish species in major river basins.

This map represents in simplified form the number of fish species in larger catchment basins for which estimates are available.

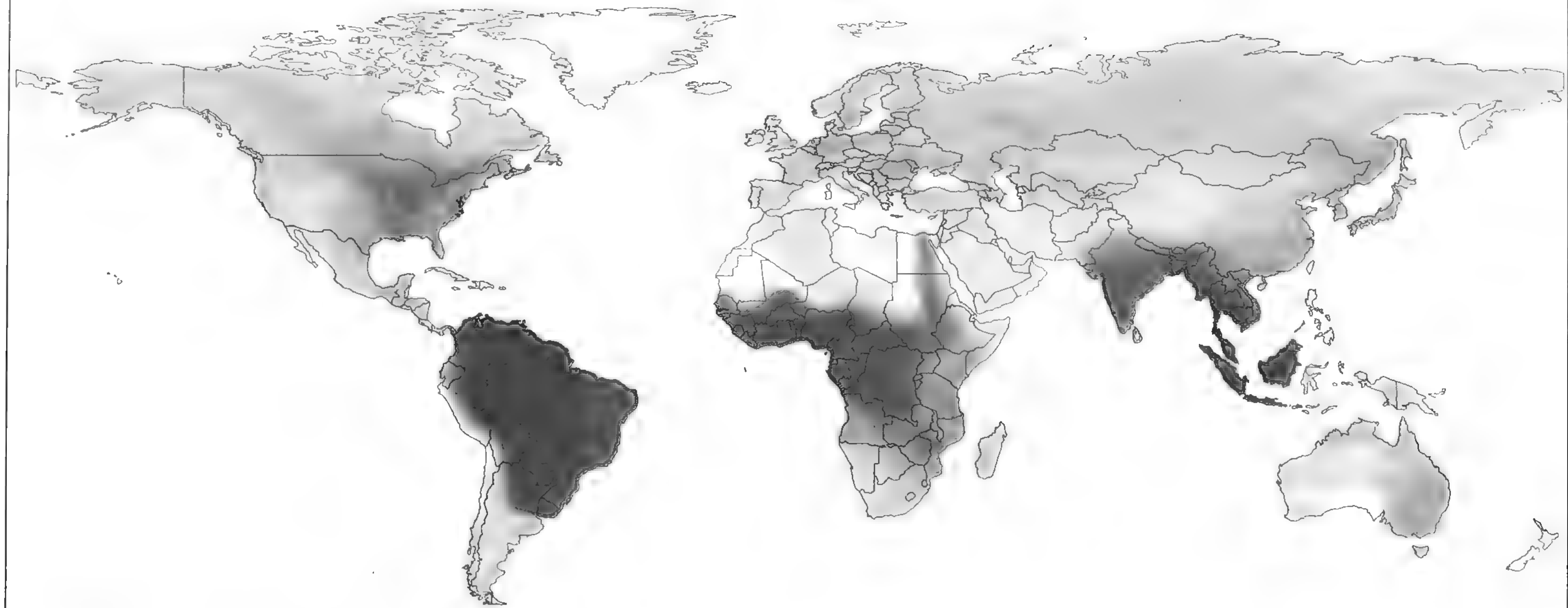


Map 7.

Fish species: relative richness.

This map is based on a regression analysis of species number against basin area, in which the distance of each point from the regression line indicates how rich or poor in species each basin is compared with the value expected on the basis of catchment area.

WORLD CONSERVATION MONITORING CENTRE



Map 8.

Freshwater fish families: the global pattern.

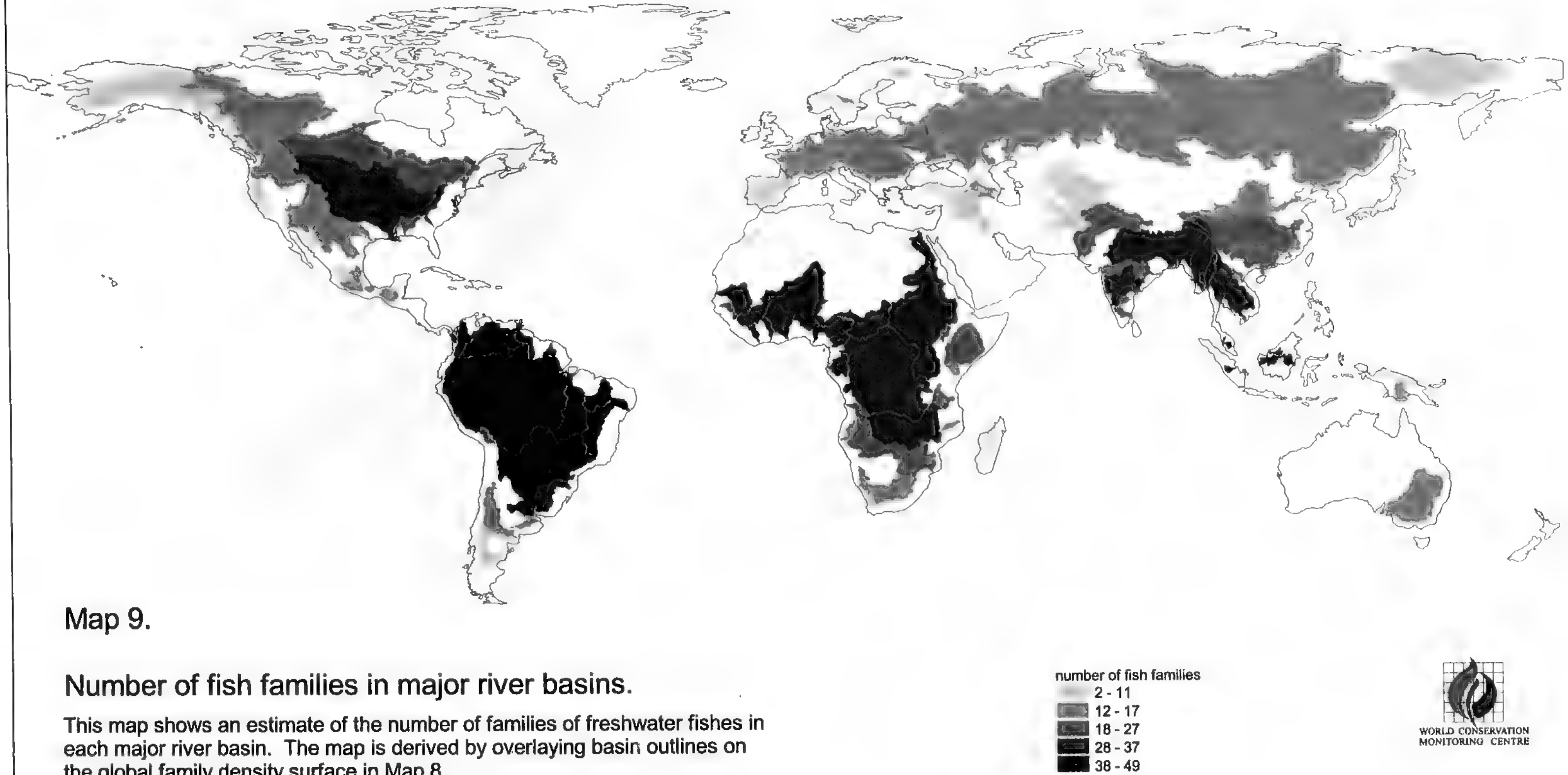
Information derived by GIS analysis of generalised range maps digitised from Berra (1981). Shading intensity represents number of families present, ranging from 2 to 49.

WORLD CONSERVATION MONITORING CENTRE

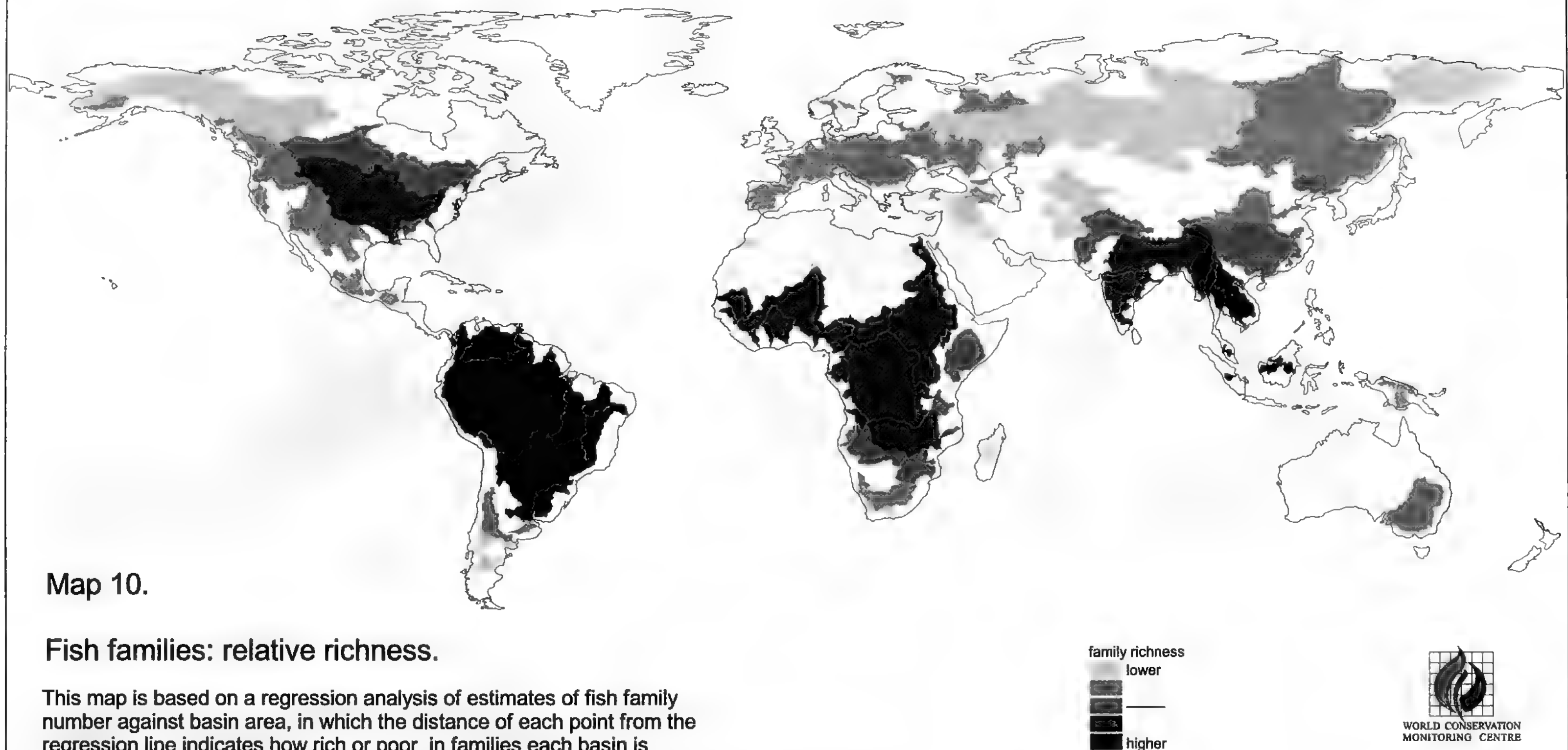
Map 9.

Number of fish families in major river basins.

This map shows an estimate of the number of families of freshwater fishes in each major river basin. The map is derived by overlaying basin outlines on the global family density surface in Map 8.

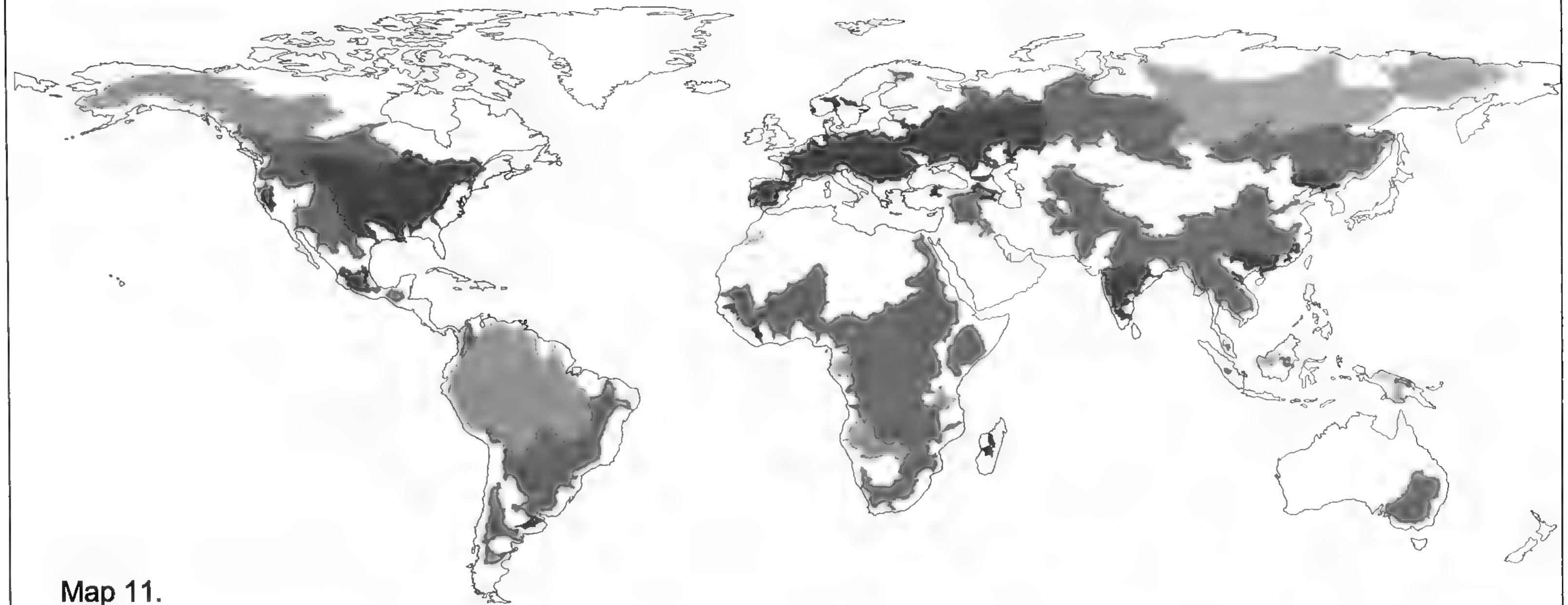


Map 10.



Fish families: relative richness.

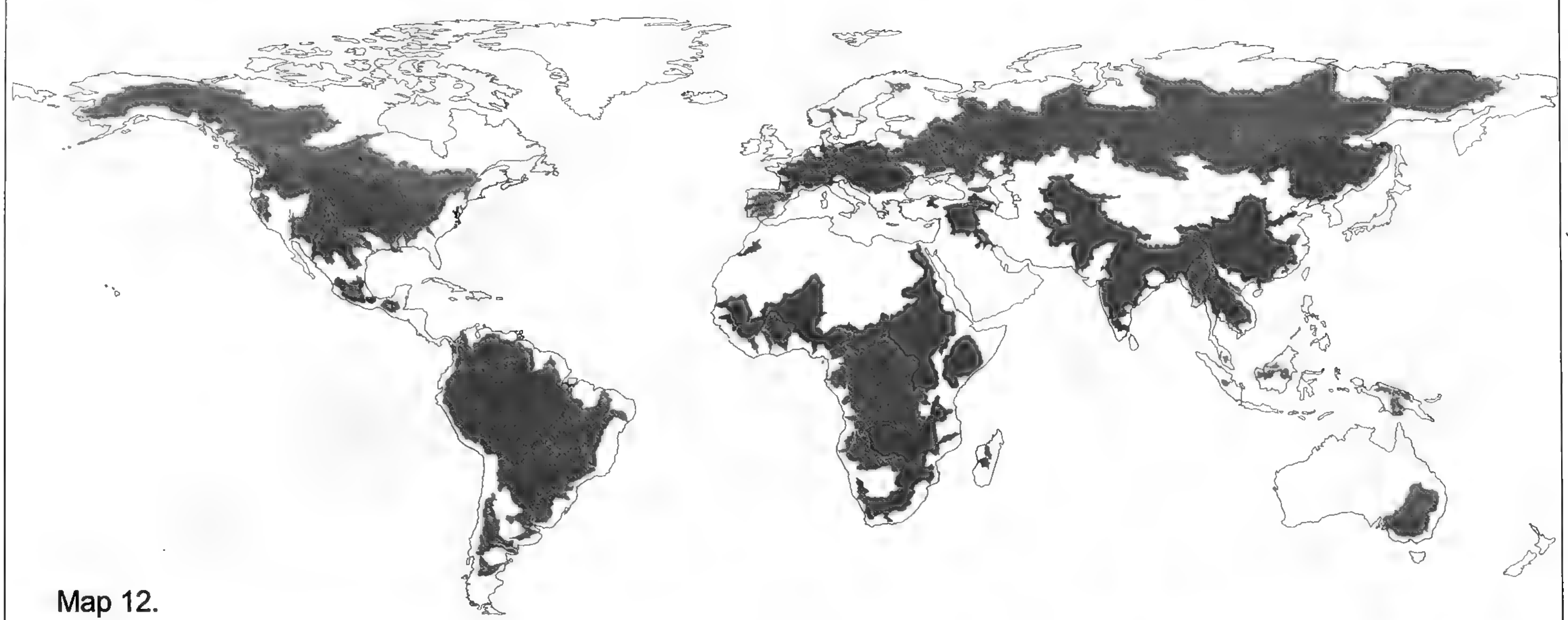
This map is based on a regression analysis of estimates of fish family number against basin area, in which the distance of each point from the regression line indicates how rich or poor in families each basin is compared with the value expected on the basis of catchment area.



Map 11.

Relative wilderness value of major river basins.

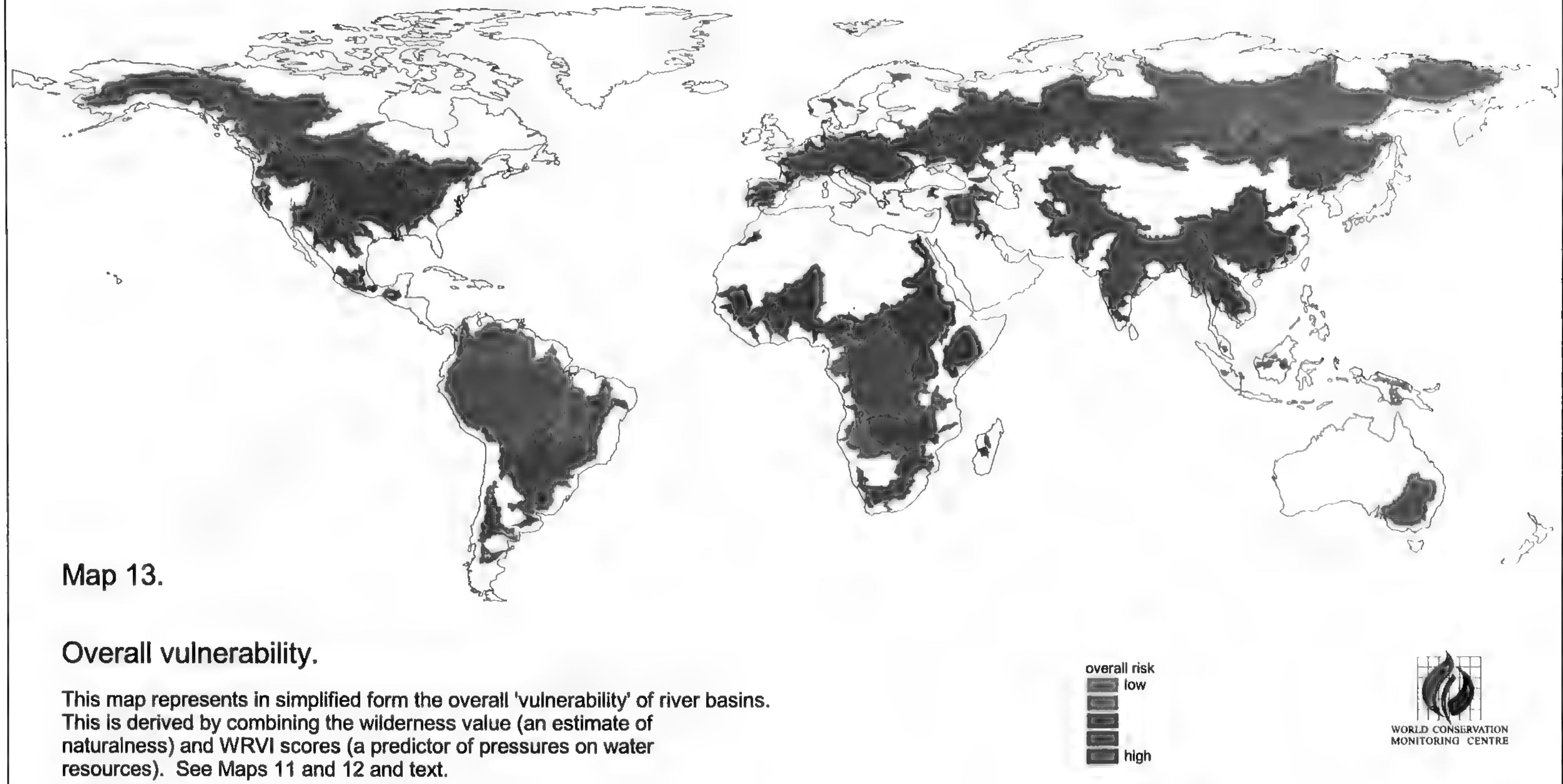
This map estimates the average wilderness value of catchments; this is assessed as the density of access routes, settlements and permanent structures. Based on data from analysis developed by R. Lesslie and Australian Heritage Commission.



Map 12.

Pressure on water resources.

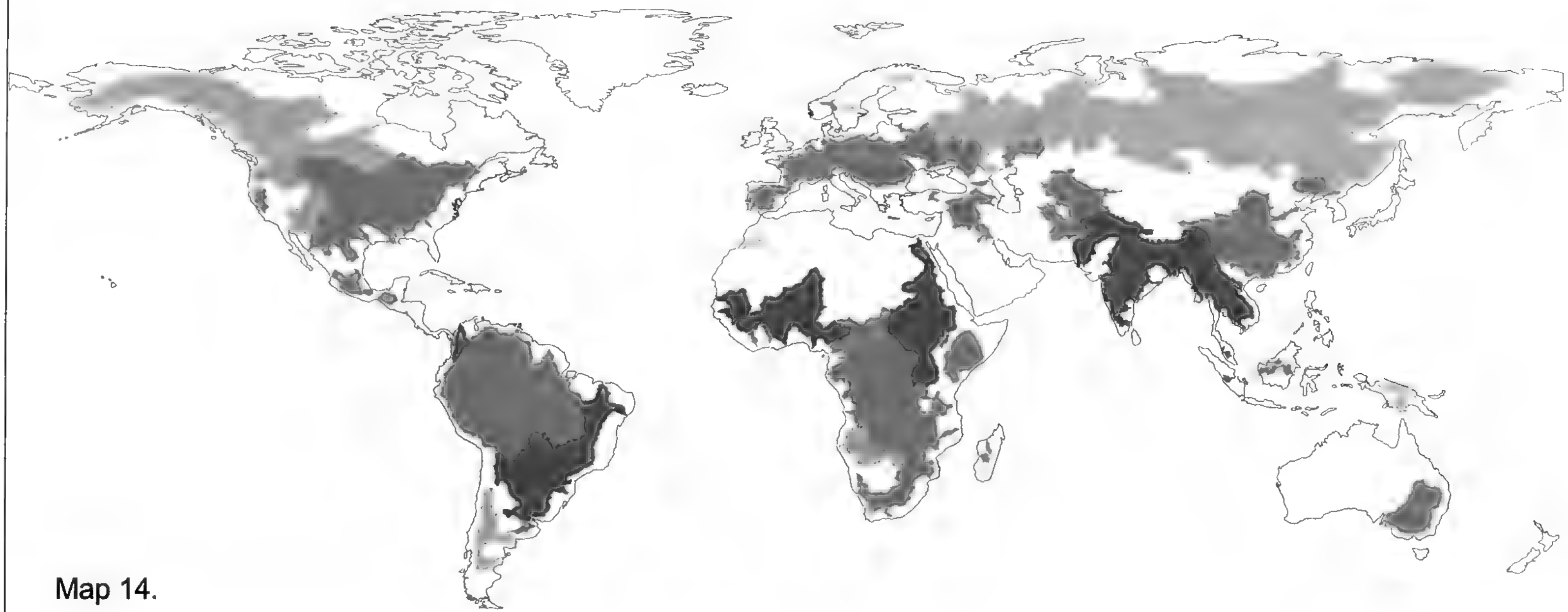
This map is based on a national water resources vulnerability index developed by Raskin et al. (1997). The map is derived by measuring the area of each basin within each country and weighting this proportion by the national WRVI. See text.



Map 13.

Overall vulnerability.

This map represents in simplified form the overall 'vulnerability' of river basins. This is derived by combining the wilderness value (an estimate of naturalness) and WRVI scores (a predictor of pressures on water resources). See Maps 11 and 12 and text.



Map 14.

River basins: possible global priorities for action.

This map shows a possible scheme for prioritising investment and management action. In this scheme highest priority basins have both high diversity and high vulnerability. See text for explanation.

This publication has been printed on acid
free paper supplied from sustainable forests

Freshwater Biodiversity: a preliminary global assessment

This document provides information on inland waters and their biodiversity for a wide audience, ranging from those interested in the state of the world environment generally, to those needing an overview of the global and regional context in order to improve planning, management and investment decisions. The report includes the first global assessment of areas of special importance for freshwater biodiversity, based on expert opinion and the data already available. It also includes a first comparative analysis of major river basins, using indicators of biodiversity, the condition of catchment basins and pressures on water resources, in order to generate indices of importance and risk.

The **WCMC Biodiversity Series** presents the results of projects carried out by the World Conservation Monitoring Centre, often in partnership with other organisations. This series is focused on providing support to the Parties to the **Convention on Biological Diversity**, helping them to identify and monitor their biodiversity, to manage and apply information on biodiversity effectively and to exchange information. The WCMC Biodiversity Series **General Editor** is Mark Collins, Chief Executive of the World Conservation Monitoring Centre.

Other titles in the series:

1. Biodiversity Data Sourcebook
2. The Biodiversity Clearing House - Concept and Challenges
3. Priorities for Conserving Global Species Richness and Endemism
4. The Diversity of the Seas: a regional approach
5. Assessing Biodiversity Status and Sustainability
6. Biodiversity Conservation in the Tropics
7. Industrial Reliance on Biodiversity

The **World Conservation Monitoring Centre**, based in Cambridge, UK, was established in 1988 as a company limited by guarantee with charitable status. WCMC is managed as a joint venture between the three partners in the World Conservation Strategy and its successor Caring For The Earth: IUCN - The World Conservation Union, UNEP - United Nations Environment Programme, and WWF - World Wide Fund for Nature. WCMC provides information services on the conservation and sustainable use of the world's living resources and helps others to develop information systems of their own.

IUCN
The World Conservation Union
UNEP
WWF

WORLD CONSERVATION
MONITORING CENTRE

Further information is available from
World Conservation Monitoring Centre
219 Huntingdon Road
Cambridge CB3 0DL, United Kingdom
Tel: +44 (0)1223 277314
Fax: +44 (0)1223 277136
Email: info@wcmc.org.uk

WORLD CONSERVATION PRESS
ISBN 1 899628 12 6