Secretariat
of the Convention on
Biological Diversity

CBD Technical Series No.

11

STATUS AND TRENDS OF BIODIVERSITY OF INLAND WATER ECOSYSTEMS

WRI

UNEP

CDB

Ramsar
CONVENTION ON WETLANDS

WETLANDS
INTERNATIONAL

STATUS AND TRENDS OF BIODIVERSITY OF INLAND WATER ECOSYSTEMS

December 2003

Published by the Secretariat of the Convention on Biological Diversity ISBN: 92-807-2398-7

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the World Resources Institute, Wetlands International, the Netherlands Ministry of Foreign Affairs (DGIS), the Bureau of the Ramsar Convention on Wetlands or the Secretariat of the Convention on Biological Diversity concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The views expressed in this publication are those of the authors and do not necessarily reflect those of the World Resources Institute, Wetlands International, the Netherlands Ministry of Foreign Affairs (DGIS), the Bureau of the Ramsar Convention on Wetlands, Wetlands International or the Secretariat of the Convention on Biological Diversity.

Citation
Revenga, C. and Y. Kura. 2003. Status and Trends of Biodiversity of Inland Water Ecosystems. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 11.

For further information please contact:
Secretariat of the Convention
on Biological Diversity
World Trade Centre, 393 St. Jacques, Suite 300,
Montreal, Quebec, Canada H2Y 1N9
Phone: 1 (514) 288 2220
Fax: 1 (514) 288 6588
E-mail: secretariat@biodiv.org
Website: http://www.biodiv.org

FOREWORD

That water is important to life on earth, including for sustaining human populations, is self-evident to most of us. What is less widely appreciated is that out of the world's total water resources, less than 3% is represented by freshwater and less than 1% of that (less than 0.01% of total water) occurs in the earths liquid surface freshwater (the remainder being locked in ice-caps or as groundwater, below the planet's surface). This fraction of water available on earth is home to an extraordinarily high level of biodiversity that is directly supported through a range of freshwater ecosystem types that includes running waters in rivers, standing waters of lakes and marshes and areas of transient water availability in seasonal or ephemeral wetlands. These inland water ecosystems provide a vital range of goods and services essential for sustaining human well-being.

The complexity, and variability in space and time, of these ecosystems is still being documented by scientists but their importance is unquestioned. Witness for example, the fact that all major civilizations have evolved in association with river systems, as confirmed today by the location of most major cities. Humans need freshwater not only for drinking, but also for agriculture, industry, transportation and many other important uses. But as human populations have grown, and consumptive uses of water increased, our activities have taken an enormous toll on the global freshwater resource. Not only are we over-consuming a very valuable and finite resource, and the life it supports, we are abusing it by, for example, allowing pollution from activities on the land to flow into rivers, to be transported for eventual dilution in the sea, or to be accumulated in lakes and other wetlands. It is not surprising that the stresses we have placed upon inland waters have resulted in them now being considered amongst the most threatened global ecosystems.

We are starting to take notice of these problems, and have begun efforts to address them. *The Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar, Iran, 1971),* commonly referred to as the "Ramsar Convention", was the first formal global inter-government initiative to improve the sustainability of life dependent upon inland waters. While the *Convention on Biological Diversity* (1992) covers all ecosystem types and geographical regions, it has identified "inland waters" as an immediately important thematic area of work. A considerable number of local, national, regional and global initiatives are also now focussing directly or indirectly on conservation and sustainable use of inland waters, including many sponsored by non-government organisations such as *Wetlands International, IUCN — The World Conservation Union, The WWF for Nature and BirdLife International.*

Our ability to identify the current status of, and subsequently monitor, the biodiversity of inland waters and the ecosystem services they provide for the planet is a fundamental requirement. If we cannot do this, we cannot assess our progress towards meeting key conservation and sustainable use goals in this important area. In recognition of this fact, the Parties to the Convention on Biological Diversity have requested the Subsidiary Body on Scientific, Technical and Technological Advice to review this subject as a priority. We are pleased to present this review as a joint effort between the Convention on Biological Diversity and the Ramsar Convention to further illustrate their continued co-operation towards achieving important common goals, and especially as a contribution towards the overall goal of the World Summit on Sustainable Development of significantly reducing the rate of loss of biodiversity by 2010.

The subject matter in this document is complex. Data and information are often lacking or, at best, difficult to access. We present this document as neither a comprehensive nor a final text, but rather as a starting point. "Trends", by definition, infer analysis over time. We hope that this document will be upgraded and updated on a regular basis.

Hamdallah Zedan
Executive Secretary
Convention on
Biological Diversity

Peter Bridgewater
Secretary General
Convention on Wetlands
(Ramsar, Iran, 1971)

Acknowledgements

The support of the World Resources Institute in this process is acknowledged. Preparation of this report was made possible through financial support from the Dutch Ministry of Foreign Affairs (DGIS) under the "Conservation and Wise Use of Wetlands — Global Programme" managed by Wetlands International (WI) as part of a Grant Agreement between WI and the Bureau of the Ramsar Convention on Wetlands. It draws heavily on material previously published by the World Resources Institute and contains sections previously published in *Revenga, C., J. Brunner, N. Henninger, K. Kassem, and R. Payne. 2000. Pilot analysis of global ecosystems: freshwater systems. World Resources Institute, Washington DC.* Copyright for these verbatim sections remains with the World Resources Institute.

The original draft was peer reviewed by a number of specialists at the Secretariat of the Convention on Biological Diversity, the Bureau of the Ramsar Convention on Wetlands and Wetlands International and externally. A number of specialists contributed additional materials to the report during this process. The Secretariat of the Convention on Biological Diversity wishes to acknowledge all these efforts in the production of this document.

Hamdallah Zedan
Executive Secretary

EXECUTIVE SUMMARY

1. In paragraph 8 (a) of the programme of work on inland water ecosystems contained in Annex I to decision IV/4, the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) was requested to use existing information and draw upon relevant organizations and experts to develop, as part of its work plan, an improved picture of inland water biological diversity, its uses and its threats, around the world, and to highlight where the lack of information severely limits the quality of assessments.

2. To assist SBSTTA in implementing this task, the Executive Secretary commissioned the World Resources Institute (WRI) to prepare this report of the status and trends of inland water biodiversity. The Executive Secretary has previously prepared a short version of this report (UNEP/CBD/SBSTTA/8/8/Add.1). The present note overviews the distribution and extent of inland water ecosystems, and presents a review of inland water species, major pressures upon them, and some conclusions regarding gaps in information.

3. In general, the extent and distribution of inland water ecosystems are not properly documented at the global or regional scale and, in some cases, there is no comprehensive documentation even at the national levels. Several inventories have been published listing the major river systems with their drainage area, length and average runoff. The International Lake Environment Committee (ILEC) and the UNEP-World Conservation Monitoring Center (WCMC)'s global map of wetlands, among others, maintain geographic descriptions, and/or physiographic, biological and socio-economic information on lakes. They do not provide comprehensive information on the distribution and extent of lakes at the global level. There are about 10,000 lakes with a size over 1km^2 worldwide. The location and distribution of *stricto sensu* wetlands i.e. areas that are often transitional and can be seasonally or intermittently flooded, and other classes of inland waters such as underground water and human-made systems are not well documented except in North America and Western Europe. Information on the status and trend of water availability and quality is also generally lacking.

4. The important relationships between inland waters, the biodiversity it supports and the livelihoods of people are not well document. Most reviews are based upon the FAO Fisheries Statistics which are acknowledged to be weak on this subject and seriously underestimate true values of the resource. Much improved information on production, the level of livelihoods dependency upon and the extent of utilisation of inland waters biodiversity is urgently required.

5. Major microbial groups present in inland waters include viruses, bacteria, fungi, protozoa and algae. Aquatic plants include angiosperms (flowering plants), pterophytes (pteridophytes, ferns), bryophytes (mosses, hornworts, and liverworts) and a number of tree species. Information on invertebrate species diversity is fragmentary. With regard to vertebrates, most global and regional overviews of inland water biodiversity include more information on the diversity of fishes than most other inland water groups, including *inter alia* amphibians, reptiles, and mammals. Waterbirds tend to have better coverage.

6. In general, information on species important for conservation pursuant to Annex I of the Convention, is generally fragmentary and, in a number of countries and regions, lacking for some categories of inland water biodiversity, particularly for species of socioeconomic, scientific and cultural value. Similarly, related information for genetic diversity (including

genomes, strains, varities, populations etc.) is even more fragmentary as is accurate data for ecosystem diversity. This information needs to be improved to be more useful to policy and decision-makers.

7. Microorganisms are rarely part of biodiversity status assessments, in spite the fact that their role in nutrient cycling, water purification and the food web is well known. Information on the conservation status of plants and animals was synthesized from internet checklists of specific animal and plant families and existing databases, mainly those of threatened species such as *inter alia* the 2002 IUCN Red Lists of Threatened Species and previous IUCN Red Lists, the UNEP-WCMC Threatened Plants Database and the BirdLife International Threatened Birds of the World. In every group of organisms considered, including aquatic plants and invertebrate and vertebrate animal species, examples of extinct, critically endangered, endangered, and vulnerable taxa are given. Some of the main threats to these taxa are also listed. Based upon these sources of information, it is clear that inland waters are amongst the most threatened of all environments.

8. Major threats to inland water ecosystems include, *inter alia,* modification of river systems and their associated wetlands, water withdrawals for flood control or agriculture, introduction of invasive alien species, pollution and eutrophication, overharvesting and the impact of climate change. These pressures occur all over the world. Their reported impacts vary from one watershed to another and are considered to be largely underestimated.

9. In conclusion, it is noted that
   (a) Additional efforts and financial commitments are needed to improve national, regional and global data on components of inland water ecosystems, their extent , functioning and response to pressures, the livelihoods dependency of people upon inland water biodiversity and related socioeconomic information;
   (b) Most data on water availability and use, including ground water, and such variables as river flow, water withdrawals and aquifer recharge rates, are generally only available at the national level, which makes it difficult to manage river basins that cross national borders;
   (c) New initiatives will assist in filling the large information gap regarding inland water species, especially at lower taxonomic orders. They include *inter alia* the monitoring projects sponsored by the IUCN's freshwater biodiversity assessment and species mapping programs; the work being done by BirdLife international on the location, distribution and population status of birds; the OECD's Global Biodiversity Information Facility (GBIF); the states of the world's plant and animal genetic resources for food and agriculture of the Food and Agriculture Organization of the United Nations, the Global Taxonomy Initiative of the Convention on Biological Diversity and the European Space Agency. These initiatives could also assist in mapping seasonal and forested wetlands which are difficult to map by other means;
   (d) Most species inventories are organized by taxonomic group. This should be broadened to include genetic diversity. It would be useful to also carry out inventories by ecosystem type to allow an assessment of the condition of inland water ecosystems; this should include accurate diagnostics of the temporal dimension on inland water ecosystems, in particular the hydrological regimes of rivers and the associated seasonal changes of wetlands;

(e) In order to obtain information of trends, baseline information will have to be gathered. Without population trends of species, it is hard to assess the effects of pressures or the risk of extinction of species. Tracking changes in habitat extent and quality also requires appropriate baseline information. An agreement on outcome targets such as the ones defined in the Convention's Strategic Plan and in the Global Strategy for Plant Conservation of the Convention would facilitate the development of monitoring mechanisms that could provide information on trends in inland water biodiversity;

(f) Because of the large impact that introduced species can have on inland water ecosystems, information on the location of introduced and alien invasive species is urgently needed.

TABLE OF CONTENTS

1. INTRODUCTION

The programme of work on the biological diversity of inland water ecosystems was adopted at the fourth meeting of the Conference of the Parties to the Convention on Biological Diversity as annex I to decision IV/4. The first programme element relates to the assessment of the status and trends of the biological diversity of inland water ecosystems and the identification of options for conservation and sustainable use. In paragraph 5 of decision V/2, adopted in 2000, the Conference of the Parties requested the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to review the implementation of this programme of work and to include in its review advice on the further elaboration and refinement of the programme of work. The CBD and Convention on Wetlands also have a joint work programme.

This report, prepared by the World Resources Institute (WRI) for the CBD and the Ramsar Convention, provides an overview of the current knowledge of the condition of inland water ecosystems and their biodiversity. It reviews the current knowledge and information on inland water ecosystems and their dependent species in order to identify information gaps and needs that should be addressed by the CBD programme of work on the biological diversity of inland water ecosystems.

The document consists of five major sections covering the following topics:

1. Distribution and extent of inland water ecosystems;
2. Overview of the condition and threats to inland water ecosystems (focusing on the fragmentation of river systems, water scarcity, pollution, habitat loss, invasive alien species, fisheries exploitation, and the impacts of climate change);
3. Review of knowledge of inland water biodiversity. This section reviews the distribution, richness and conservation status of freshwater-dependent taxa (i.e., mammals, birds, amphibians, reptiles, fish, invertebrates and aquatic plants);
4. Identification of habitats and ecosystems that have been identified as conservation priority areas through different priority-setting approaches;
5. Identification of data gaps and future assessments needs.

The report includes an annex describing ongoing assessment or monitoring programmes that focus on water resources and freshwater biodiversity.

1.1 LIMITATIONS OF THIS REPORT

An exhaustive literature review of all existing information on taxa that include freshwater species was not attempted in this review. The document therefore relies heavily on existing and available information provided by experts of the Species Survival Commission network of the World Conservation Union (IUCN/SSC) and other organizations working on biological diversity such as the WWF, and the United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC). The document is based in part on previously published materials and analyses from the World Resources Institute (WRI) and on readily available information from well-documented and peer-reviewed sites on the Internet, and literature published primarily in the English language. For some taxa, Japanese, French and Spanish publications were used.

This report is global and to certain extent regional in scope, therefore only information at the global and/or regional scale was consulted. There is considerable knowledge and information at the national level, particularly on certain species groups. However it was not possible to consult or incorporate such information for this report.

Coverage of the uses of inland water biodiversity is not comprehensive. Data for this are hard to come by. In references to the FAO statistics for inland fisheries, for example, it should be noted that these are acknowledged by the FAO itself as seriously underestimating the importance of inland water bio-

diversity, and in particular do not adeqately cover small-scale uses or livelihoods aspects (www.fao.org). It is widely known that the existing uses of inland water biodiversity, and the levels of livelihoods dependency upon it, is one of the most significant benefits of the resource. A more thorough review of this subject would have particular relevance to Article 10 (on sustainable use) of the Convention.

Coverage of genetic diversity in inland waters is limited and refers mainly to genetic diversity implied by populations or sub-populations of a limited number of animals, particularly birds. The nature of inland water ecosystems promotes very high levels of genetic diversity (i.e., diversity within species, of varieties, strains, populations etc.). This is often because groups of freshwater organisms can be isolated from one another between, and even within, catchments (basins), including those which are geographically very close, even adjacent.

The diversity of inland water ecosystems and habitats (as a component of biodiversity in its own right) is another area that is difficut to review, not least because of constraints with, and differences in, classification systems and terminology. In particular, the temporal aspects of ecosystem diversity in inland waters (e.g. seasonal wetlands, hydrological cycles in rivers) are especially difficult to quantify but nevertheless are perhaps more marked in inland waters than in any other ecosystem type.

Amongst the taxa covered, microorganisms remain a significant ommission. Until recently, these biota have tended to be poorly studied and typically negelected in assessments of the biodiversity of aquatic ecosystems. Nowadays, the important roles played by these organisms in maintaining many biological and geological processes in inland water ecosystems are gradually becoming understood, as are the implications of the loss of such elements of biodiversity. The largely unexplored potential of microorganisms, such as protozoa, as indicators of ecosystem health or condition is another area that requires further attention and research focus.

All of these areas, amongst others, would benefit from more focussed additional attention.

1.2 DISTRIBUTION AND EXTENT OF INLAND WATER ECOSYSTEMS

Inland water ecosystems encompass habitats with a wide variety of physical, temporal, chemical and biological characteristics, and include lakes and rivers, floodplains, peatlands, marshes and swamps, small streams, ponds, springs, cave waters, and even very small pools of water in tree holes and other cavities in plants and soil. The terms "inland waters" and "freshwater" are often used interchangeably. However, some important inland water ecosystems are saline or brackish (e.g., lagoons, inland seas or lakes) and not freshwater. Also "freshwaters" can extend a considerable distance out into the sea (at large river mouths where water is still potable several kilometres offshore) but such areas of freshwater influence are not usually covered by the term "inland waters". The temporal dimension of inland water bodies can be perennial or ephemeral and includes the dynamic dimension of running systems (i.e., rivers or lotic systems), standing systems such as lakes and ponds (i.e., lentic systems) and the seaonality of inundation of wetlands (UNEP/CBD/SBSTTA/3/7 and UNEP-WCMC 2000).

The remainder of this section of the report provides an overview of what is known about the distribution of the world's inland water ecosystems and highlights some of the limitations and difficulties encountered by the research and conservation

1 The most widely used definition of inland wetlands is that adopted by the Convention on Wetlands (Ramsar, Iran, 1971), which covers all wetland types, including artificial wetlands, occurring in inland situations, and encompasses riverine, lacustrine, and palustrine systems (see Ramsar Classification System for Wetland Type in the Annex to Resolution VII.11, available on http://www.ramsar.org/key_res_vii.11e.htm). However, it should be noted that some definitions of "wetland" are more restrictive and, for example, cover only shallow vegetated systems, so excluding open water systems. Since the main sources of available information on global and regional wetland distribution used here report on all inland water types covered by the Ramsar Convention, the Ramsar inland wetland scope is used in this section.

community in mapping and inventorying these ecosystems around the world.

1.3 EXTENT AND DISTRIBUTION OF WETLANDS

In this section, the term "wetland"[1] covers all natural and artificial inland water habitat types covered by the Ramsar Convention, including freshwater, brackish and saline systems, permanent and temporary systems and above ground and underground (karst and cave) systems.

In most cases there is no clear boundary between inland and coastal systems, and there is an array of wetland habitats that have either saline or freshwater attributes or a mixture of the two seasonally (UNEP/CBD/SBSTTA/3/7 and UNEP-WCMC 2000). Many seasonal and ephemeral wetlands are estimated to disappear in the coming 100 years (Bledzki, pers. comm. 2003). The complex coupling of climatic, edaphic, and biotic factors that drive ecosystem processes change quickly over both space and time. Furthermore, interactions between these processes promote the persistence of rare species and the maintenance of critical ecosystem functions that would disappear with the loss of the ephemeral and seasonal wetlands.

A *Global Review of Wetland Resources and Priorities for Wetland Inventory (GRoWI)* (Finlayson & Spiers 1999) was prepared for the Ramsar Convention. This derived estimates of the global extent of wetlands from compilation of national inventory sources, and from regional and global sources, and compared these with previous estimates. An overall global estimate, including coastal wetlands in some countries, was 1,276-1,279 million hectares, compared with previous estimates of inland waters of 530-970 million hectares derived mostly from remotely sensed information. These estimates include 530 million ha for natural freshwater wetlands (i.e. excluding irrigated rice fields) (Matthews & Fung 1987) and 700 million ha (including rice paddies) (Aselmann & Crutzen 1989).

Global figures for the area and distribution of different inland water types are not generally available. However, a substantial proportion of the inland water resource is known to be peatland[2]. Although size estimates vary, peatlands are considered to cover at least 242 million ha (Spiers 1999), and the Global Peatland Initiative has recently estimated coverage of 324 million ha (http://www.wetlands.org/projects/GPI/peatland.htm), some 25-46% of the total area of inland waters from different sources. Cultivated rice paddies also form a significant area of the inland resource, covering at least 130 million ha (Aselmann & Crutzen 1989). Further information on rivers and lakes is provided in Sections 1.4 and 1.5 below.

In interpreting all these estimates it is important to be aware that Finlayson & Spiers (1999) concluded that based on existing information it is not possible to reliably estimate the total extent of wetlands at a global scale, so all the estimates summarised in Table 1 are indicative and should be interpreted with caution. There are many reasons for the difficulty of establishing an accurate estimate of wetland extent and distribution (see Box 1).

The GRoWI report concluded that national and regional data for Oceania, Asia, Africa, Eastern Europe, and the Neotropics allow just a cursory assessment of wetland extent and location. Only for North America and for Western Europe have more robust estimates of wetland extent been published. Of 206 countries or territories for which the state of inventory was assessed, only 7% had adequate or good national inventory coverage. Of the remainder, 69% had only partial coverage, and 24% had little or no national wetland inventory (Finlayson & Davidson 1999). More detailed discussions on each region, including country-specific assessments, are available in Finlayson & Spiers (1999).

2 Peatlands are areas of landscape with a naturally accumulated peat layer on its surface, and include active peatlands ('mires') where peat is currently forming and accumulating (Ramsar Resolution VIII.17 *Guidelines for Global Action on Peatlands*)

Table 1. Estimates of Regional and Global Freshwater Wetland Area

Figures are in millions of hectares.

Region (regionalization scheme differs between GRoWI and UNEP-WCMC sources)	**GRoWI compilation of national wetland inventories**[1]	**Previous regional and global estimates**[1]	**UNEP-WCMC (1998) map**[2]
Africa	111.6-112.2[3]	34.5-35.6[5]	132.4
Asia	207.4[4]	> 120[4]	343.6
Europe	227.8[3]	0.7[5]	35.8
Neotropics	414.9[4]	153.8[5]	156
North America	241.6[4]	167.3[4]	– [6]
Oceania	35.8[4]	No data	20.5
Total	**1,236.5**	**> 474.5-475.6**	**> 688.3**

Sources: [1] Finlayson & Spiers (1999) and its global and regional reports; [2] UNEP-WCMC (1998)

Notes: [3] 'inland' and 'human-made' wetland types only; [4] all wetlands; [5] freshwater wetlands only; [6] area estimate not available — shown on map as percentage of area covered by wetlands.

Box 1

Wetland inventories have been incomplete, are inconsistent in coverage and are difficult to undertake for a number of reasons, including:

- *Definitions:* The definition of a wetland varies depending on research purpose and an organization's mandate. For example, the Ramsar Convention uses a very broad definition, covering both inland waters and coastal zones. The latter includes reefs and seagrass beds as specific habitat types up to a water depth of six meters;
- *Scope:* Data from national inventories are often incomplete and difficult to compare with each other because some concentrate on specific habitat types, such as wetlands of importance to migratory birds, whereas others include artificial wetlands, such as rice paddies;
- *Limitation of maps:* Wetland inventories sometimes use existing maps, such as Operational Navigation Charts (ONC), to estimate wetland extent. Wetland extent then becomes a function of scale and the cartographic convention of the mapmaker. For example, navigation charts will depict only wetlands that are visible by pilots. In addition, the rules for placing wetlands symbols on a map usually vary with institutions;
- *Boundaries:* Researchers often have difficulty defining the boundaries and differentiating individual wetlands from wetland complexes, often because of seasonal changes. Establishing inland water boundaries is a particular challenge for temporary and ephemeral wetlands;
- *Limitation of remote sensing products:* The wide range in the sizes and types of wetlands and the problem of combining hydrologic and vegetation characteristics to define wetlands make it difficult to produce a global, economical, and high-resolution data set with existing sensors.

In terms of mapped information, the best global GIS database of wetlands currently available is UNEP-WCMC's Global Wetland Distribution. UNEP-WCMC and IUCN estimated the location and extent of the wetlands through expert opinion by delineating wetland boundaries from Operational Navigation Charts (WRI 1995). Unfortunately wetland characterization and the level of detail varies from region to region, with Africa being the most comprehensively mapped, while most of North America is much less accurate. Map 1 *(see Appendix A, page 117)* shows UNEP-WCMC's coverage of wetlands for Africa together with the locations of Ramsar sites and

registered dams. UNEP-WCMC's global map of wetlands provides more detail than other global, coarse resolution data sets that use vegetation, soils, and terrain to delineate wetlands—for example, data produced to estimate methane emissions (Matthews and Fung 1987). It also provides more detail on wetlands than the most recent land cover characterization map by the International Geosphere-Biosphere Programme (IGBP) of the International Council for Science (ICS), which mostly shows coastal wetlands.

The University of Kassel in Germany has compiled a global 1-minute resolution map of wetlands, lakes and reservoirs. The map was derived by combining various digital maps including ESRI's 1992 and 1993 maps of wetlands, lakes and reservoirs, UNEP-WCMC's map of lakes and wetlands and the Vörösmarty et al. (1997a) map of reservoirs. Attribute data on reservoirs and lakes were also included from the International Commission on Large Dams and other sources. The map distinguishes 'local' from 'global' lakes and wetlands, the local open-water bodies being those only supplied by the runoff generated within the grid-cell and not by additional inflow from upstream areas. The resulting map is a generated data set, in which vegetated wetlands cover 6.6% of the global land area (without Antarctica and Greenland), and lakes and reservoirs cover 2.1% (Lehner and Döll 2001).

1.4 EXTENT AND DISTRIBUTION OF RIVERS

Although the volume of water in rivers and streams is only a fraction of the water in the entire hydrosphere, in many parts of the world this water constitutes the most accessible and important resource (WWDR 2003). Precipitation and runoff, which influence the distribution of river networks, are unevenly distributed across the world. It is estimated that Asia and Latin America each contribute over 30% of the world's freshwater discharged into the ocean, while North America contributes 17, Africa 10, Europe 7, and Australasia 2% (Fekete et al. 1999).

There are several published inventories of rivers, listing the major river systems with their drainage area, length, and average runoff (e.g. Baumgartner and Reichel 1975; Gleick 1993; Shiklomanov 1997). The variability between estimates can be explained by different definitions regarding the extent of a river system and different time periods or locations for the measurement of

Box 2

Calculating drainage area requires a definition of watersheds. Data on river networks and topography are essential in determining the extent of a drainage basin. The Eros Data Center of the United States Geological Survey developed a GIS database in 1999 called *HYDRO 1K*, which delineates basin boundaries at a scale of 1:1,000,000. *HYDRO 1K* is currently the most detailed global database that provides comprehensive and consistent coverage of topographically derived data sets with hydrologic modelling applications, including flow direction and drainage basins. Some of the limitations of this database, however, are that most of the basins do not have the name of the river system or the catchment, which makes manipulation and use difficult and many need to be edited, together with a river coverage, to ensure that rivers do not cross basin boundaries. Global river networks have also been digitally mapped by the U.S. National Imagery and Mapping Agency, at the scale of 1:1,000,000 based on the Operational Navigation Chart series (VMAP Level 0, 3rd edition, 1997). However, the only descriptive information contained in this database is whether the river is perennial or intermittent. Neither the name of the river system nor the catchment are included.

The World Meteorological Organization's (WMO) Global Runoff Data Centre compiles and maintains a database of observed river discharge data from gauging stations worldwide. Although this is the best global database currently available, the number of operating stations has significantly declined since 1980s—meaning the discharge data for many rivers have not been updated in the last two decades.

discharge. The commonly used virgin mean annual discharge (VMAD) is an estimate of the discharge "before any significant human manipulation" of the river system has taken place (Dynesius and Nilsson 1994). The VMAD is therefore usually higher than discharge figures measured at the mouth of the river, which often reflect consumptive water usage upstream.

Table 2 presents the drainage basin areas based on the currently available Geographic Information System (GIS) data that has a globally consistent level of detail.

The coverage and reliability of hydrological information obtained through measurements varies from country to country. Most scenarios and projections for water use and water scarcity are therefore derived from global models that utilise a combination of climate and elevation data and are, wherever possible, calibrated with observed data. These models do not supply the level of detail required to establish management options, assess threats to species and ecosystems or evaluate trade-offs. Better and more reliable information on actual stream and river discharge, and the amount of water withdrawn and consumed at the river basin level, would increase our ability to manage inland water ecosystems more efficiently, evaluate trade-offs between different uses, and set conservation

Table 2. Twenty Largest River Basins of the World (by drainage area)

River/ Lake Basin	Basin Area[a] (km^2)	River Length (km)	Countries Sharing the Basin (Number)	Virgin Mean Annual Discharge (m^3/s)
Amazon	6,145,186	6280 - 6570	7	200,000
Congo	3,730,881	4370 - 4700	9	41,000
Nile	3,254,853	6484 - 6670	10	~3,000
Mississippi	3,202,185	5970 - 6019	2	18,400
Ob	2,972,493	3180 - 5570	4	12,800
Parana	2,582,704	4700 - 4880	4	21,000
Yenisey	2,554,388	3490 - 5870	2	20,000
Lake Chad	2,497,738	1400 - 1450 (Chari River)	8	1,200
Lena	2,306,743	4270 - 4400	1	18,900
Niger	2,261,741	4030 - 4200	10	6,100
Amur	1,929,955	2820 - 5780	3	10,900
Yangtze	1,722,193	5520 - 6300	1	29,460
Mackenzie	1,706,388	4240 - 4250	1	9,910
Volga	1,410,951	3350 - 3688	2	8,050
Zambezi	1,332,412	2650 - 3500	8	7,070
Tarim	1,152,448	2000	2	650
Nelson	1,093,141	2575 - 2600	2	2,830
Indus	1,081,718	2880 - 3180	4	–
Murray	1,050,116	2570 - 3750	1	–
St. Lawrence	1,049,636	3060 - 4000	2	10,800

Note: [a] Basin area was digitally derived from elevation data using a Geographic Information System, and areas may differ from other published sources.

Sources: Basin area and number of countries sharing the basin from WRI (2000); river length from Gleick (1993); virgin mean annual discharge from Dynesius and Nilsson (1994) and Revenga et al. (2000).

Table 3. Information for Some Selected Lakes of the World

Lake Name	Surface Area (km^2)	Max. Depth (m)	Mean Depth (m)	Volume (km^3)	Drainage Area (km^2)	Major problems affecting the Lake
Africa						
Chivero	25.3	–	9.5	0.25	2,230	Salinization Eutrophication Exotic Species
Tanganyika	32,000	1471	570	17,800	263,000	Eutrophication
Victoria	68,800	84	40	2,750	284,000	Eutrophication Exotic Species
Asia						
Aral	60,000 (1960)	69 (1960)	16	1,090 (1960)	–	Water level change
Baikal	31,500	1637	751	23,670	540,000	–
Biwa	674	104	41	27.5	3,174	Eutrophication Exotic Species
Bhoj Wetland	37.5	11.7	3.4	0.121	371	Toxic pollution Eutrophication
Kinnerent	170	43	–	–	–	Eutrophication
Laguna de Bay	948	20	2.0	2.16	3,820	Toxic pollution Eutrophication
Tai-hu	2,428	3.0	2.0	4.46	36,500	Toxic pollution Eutrophication
Toba	–	529	485	–	–	Toxic pollution Eutrophication
Tonle sap	2,450- 12,000	12	–	–	–	–
Australasia						
Corangamite	251.6	6.0	6.0	1.5	–	Water level change
Europe						
Balaton	596	12	3.2	1.9	–	Eutrophication
Bodensee	539	252	90	48.5	–	Eutrophication
Maggiore	212.5	370	176.5	37.5	–	Eutrophication
Ohrid	358	289	164	58.6	–	Toxic pollution Eutrophication
Orta	18.2	143	71	1.3	–	Toxic pollution Acidification
Peipsi	3,555	15.3	7.0	25.1	–	Eutrophication
N. America						
Champlain	1,130	123	22.8	25.8	–	Eutrophication
Mono	158-223	45.7-56.7	15.2-22.9	2.8-5	–	Salinization Water level change
Ontario	19,000	245	86	1,634	75,872	Eutrophication Exotic Species Toxic Pollution
Tahoe	501	505	313	156.8	841	Eutrophication
S. America						
Titicaca	8,372	281	107	8.96	–	Eutrophication
Tucurui	2,430	75	18.9	46	–	Siltation Eutrophication

Source: Jorgensen et al. 2001

measures for ecosystems and species. However, much effort and financial commitment would have to be made to restore hydrological stations, the number of which has declined around the world since the mid-1980s.

1.5 EXTENT AND DISTRIBUTION OF LAKES

Of the estimated 5-15 million lakes across the globe (Herdendorf 1982; WWDR 2003) there are about 10,000 lakes with a size over 1 km^2, the majority of which are young in geological terms (UNEP-WCMC 2000). Table 3 lists some of these together with relevant statistics and threats affecting them. Only about 15-20 existing lakes in the world are known to be far older than 1 million years (LakeNet 2003) (see Table 4).

A disproportional share of large lakes—with a surface area over 500 km^2—is found in North America, especially Canada, where glacial scouring created many depressions in which lakes have

Table 4. Ancient Lakes of the World

Lake Name	Countries	Age (million years)
Eyre	Australia	20-50
Maracaibo	Venezuela	> 36
Issyk-Kul	Kyrgizstan	25
Baikal	Russia	20
Tanganyika	Burundi Tanzania Dem. Rep. of Congo Zambia	20
Caspian Sea	Azerbaijan Iran Kazakhstan Russia	> 5
Aral Sea	Kazakhstan	> 5
Ohrid	Albania Macedonia	> 5
Hovsgol	Russia	2-5
Prespa	Albania Greece Macedonia	> 5
Victoria	Kenya Tanzania Uganda	> 4?
Titicaca	Bolivia Peru	3
Malawi	Malawi Mozambique Tanzania	> 2
Lanao	Philippines	> 2
Biwa	Japan	2
Tahoe	United States	2

Source: Compiled by Duker and Borre (2001) based on various sources.

formed. Knowing the depth and water volume is important for the understanding of lake water movement and potential productivity. However, the calculations of these require detailed knowledge of the lake bottom and thus are often estimated rather than measured. Lakes undergo seasonal changes and are modified through tectonic events or volcanic activity, landslides and erosion or wind. Measurements or estimates of surface area, depth or water volume can therefore vary among different investigators (WRI et al. 1994).

The International Lake Environment Committee (ILEC) maintains a database of over 500 lakes worldwide, with some physiographic, biological and socio-economic information (Kurata 1994; ILEC 2002). In collaboration with UNEP and the Japan Environment Corporation, ILEC has undertaken a *Survey of the State of the World Lakes* which has resulted in the publication of five volumes (1988-1993) containing detailed data for 217 lakes in 73 countries. The data collected by ILEC highlight seven major problem areas that are widespread among lakes and reservoirs. These are: lowering of the water level; siltation; acidification; chemical contamination; eutrophication; salinization; and the introduction of exotic species (Kira 1997; Jorgensen et al. 2001). The major limitation of ILEC's database is that it is questionnaire-based and thus the information is largely descriptive, often incomplete, and is not regularly updated. Revisions and updates have recently been completed for 25 lakes, based on data as recent as the year 2000 (Ballatore pers. comm. 2002). However, due to the lack of a comprehensive data set, the figures are not comparable. The main conclusion drawn by this study is that most of the 25 lakes suffer from declining water quality, which is leading to a severe reduction in their ability to satisfy human needs. Eutrophication, which is recognized as the most widespread problem is also one of the most difficult to abate (Jorgensen et al. 2001).

The Global Lake Status Data Base (GLSDB) compiles information on lake-level and relative water depth through historical time periods. This database is used to document long-term changes in regional water budgets, and for the evaluation of climate models using lakes as indicators of palaeoclimatic changes at a continental to global scale. The database is updated on a region-by-region basis (Harrison 2001).

In terms of geographic location and extent, UNEP-WCMC's global map of wetlands includes several thousands of records classified as lakes or salt pans, many of which have information on the name and a very brief description of the site.

Lake and pond boundaries are also mapped in another geographically referenced database, the ESRI *ArcWorld* database (1992). This mapped database with a resolution of 1:3,000,000 is slightly more detailed than that of UNEP-WCMC, but the water bodies are only differentiated by types, and not by individual name or site description.

The location of large water bodies can also be identified with coarse-scale satellite-based land-cover datasets, such as Global Land Cover Characteristics Database (GLCCD 1998), a global dataset at a resolution of 1:1,000,000, derived from Advanced Very High Resolution Radiometer (AVHRR) satellite data. The AVHRR provides 4- to 6-band multispectral data from the NOAA polar-orbiting satellite series. There is fairly continuous global coverage since June 1979, with morning and afternoon acquisitions available. The resolution is 1.1 km at nadir.

2. CONDITION OF, AND THREATS TO, INLAND WATER ECOSYSTEMS[3]

In many parts of the world freshwater ecosystems are being intensely modified and degraded by human activities. The rapid proliferation of dams, river and stream embankments, and the draining of wetlands for flood control and agriculture, for example, have caused widespread loss of freshwater habitats, especially waterfalls, rapids, riparian floodplains and related wetlands. A summary of global and regional extents of known inland wetland habitat losses and degradation is provided by Spiers (1999).

Habitat loss has been accompanied by a decline and loss of freshwater species, to a point where the biodiversity of freshwater ecosystems is currently in far worse condition than that of forest, grassland, or coastal ecosystems (WRI 2000). Habitat degradation, physical alteration through dams and canals, water withdrawals, overharvesting, pollution, and the introduction of exotic species all contribute directly or indirectly to the decline in freshwater biodiversity. These pressures occur all over the world, although the particular effects of these stresses vary from watershed to watershed. Findings from a study carried out on freshwater fishes show that habitat alteration and the introduction of exotic species are the two main causes of species extinction (Harrison and Stiassny 1999). The study attributed 71% of extinctions to habitat alteration, 54% to the introduction of exotic species, 29% to over-harvesting, 26% to pollution, and the rest to either hybridization, parasites and diseases, and intentional eradication (some extinctions may have had several causing factors and, therefore, percentages do not add up to 100) (Harrison and Stiassny 1999).

The combination of pressures on freshwater systems has resulted in more than 20% of the world's freshwater fish species to become extinct, endangered, or threatened in recent decades (Moyle and Leidy 1992). This estimate is considered too low by some authors (Bräutigam 1999). In North America research shows that species are being lost at an "ever-accelerating rate" (Moyle and Leidy 1992). Future extinction rates are believed to be five times higher for freshwater animals than for terrestrial species (Ricciardi and Rasmussen 1999). With population growth, industrialization, and the expansion of irrigated agriculture, the demand for all water-related goods and services will continue to increase dramatically, thereby increasing pressures on freshwater species and habitats.

Direct threats to different species groups are discussed in detail in *Section 3: Review of Inland Water Species Richness, Distribution and Conservation Status* of this document. The remainder of this section focuses on overall threats to the integrity of freshwater ecosystems at the global level. In particular it focuses on the level of modification of river systems, the current and projected degree of water scarcity, the impact of invasive species on inland water ecosystems, the condition of inland water fisheries, and the impacts of climate change on inland waters. Habitat loss and water quality, some of the most important threats to freshwater biodiversity, are not discussed in detail because of the lack of comprehensive data at global scale.

2.1 MODIFICATION OF RIVER SYSTEMS

Rivers have been altered since historical times, but such modifications skyrocketed in the early to mid-1900s. Modifications include river embankments to improve navigation, drainage of wetlands for flood control and agriculture, construction of dams and irrigation channels, and the establishment of inter-basin connections and water transfers. These changes have improved transportation, provided flood control and hydropower, and boosted agricultural output by making more land and irrigation water available. At the same time, these physical changes in the hydrological cycle discon-

3 This section is largely extracted from Revenga et al. 2000. *Pilot Analysis of Global Ecosystem: Freshwater Systems, World Resources Institute, Washington DC, USA*, and has been adapted and edited for this paper in agreement with the CBD Secretariat and the Ramsar Bureau.

nect rivers from their floodplains and wetlands and slow water velocity in riverine systems, converting them to a chain of connected reservoirs. This, in turn, impacts the migratory patterns of fish species and the composition of riparian habitats, opens up paths for exotic species, changes coastal ecosystems, and contributes to an overall loss of freshwater biodiversity and inland fishery resources (Revenga et al. 2000). Dams also affect the seasonal flow and sediment transport of rivers for an average of 160 kilometers downstream. Some major water projects, such as the Aswan High Dam in Egypt, have an effect that extends more than 1,000 kilometers downstream (McAllister et al. 1997).

Humans have built large numbers of dams all over the world, most of them in the last 35 years. Today, there are more than 45,000 large dams (more than 15 meters high) in the world, 21,600 of which are in China alone (ICOLD 1998; WCD 2000). This storage capacity represents a 700% increase in the standing stock of water in river systems compared to natural river channels since 1950 (Vörösmarty et al. 1997a). Table 5 shows the distribution of large dams by continent, based on the 25,410 registered dams reported by the International Commission on Large Dams (ICOLD) and the storage capacity of large reservoirs. Obviously, differences between sources are evident as Table 5 does not reflect the aforementioned statistic for the proportion in China.

In terms of storage capacity, Asia and South America have seen the biggest recent increase in the number of reservoirs. In Asia, 78% of the total reservoir volume was constructed in the last decade, and in South America almost 60% of all reservoirs have been built since the 1980s (Avakyan and Iakovleva 1998). The inventory of dams and reservoirs is incomplete for China and the former Soviet Union, which, together with the United States, are the world's top ranking countries in terms of number of large dams (ICOLD 1998). Reservoirs with more than 0.5 km^3 maximum storage capacity intercept and trap an estimated 30% of global suspended sediments (Vörösmarty et al.1997b).

River fragmentation, the interruption of a river's natural flow by dams, inter-basin transfers, or water withdrawal, is an indicator of the degree

Table 5. Large Dams and Storage Capacity of Large Reservoirs by Continent

Continent	World Registered Dams		Number of Large Reservoirs*	Storage Capacity of Large Reservoirs* Total Volume (km3)
	Number**	Percent		
Africa	1,265	5%	176	1,000
Asia	8,485	33.4%	815	1,980
Oceania	685	2.7%	89***	95***
Europe	6,200	24.4%	576	645
North America	7,775	30.6%	915	1,692
Central and South America	1,005	3.97%	265	972
Total Registered Number	25,410**	—	—	—
Estimated Total Number	41,413	—	2,836	6,385

* Large reservoirs are those with a total volume of 0.1 km^3 or more. This is only a subset of the world's reservoirs. A figure of 47,655 is given for large dams by WCD (2000).
** Total number of dams may not add up due to rounding. ICOLD reports a total of 25,410 registered dams.
*** Includes only Australia and New Zealand.

Sources: Revenga et al. 2000 based on data from ICOLD (1998) and Avakyan and Iakovleva (1998).

of modification of rivers by humans (Ward and Stanford 1989; Dynesius and Nilsson 1994). The WRI, in collaboration with the University of Umeå in Sweden (Revenga et al. 2000), assessed the degree of fragmentation of the main large rivers of the world, with the exception of areas in South Asia and Oceania *(see Map 2, Appendix A, page 118)*. The degree of fragmentation of rivers was divided into three categories: strongly affected systems, moderately affected and free flowing. Strongly affected rivers included those with less than one quarter of their main channel left without dams, where the largest tributary had at least one dam, as well as rivers whose annual flow patterns had changed substantially. Unaffected rivers were those without dams in the main channel of the river and, if tributaries had been dammed, river discharge had declined or been contained in reservoirs by no more than 2%.

The study showed that, of the 227 major river basins assessed, 37% were strongly affected by fragmentation and altered flows, 23% were moderately affected, and 40% were unaffected. Strongly or moderately fragmented systems were widely distributed in all assessed regions. River systems with parts of their basins in arid areas or that had internal drainage systems were strongly affected. The only remaining large free-flowing rivers in the world were found in the tundra regions of North America and Russia, and in smaller coastal basins in Africa and Latin America. It should be noted, however, that considerable parts of some of the large rivers in the tropics, such as the Amazon, the Orinoco, and the Congo, would be classified as unaffected rivers if an analysis at the sub-basin level was done. The Yangtze River in China, which was classified as moderately affected, has become strongly affected since the Three Gorges dam was completed.

The demand and untapped potential for dams is still high in the developing world, particularly in Asia. As of 1998, there were 349 dams over 60 meters high under construction around the world (IJHD 1998). The countries with the largest number of dams under construction were Turkey, China, Japan, Iraq, Iran, Greece, Romania, and Spain, as well as the Paraná basin in South America. The river basins with the most large dams under construction were the Yangtze in China, with 38 dams under construction, the Tigris and Euphrates with 19, and the Danube with 11. In the future the increasing number of dam removals that becomes necessary will again strongly impact the hydrology and ecology of the affected rivers. In the last 20 years, over 500 dams have been removed worldwide (Bledzki pers. comm. 2003). However, the ecological implications of removal, and appropriate removal strategies, are not fully understood.

Direct impacts of dams on diadromous fish species such as salmon, are well documented. Indirect impact of flow alteration on fish species assemblages has also been documented for several artificial reservoirs in Africa. The reservoirs in these catchments have replaced running water habitats such as rapids and waterfalls, resulting in the disappearance of fish species adapted to lotic systems and the proliferation of other, in many cases exotic, species adapted to lentic systems. One example is the dramatic decline in the population of two commercially important fish species in the Zambezi River, *Labeo congoro* and *Labeo altivelis.* These two cyprinid species were abundant and maintained a healthy fishery before the dam was built and Lake Kariba was formed in 1958. The construction of the dam blocked their spawning migration and inundated riparian wetlands that constituted their preferred habitat causing the decline in species abundance. In just a few years, from 1960 to 1967, the species composition of the catch shifted from being dominated by *Labeo* to containing practically no *Labeo* (Lévêque 1997). When Kariba dam was built, it was hoped that the formation of the lake would result in a productive fishery. However, Lake Kariba was so unproductive that the Zimbabwean government decided to introduce a "sardine" endemic to Lake Tanganyika in 1967-68. This sardine now accounts for over 80% of the commercial catch of the lake (Gréboval et al. 1994.)

In West Africa, a sharp decline of Mormyridae (an elephant-nosed fish family of Osteoglossiformes) was observed in Lakes Kainji and Volta, after the inundation of their preferred habitats as a result of dams. On the other hand, small pelagic fishes and the predators that feed on these became adapted to the newly created reservoir environments and gradually replaced the native fauna (Lévêque 1997). Cases of adverse impact on the structure of riparian vegetation from dams, embankments and canals are also widely reported (Nilsson and Berggren 2000). In tropical Asia, changes in flooding patterns due to river modifications have also affected riverine and wetland-dependent mammal populations, such as marshland deer and the Asian rhino in Thailand, India, and China, as well as diadromous fish stocks, such as sturgeons in China (Dudgeon 2000). Similar cases have been reported for North and South America, including eight species of salmonids, seven species of sturgeons, and five species of shads and herrings in North America; diadromous coporo (*Prochilodus mariae*) in western Venezuela and Columbia; and Amazon river dolphins in the Amazon basin (Pringle et al. 2000).

2.2 WATER SCARCITY

Humans withdraw about 4,000 km^3 of water a year, or about 20% of the world's rivers' base flow (the dry-weather flow or the amount of available water in rivers most of the time) (Shiklomanov 1997). Between 1900 and 1995, water withdrawals increased by a factor of more than six, which is more than twice the rate of population growth (WMO 1997). In river basins in arid or populous regions, the proportion can be much higher. This has implications for the species living in or dependent on freshwater systems, as well as for future human water supplies.

Many experts, governments, and international organizations around the world predict that water availability will be one of the major challenges facing human society in the 21st century and that the lack of water will be one of the key factors limiting development (WMO 1997; WWDR 2003). The agricultural sector, society's major user of water, withdraws 70% of all water for irrigation (WMO 1997). Decreased river flows and falling ground water levels are common problems in irrigated areas, mostly because of the few incentives to conserve water and improve the efficiency of irrigation systems (Wood et al. 2000). In most regions around the world with large-scale irrigation schemes, water is undervalued and usually subsidized, which reinforces the lack of incentives for its conservation and reduced consumption.

As populations grow, demand for food and, therefore, water for irrigation increases, placing higher pressures on the water left in rivers and streams. The Aral Sea represents one of the most extreme cases in which water for irrigation has caused severe and irreversible environmental degradation of an aquatic system. The volume of water in the Aral basin has been reduced by 75% since 1960, due, mainly, to large-scale upstream diversions of the Amu Darya and Syr Darya river flow for irrigation of close to seven million hectares of land (Postel 1999; UNESCO 2000). This loss of water, together with excessive chemicals from agricultural runoff, has caused a collapse of the Aral Sea fishing industry, a loss of biodiversity and wildlife habitats, particularly the rich wetlands and deltas, and an increase in human pulmonary and other diseases in the area resulting from the toxic salts and pesticides in the exposed seabed that are being spread by dust storms (WMO 1997; Postel 1999). Even though the Aral Sea is the most commonly cited and one of the most extreme cases, there are many other examples where diversion for agriculture has caused a decline in species richness and a disappearance of valuable wetland habitats. In the majority of cases, the most impacted people are poor residents, who depend on freshwater resources not only for drinking water but as a source of food supply, especially animal protein, and income.

A global analysis of water scarcity indicates that currently more than 40% of the world's pop-

ulation lives in water-scarce river basins (Revenga et al. 2000) *(see Map 3a, Appendix A, page 119)*. Water experts define areas where per capita water supply drops below 1,700 m^3/year as experiencing "water stress"—a situation in which disruptive water shortages can frequently occur (Falkenmark and Widstrand 1992; Hinrichsen et al. 1998). In areas where annual water supplies drop below 1,000 m^3 per person per year, the consequences can be more severe and lead to problems with food production and economic development unless the region is wealthy enough to apply new technologies for water use, conservation, or reuse. With growing populations, water scarcity is projected to increase significantly in the next decades, affecting half of the world's people by 2025 *(see Map 3b in Appendix A, page 119)*. Of the basins in which the projected population is expected to be higher than 10 million inhabitants by 2025, Revenga et al. (2000) estimated that six basins, specifically the Volta, Farah, Nile, Tigris and Euphrates, Narmada, and the Colorado River basin, will go from having more than 1,700 m^3 to less than 1,700 m^3 of water per capita per year. Another 29 basins will descend further into scarcity by 2025, including the Jubba, Godavari, Indus, Tapti, Syr Darya, Orange, Limpopo, Huang He, Seine, Balsas, and the Rio Grande.

While water demand is increasing, pollution from industry, urban centres, and agricultural runoff is limiting the amount of water available for domestic use and food production. In developing countries, an estimated 90% of wastewater is discharged directly into rivers and streams without prior treatment (WMO 1997). In many parts of the world, rivers and lakes have been so polluted that their water is unfit even for industrial uses (WMO 1997). Threats of water quality degradation are most severe in areas where water is scarce because the dilution effect is inversely related to the amount of water in circulation.

Widespread depletion and pollution also extends to groundwater sources, which account for about 20% of global water withdrawals (Shiklomanov 1997). However, information of the condition and even location of groundwater aquifers is very limited. Although there are no complete figures on groundwater use by the rural population, many countries are increasingly dependent on this resource for both domestic and agricultural use (Foster et al. 2000). Because much of the groundwater comes from shallower aquifers that draw from the same global runoff that feeds freshwater ecosystems, overdrafting of groundwater sources can rob streams and rivers of a significant fraction of their flow. In the same way, pollution of aquifers by nitrates, pesticides, and industrial chemicals often affects water quality in adjacent freshwater ecosystems.

Distribution of irrigated agricultural systems significantly influences the current and future water resource use pattern. However, detailed information on the irrigated areas and the intensity of water use in these areas are not available globally (Wood et al. 2000).

2.3 INVASIVE ALIEN SPECIES

The introduction of exotic species is the second-leading cause, after habitat degradation, of species extinction in freshwater systems (Hill et al. 1997). Exotic species affect native faunas through predation, competition, disruption of food webs, and the introduction of diseases. The spread of exotic species is a global phenomenon, which is increasing with the spread of aquaculture, shipping, and global commerce. The species introduced either intentionally or accidentally include a variety of taxa from fish and higher plants (such as water hyacinth) to invertebrates and microscopic plants (such as dinoflagellates). Worldwide, two thirds of the freshwater species introduced into the tropics and more than 50% of those introduced to temperate regions have become established (Welcomme 1988).

Although the problem of exotic species is global in scope, no comprehensive information on their distribution and their effects on biodiversity

and ecosystem condition are available at the global or regional levels.[4] Therefore, this report focuses on some of the better-documented cases.

2.3.1 Fish Introductions

Exotic fish introductions are common in most parts of the world, and they are an increasingly important component of aquaculture (FAO 1999a). Introductions are usually done to enhance food production and recreational fisheries, or to control pests such as mosquitoes and aquatic weeds. Introduced fish, for example, account for 96.2% of fish production in South America and 84.7% in Oceania (Garibaldi and Bartley 1998). The 2,574 records of international fish introduction found in FAO's Database on Introductions of Aquatic Species (DIAS) comprise over 80% of the total records, which includes vertebrates, invertebrates, and plants (FAO 1998).

Naturally, the introduction of exotic fish has its ecological costs. A survey of 31 studies of fish introductions in Europe, North America, Australia, and New Zealand found that in 77% of cases native fish populations were reduced or eliminated following the introduction of exotic fish. In 69% of cases the decline followed the introduction of a single fish species, with salmonids responsible for the decline of native species in half of these cases (Ross 1991). In North America, there have been recorded extinctions of 27 species and 13 subspecies of fish in the past 100 years. The introduction of alien species was found to be a contributing factor in 68% of these extinctions, although in almost every case there were multiple stresses, such as habitat alteration, chemical pollution, hybridization, and overharvesting (Miller et al. 1989).

A good review of literature on the effect of carp on freshwaters, including those of America, can be found in Zabrano et al. (2001). For Europe there is abundant evidence of the harmful impact of common carp on fresh-water ecosystems (Breukelaar et al. 1994, Carvalho and Moss, 1995). Although with less details, the adverse impact of introduced species on the native fauna is also documented for Africa, Asia and South America.

The introduction of exotic predators to Lake Victoria illustrates the profound and unpredictable trade-offs that can occur when management decisions are made without regard to the possible effects on the ecosystem. Before the 1970s, Lake Victoria contained more than 350 species of fish in the cichlid family, of which 90% were endemic, representing one of the most diverse and unique assemblages of fish in the world (Kaufman 1992). Today, more than half of these species are either extinct or found only in very small populations (Witte et al. 1992). The collapse in the lake's biodiversity was caused primarily by the introduction of the Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromis niloticus*), which predated on and outcompeted the cichlids for food. But other pressures factored in the collapse as well. Overfishing depleted native fish stocks and provided the original motivation for introducing the Nile perch and tilapia in the early 1950s. Land-use changes in the watershed led to increased release of pollutants and silt into the lake, increasing nutrient load and causing eutrophication. These changes resulted in major shifts in the lake's fish populations. Cichlids once accounted for more than 80% of Lake Victoria's fish biomass and provided much of the fish catch (Kaufman 1992). The most important catfish in the original fish fauna, *Bagrus docmac* and *Clarias gariepinus*, also declined after the introduction of Nile perch (Lévêque 1997). The fish biomass of the lake now consists mostly of only three species: Nile perch (60%), Nile tilapia (2.5%), and native small pelagic *Rastrineobola argentea* (35%) (Rabuor and Polovina 1995). Similar impacts have been reported for Lake Kyoga in Uganda (Lévêque 1997).

There have been three types of major fish introductions to tropical Asia and America over the last 150 years: piscivorous sport fishes such as trout and bass, and carps and tilapias for enhancing food

4 Note: a separate analysis of the impacts of invasive species on inland water ecosystems is in preparation for the CBD.

fisheries. Temperate piscivores and carnivores seem to have had the most reported negative impacts on indigenous fish fauna. Destructive impacts are recorded from Cuban freshwaters, Lake Titicaca (Peru, Bolivia), and Lake Atitlan (Guatemala). In a review of introductions in tropical Asia and America, on the other hand, introduced fishes were found not to have caused severe damage to indigenous species except for some incidents in Latin America where piscivores were used (Fernando 1991). In recent decades, tilapias have established and become a substantial contributor to inland fisheries in Mexico, the Dominican Republic, Northeast Brazil, and Cuba (as much as 90% of the catch) (Fernando 1991). Although this does not necessarily mean that the native fish stocks have collapsed it indicates a significant shift in the composition and structure of biological communities in those systems.

In tropical Asia, herbivores and omnivores, such as Indian, Chinese, and common carps, comprise the majority of introductions. Except for China, these temperate species of carps have not contributed much to fishery yield in the tropics. In comparison, tilapias have boosted capture fishery in Sri Lanka and Thailand, and aquaculture in Philippines, Taiwan, and Indonesia (Fernando 1991).

In China, the world's largest producer of inland fish, Black carp (*Mylopharyngodon piceus*), Silver carp (*Hypophthalmichthys molitrix*), bighead (*Aristichthys nobilis*), and Grass carp (*Ctenopharyngodon idella*), which have been introduced from their native ranges to other regions in China, are widely distributed and contribute significantly to fisheries production. Although research on the impact of introduced species on the native aquatic ecosystems of China is limited, a few well-documented cases exist. For example, Dianchi Lake in Yunnan Province, where each river or lake system has a distinct fish species composition and contains a high number of endemics, the number of native fish species declined after the introduction of over 30 alien species in the early 1970s. Likewise, the fish community structure of Donghu Lake, Hunan Province, has completely changed from a diverse species assemblage to a system dominated by a few species after the introduction of aquaculture (Xie et al. 2001).

2.3.2 Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) is another example of an alien species that becomes invasive in many tropical and sub-tropical inland waters causing considerable economic and ecological damage in numerous aquatic systems around the world. This plant, believed to be indigenous to the upper reaches of the Amazon basin, was spread throughout much of the planet for use as an ornamental beginning in the mid-19th century (Gopal 1987). By 1900 it had spread to every continent except Europe and has now a pan-tropical distribution. The plant quickly extended its range throughout rivers and lakes in the tropics, clogging waterways and infrastructure, reducing light and oxygen in freshwater systems, and causing changes in water chemistry and species assemblages (Hill et al. 1997).

In recent years, water hyacinth has spread very rapidly in Africa, from the Nile Delta and the Congo basin to regions in West Africa (particularly Cote d'Ivoire, Benin, and Nigeria), the equatorial zone of East Africa, and to the southern part of the continent, specifically Zambia, Zimbabwe, Mozambique, and South Africa (Harley et al. 1997). In many of the freshwater bodies in affected parts of Africa, water hyacinth control and eradication has become one of the top priorities for environmental agencies and fisheries departments. The presence and rapid proliferation of this weed causes severe damage to fisheries, infrastructure, and navigation.

In Australia, water hyacinth has spread along the entire coast, although its impact is being reduced by biological control. It has also spread to many Pacific Islands, including New Zealand. In Papua New Guinea, water hyacinth has been confirmed in almost 100 locations with the most

serious infestation reported for the Sepik River, where it has had "devastating effects on socioeconomic structure and on the environment" (Harley et al. 1997).

In South America, its native range, water hyacinth is found in the majority of the Amazon tributaries, as well as in Guyana, Surinam, Argentina, Paraguay, Uruguay, the northern part of Colombia, Venezuela, and the central rivers in Chile. It is also found in most of Central America and the Caribbean islands (Gopal 1987; Harley et al. 1997). Water hyacinth has become a pest in Guyana and Surinam and has spread into adjacent regions, creating problems in rivers and reservoirs by clogging dams and intake valves in Argentina, Bolivia, Cuba, and Mexico (Harley et al. 1997).

In Asia, it has widely spread through the Southeast and India. In Europe, however, it has been reported only in Portugal (Gopal 1987).

Unfortunately, despite the many problems associated with the water hyacinth, comprehensive global studies quantifying its distribution, its impact on biodiversity, and its socioeconomic parameters within freshwater systems and rural riparian communities are lacking. However, socioeconomic impacts are known to be very great. For example, at its peak of infestation in an area of southern Benin with a total population of 200,000 people, annual yearly loss of income (chiefly from fishing and food crops) caused by spread of water hyacinth has been estimated as US$84 million (De Groote et al. 2003).

2.4 FISHERIES EXPLOITATION

Inland fisheries from rivers, lakes, and other wetlands are a major source of protein for a large part of the world's population, particularly the poor. In contrast to marine fisheries, where part of the catch is discarded or converted to fishmeal for animal feed, in inland fisheries almost the entire catch is directly consumed by people—there is hardly any bycatch or "trash" fish (FAO 1999a). The population of Cambodia, for example, obtains about 60% of its total animal protein from the fishery resources of the Tonle Sap alone (MRC 1997). In some landlocked countries, this percentage is even higher. Inland fisheries in Malawi provide about 70-75% of the total animal protein for both urban and rural low-income families (FAO 1996).

In 1997 the catch from inland fisheries totaled 7.7 million metric tonnes, or nearly 12% of all fish directly consumed by humans from all inland and marine capture fisheries (FAO 1999b). Inland fisheries landings are comprised mostly of fish, although molluscs, crustaceans, amphibia, some aquatic reptiles and many other miscellaneous species also are caught and are of regional and local importance (FAO 1999b). The catch from inland fisheries is believed to be greatly underreported by factor of two or three (FAO 1999a). Asia and Africa are the two leading regions in inland capture fish production. China is, by far, the most important inland capture fisheries producer, accounting for nearly 28% of the global total in 1999 (2.3 million tonnes), followed by India (8.3%) and Bangladesh (7.1%) (Kapetsky 2001).

According to the FAO, most inland capture fisheries that depend on natural production are being exploited at or above their maximum sustainable yields (FAO 1999a). Globally, inland fisheries landings increased at 2% per year from 1984 to 1997, although in Asia the rate has been much higher: 7% per year since 1992. This increase is partially a result of efforts to raise production above natural levels through fisheries enhancements and of eutrophication of inland waters from agriculture run-off and certain types of industrial effluents (FAO 1999a; Kapetsky, personal communication, 1999). China's inland fisheries production, for example, is much larger than would be expected given the available freshwater area it has compared to other regions of the world. This fact as well as the large number of reservoirs in the country, points to the strong use of fishery enhancements, such as stocking and aquaculture, to increase yields (FAO 1999a). These enhancements, however, can seriously affect

the condition and long-term functioning of freshwater ecosystems.

Freshwater aquaculture with a total production estimated to be 17.7 million metric tonnes in 1997 (FAO 1999a), is in large part responsible for the high freshwater fisheries production in Asia, and most certainly in China. Most of China's production is carp. However, many aquaculture operations, depending on their design and management, can and have contributed to habitat degradation, pollution, introduction of exotic species, and the spread of diseases through the introduction of pathogens (Naylor et al. 2000).

In Europe and North America, freshwater fish consumption has decreased over time and recreational fishing is replacing inland food fisheries (FAO 1999a). Currently recreational catch is estimated at about 2 million metric tons per year (FAO 1999a). A positive trend in recreational fishing is being observed in countries across all economic levels (Kapetsky 2001). In recent years recreational fisheries contributed 52,000 metric tons to domestic consumption in Eastern Europe and 113,000 metric tons in Western Europe (Varadi 2001).

Recreational and food fisheries in many countries are maintained by fishery enhancements, particularly species introductions and stocking (FAO 1999a). Enhancements to increase recreational fisheries are more prevalent in North America, Europe, and Oceania, while enhancements to increase food production are more prevalent in Asia, Africa, and South America (FAO 1999a).

Assessing the pressure on inland fisheries and the consequences for inland water ecosystems is difficult, partly because of the paucity of reliable and comprehensive data on fish landings and watershed condition, and because of partial and incomplete reporting by countries. For instance, reporting of inland catch is rarely done at the species level. Despite the shortcomings, the FAO database on inland fisheries statistics is the most complete data set on fishery resources at the global level (*see Section 5 on Data Gaps and Information Needs* for further discussion on fisheries data.)

2.5 EFFECTS OF CLIMATE CHANGE

This section provides a summary of the impacts of climate change on wetlands based on an Information Paper "*Climate Change and Wetlands: Impacts, Adaptation and Mitigation*" prepared for Ramsar's 8th meeting of the Conference of the Contracting Parties (COP8-DOC.11). This document provides an in-depth review of the potential impacts of climate change to inland waters by geographic region. The overall impacts on wetlands from climate change are summarized in Table 6.

Climate change can directly or indirectly affect many ecosystem functions and thus the goods and services they can provide. Wetlands are no exception. The Intergovernmental Panel on Climate Change (IPCC) defines habitats and ecosystems vulnerable to climate change as "those that are naturally sensitive to climate change because of their geographical location or biophysical characteristics or those that have few or no adaptation options to reduce the impacts of climate change" (IPCC 2001b). Because most wetlands lack adaptation options many can be considered to be vulnerable to climate change. Particularly vulnerable wetlands are those at high latitudes and altitudes, e.g., Arctic and Sub-Arctic bog communities, or alpine streams and lakes (Gitay et al. 2001). Wetlands that are isolated are also considered to be vulnerable, primarily because if they experience species loss, the chance of recolonisation by species would be very low (Pittock et al. 2001).

The assessment of the IPCC has documented a series of changes in the planet's characteristics as a consequence of a warming climate (IPCC 2001a). These changes occur as a result of internal variability of the climate system as well as both natural and human-induced external factors. Some of these observed and documented changes include an increase in global surface temperature (0.4 to 0.8 C); an increase in precipitation in many parts of the northern hemisphere; an increase in heavy and extreme precipitation events over land in the mid- and high latitudes; an increase in the inten-

sity and frequency of El-Niño events that can affect drought and/or floods in many parts of the southern hemisphere; and a decline in Arctic sea-ice extent, particularly in spring and summer with about a 40% decrease in the average thickness of summer Arctic sea ice over the last three decades of the 20th century (IPCC 2001c).

The IPCC has also made some projections of future changes in CO_2 concentrations, temperature, precipitation, and sea-level rise based on several new greenhouse gas emission scenarios that are based on narrative storylines. All the scenarios are plausible and internally consistent, but have not been assigned probabilities of occurrence. Each scenario has its own greenhouse gas emission trajectories and combines different degrees of demographic change, social and economic development, and broad economic developments.

The impacts of climate change on wetlands will come from "alterations in hydrological regimes, including the frequency and severity of extreme events; increased temperature and altered evapotranspiration rates, altered biogeochemistry, etc. (IPCC 1998; Burkett and Kusler 2000; USGCRP 2000)." The report provides a summary of the projected impacts, which are replicated in Table 6.

The major impacts to inland waters described by the IPCC include warming of rivers, which in turn can affect chemical and biological processes, reduce the amount of ice cover, reduce the amount of dissolved oxygen in deep waters, alter the mixing regimes, and affect the growth rates, reproduction and distribution of organisms and species (Gitay et al. 2001). Species in small rivers and lakes are thought to be more susceptible to changes in temperature and precipitation than those in large rivers and lakes.

Predictions forecast that fish species distribution will move towards the poles, with cold water fish being further restricted in their range, and cool and warm water fish expanding in range. Aquatic insects, on the other hand will be less likely restricted given their aerial life stages. Less mobile aquatic species, such as some fish and molluscs, are predicted to be more at risk because of their presumed inability to keep pace with the rate of change in freshwater habitats (Gitay et al. 2001).

It is also predicted that with warmer weather conditions, the establishment of invasive species will be facilitated. At high latitudes warming is expected to increase biological productivity whereas at low latitudes the boundaries between cold and cool-water species may change and possibly lead to extinctions (IPCC 1996). The effects of climate change on nutrient cycling and water quality are uncertain, although it is apparent that they will be influenced (van Dam et al. 2002).

Sea level rise may affect a range of freshwater wetlands in low-lying regions of the world. For example, in tropical regions, low lying floodplains and associated swamps could be displaced by salt water habitats due to the combined actions of sea level rise, more intense monsoonal rains, and larger tidal/storm surges (Bayliss et al. 1997 as cited in Ramsar COP8-DOC 11). Such changes will result in dislocation if not displacement of many wetland plant and animal species. Plant species not tolerant to increased salinity or inundation could be eliminated whilst salt-tolerant mangrove species could expand from nearby coastal habitats. Migratory and resident animals, such as birds and fish, may lose importantresting, feeding and breeding grounds.

Climate change may also affect the wetland carbon sink, although the direction of the effect is uncertain due to the number of climate-related contributing factors and the range of possible responses. Any major change to the hydrology and vegetative community of a wetland will have the potential to affect the carbon sink. The impact of water level draw-down in northern latitude peatlands has been well studied and is thought to provide some insight for climate change impacts. Vegetation changes associated with the water draw-down in northern latitudes, for example, resulted in increased primary production, biomass, and slower decomposition of litter, which made the net carbon accumulation rate to remain unchanged or

even increase. However, other aspects of climate change, such as longer and more frequent droughts, and thawing of permafrost will most likely have negative effects on the peat carbon balance. In addition, human activities, such as agriculture and forestry will also continue to transform wetlands and reduce overall wetland area, potentially resulting in losses of stored carbon.

Finally, the combined effect of climate change and human-induced alterations to freshwater systems has not been studied in detail. It may be expected that changes in available water supply may lead to the construction of more dams and canals, which in turn will impact the habitats and species in those systems.

The extent of biodiversity loss or dislocation from inland water habitats will be difficult to discern from other existing pressures. However, it can be assumed that large-scale changes to these habitats will result in changes of species composition.

Table 6. Projected Impacts in Some Key Wetland Systems and Water Resources under Temperature and Precipitation Changes (based on IPCC new emission scenarios and modified in Ramsar COP8-DOC.11, from IPCC 2001c)

Indicators	2025	2100
Coastal wetlands and shorelines	Loss of some coastal wetlands to sea level rise Increased erosion of shorelines	More extensive loss of coastal wetlands Further erosion of shorelines
Ice environments	Retreat of glaciers, decreased sea ice extent, thawing of some permafrost, longer ice free seasons on rivers and lakes	Extensive Arctic sea ice reduction, benefiting shipping but harming wildlife (e.g. seals, polar bears, walrus) Ground subsidence leading to changes in some ecosystems Substantial loss of ice volume from glaciers, particularly tropical glaciers
Water supply	Peak river flow shifts from spring toward winter in basins where snowfall is an important source of water	Water supply decreased in many water-stressed countries, increased in some other water-stressed countries
Water quality	Water quality degraded by higher temperatures Water quality changes modified by changes in water flow volume Increase in salt-water intrusion into coastal aquifers due to sea level rise.	Water quality effects amplified
Water demand	Water demand for irrigation will respond to changes in climate; higher temperatures will tend to increase demand	Water demand effects amplified.
Floods and droughts	Increased flood damage due to more intense precipitation events Increased drought frequency	Flood damage several fold higher than “no climate change scenarios” Further increase in drought events and their impacts

Source: Ramsar COP-8-DOC 11

Vegetation zones and species will change in response to temperature and inundation patterns, however, the extent of such change is unknown. White et al. (1999) predict that boreal forests in Asia will extend northwards into the tundra, and also southwards. Similarly, fish migrations will be affected by both temperature and flow patterns.

The most apparent faunal changes will possibly occur with migratory and nomadic bird species that use a network of wetland habitats across or within continents. The cross-continental migration of many birds is at risk of being disrupted by changes in habitats (see references in Walther et al. 2002). Further, disruption of rainfall and flooding patterns across large areas of arid land will adversely affect bird species that rely on a network of wetlands and lakes that are alternately or even episodically wet and fresh or dry and saline (Roshier et al. 2001) such as those used by the banded stilt (*Cladorhynchus leucocephalus*) which breeds opportunistically in Australia's arid interior (Williams 1998). Responses to these climate induced changes may also be affected by adaptation and mitigation actions that cause further fragmentation of habitats or disruption or loss of migration corridors, or even, changes to other biota, such as increased exposure to predators by wading birds (Butler and Vennesland 2000).

3. REVIEW OF INLAND WATER SPECIES RICHNESS, DISTRIBUTION AND CONSERVATION STATUS

This section reviews the distribution, richness and conservation status of freshwater-dependent taxa from aquatic plants and insects to higher taxa such as birds and mammals. It does not cover microorganisms.

3.1 AQUATIC PLANTS

The definition of aquatic plants or hydrophytes has been debated for decades. In general, "all plants that tolerate or require flooding for a minimum duration of saturation/inundation are considered wetland plants" (Gopal and Junk 2000). An aquatic plant can usually be found growing in association with standing water including ponds, shallow lakes, marshes, ditches, reservoirs, swamps, bogs, canals, and sewage lagoons. Less frequently, they occur in the flowing water of streams, rivers, and springs (Hebert 2002). This section synthesizes information on plant taxa that includes a large number of better-defined aquatic species, and does not attempt to establish a new definition for what constitutes an aquatic plant.

Aquatic macrophytes include angiosperms (flowering plants), pterophytes (pteridophytes, ferns), and bryophytes (mosses, hornworts, and liverworts). Gymnosperms (conifers, cycads, and their allies) do not have strictly aquatic representatives (Cook 1990), but include a number of tree species that tolerate waterlogged soil, such as Bald Cypress (*Taxodium distichum*) which often dominates swamps in the southern U.S. (USFWS 1996). Macroaglae, such as some green and brown algae which are also considered aquatic macrophytes are not discussed here.

There are 87 families and 407 genera of aquatic vascular plants (Cook 1990). Of these it is estimated that up to 2% (or 250 species) of pterophytes (ferns and allies) and 1% (or 2,500 species) of angiosperms are aquatic (Groombridge and Jenkins 1998).

The geographic patterns of aquatic vascular plant diversity have not been summarized globally, however, a significant amount of information exist for regions where some aquatic plants are considered pests (University of Florida 2001). There are also a few studies, with limited geographic scope, that identify conditions that correlate with higher species richness or abundance (Bornette et al. 1998; Crow 1993; Zedler 2000).

3.1.1 Angiospermae (flowering plants)

Among angiosperms, 396 genera in 78 families are known to contain aquatic species (see Table 8). At the family level, 12% of dicotyledons and 35% of monocotyledons have aquatic species, indicating the widespread occurrence of aquatic species, especially in more advanced herbaceous groups (Cook 1990).

Families with a large number of aquatic species include: Alismataceae (water plantain), Araceae (arum family), Potamogetonaceae (pondweed), and Cyperaceae (sedge family) (Hebert 2002).

Geographic patterns of species diversity in aquatic angiosperms have been examined, in comparison to latitudinal distribution of terrestrial species diversity, using the information compiled from literature covering North and Central America (Crow 1993). There are some families that show highest diversity at tropical latitudes, including Podostemaceae (river weed), Hydrocharitaceae (frog-bits), Limnocharitaceae (water poppies), Mayacaceae (bogmoss), Xyridaceae (yellow-eyed

Table 7. Number of Aquatic Families in Major Angiosperm Groups

	Aquatic	Non-aquatic	Total
Dicotyledons	44	319	363
Monocotyledons	34	63	97
Total	78	382	460

Source: modified from Cook 1990.

grass), while Potamogetonaceae (pond weeds), Juncaginaceae (arrow grass), Sparganiaceae (bur-reed), Haloragaceae (water milfoil), and Elatinaceae (waterwort) show higher diversity in temperate regions. Crow concludes that in the case of aquatic angiosperms, the typical latitudinal gradient in terrestrial species diversity does not apply.

The conservation status of aquatic angiosperms has not been comprehensively assessed. The *1997 Red List of Threatened Plants* (Walter and Gillett 1998) listed the percentage of threatened species for over 300 families. Among them are a few aquatic plant families: 10 out of 75 Alismataceae species are considered threatened; 280 out of 4000 Cyperaceae; 1 out of 6 Ceratophyllaceae (water lilies); 14 out of 100 Hydrocharitaceae; 3 out of 31 Lemnaceae; 3 out of 10 Limnocharitaceae; and 4 out of 50 species of Nymphaceae (water lilies) are considered threatened. Since then, the Red List criteria have been revised; however only a limited number of plants have been assessed with these criteria. The 2002 IUCN Red List only lists 4 species as critically endangered, endangered, or vulnerable: *Achyranthes talbotii*, *Angraecopsis cryptantha*, *Ledermaniella keayi*, and *Saxicolella marginalis.* All of them are found in Cameroon (IUCN 2002).

3.1.2 Ferns

There are about 11,000 species of ferns and fern allies, of which about 75% occur in the tropics (Hebert 2002). Among the Pterophyta there are 11 genera from 9 families that contain aquatic species, of which Azollaceae (mosquito fern), Marsiliaceae (pepperworts), and Salviniaceae (water ferns) are exclusively aquatic (Cook 1990).

3.1.3 Bryophytes

A conservative estimate is that bryophytes (mosses, hornworts, and liverworts) comprise a group of 14,000-15,000 species, of which 8,000 are mosses, 6,000 liverworts, and 200 hornworts (Hallingbäck and Hodgetts 2000). Among the three classes of moss, peat mosses such as the order *Sphagnales*, are ecologically important in bogs, where they form large, floating mats over water. Liverworts grow in a variety of moist environments, including swamps and bogs, with a few species being found floating or submerged in water (Hebert 2002). Truly aquatic liverworts can be found on the surface of eutrophic lakes, including at least 16 species of Riellaceae. These are characteristic of temporary waters of semi-arid regions (Groombridge and Jenkins 2000). Although bryophytes occur almost throughout the world, some areas are recognized as being particularly rich in these species. The maximum diversity is found in highly oceanic regions, where cool or temperate and consistently moist climate conditions persisted over geological time (Groombridge 1992). Many of the bryophytes found in lowland aquatic environments, including pools and reservoirs, are rare and threatened, with a very restricted distribution. Important areas of lowland bogs, for example, occur in Tierra del Fuego in Argentina, northern Scotland, and Ireland (Hallingbäck and Hodgetts 2000).

There are 10 freshwater bryophytes listed in the IUCN Red List (IUCN 2002) as critically endangered, endangered, or vulnerable. These include critically endangered species of tropical lowland riverine systems such as *Fissidens hydropogon* (Ecuador), *Ochyraea tatrensis (Slovakia), Pinnatella limbata* (India), and *Thamnobryum angustifolium* (U.K.).

3.2 FUNGI

There are over 100,000 species of described fungi and probably over 200,000 still to be described. Most fungi are terrestrial, but they can be found in wide range of habitats, including marine and freshwater environments. There are four major groups of fungi that contain aquatic species: *Zygomycota* (true fungi), *Ascomycota* (sac fungi), *Basidiomycota* (club fungi), and *Deuteromycota* (fungi imperfecti). Aquatic ascomycetes are predominantly found on submerged wood, but others are free floating or found on sediments and algae (Hebert 2002).

An overview on the diversity of freshwater fungi is provided in Goh and Hyde (1996). Although considered to be a small fraction of all the existing species, over 600 species of freshwater fungi are currently known, including close to 340 ascomycetes of which 50 occur in the tropics. The rest are comprised by 300 hyphomycetes species the majority of which are found in cold and temperate regions. These estimates, however, are based on a limited number of detailed studies from North Queensland (Australia), one lake in Austria, Illinois (U.S.), and the Lake District and Devon (U.K.). Recent studies indicate that there are many more freshwater fungi to be discovered in temperate and tropical regions. Freshwater hyphomycetes in particular are known to have global distribution and many taxa are being discovered at a rapid rate (Goh and Hyde 1996). The total estimate of freshwater fungi species ranges from 1,000 to 10,000 (Palmer et al. 1997).

Around 20% of all fungi form lichens, a symbiotic association of a fungus and a photosynthetic organism, and 40% of lichenized fungi belong to the ascomycetes group, which produce spores in sac-shaped cells (Purvis 2000). There are about 25,000 lichen species known capable of living in extremely harsh environmental conditions. The number of aquatic lichens is limited and they typically live in the intertidal zone along seashores or in shallow streams (Hebert 2002).

No comprehensive global list of lichens exists (Purvis 2000). An Internet-based global checklist of lichens and lichenicolous fungi is currently being compiled, including more than 120 checklists for Africa, South America, Australia and many countries of Asia, North and Central America. Checklists of continental Africa and South America were scheduled to be available in 2002, completion of the global list is foreseen in 2003 (Feuerer 2002).

3.3 AQUATIC INSECTS

Insect orders that are entirely aquatic or include aquatic species are: *Odonata* (dragonflies and damselflies), *Plecoptera* (stoneflies), *Trichoptera* (caddice flies), *Ephemeroptera* (mayflies), *Megaloptera* (alderflies, dobsonflies, fishflies), *Coleoptera* (beetles), *Diptera* (two-winged, or true flies), *Collembola* (springtails), *Hemiptera* (true bugs), and *Neuroptera* (spongillaflies) (Mandaville 1999). Almost all these species can fly, so their distribution is not strictly confined to water bodies. For example, the distribution range of dragonflies goes beyond a river basin or aquatic area (Banarescu 1990). Although no major extinction crisis of aquatic insects has been reported so far, many groups are threatened by a number of factors. Physical alteration and habitat destruction due to impoundments is considered the greatest threat to rare aquatic insects, followed by water pollution and siltation that result from loss of vegetative cover in areas surrounding the water bodies. In some areas, the introduction of alien fish species that act as predators is also considered a major threat (Polhemus 1993).

The conservation status of aquatic insects has not been comprehensively assessed, except for dragonflies in some regions. The 2002 IUCN Red List reports 127 freshwater species of insects as critically endangered, endangered, or vulnerable. Of these, 17 species are beetles, one species is a mayfly, 2 are stone flies, and 107 are dragonflies. In addition 15 species from the beetle, dragonfly, damselfly, mayfly, and caddisfly groups are considered to have gone extinct. The number of threatened insect species represents a very small fraction of the total number of known aquatic insects. Many species have not been assessed and many others are believed to face local extinctions. The British Red Data Book, for example, lists 133 aquatic insect taxa as rare, endangered, or vulnerable; while the U.S. Federal Register under the Endangered Species Act lists 204 species as threatened (Polhemus 1993).

Except for certain well-studied regions, e.g. Europe (Illies, 1978), the implementation of existing laws to protect aquatic insects is limited because of the lack of precise information on species ecology and distribution. The situation is even worse in the tropics, where assessing the level of threat to aquatic insects is complicated further by the num-

bers of undescribed species and the absence of comprehensive surveys (Polhemus 1993). Access to taxonomic data and surveys is limited by the fact that these are often published in the local language and for national reports.

3.3.1 Odonata (dragonflies and damselflies)

The taxonomy of dragonflies and damselflies is relatively well known among the aquatic insects. Around 5,500 species are described globally, and endemism tends to correspond to topography rather than river basin. More species remain to be discovered especially in tropical South America and Southeast Asia, and it is estimated that the total number of species is over 9,000 (Moore 1997). The order Odonata has been widely considered as a biological indicator of environmental health, and even an indicator of vascular plant richness (Nixon et al. 2001; Sahlén and Ekestubbe 2001).

Comprehensive checklists of dragonflies exist (Davies and Tobin 1984 and 1985; Tsuda 1991). Tsuda's work also provides information on the distribution range of the species. The most comprehensive and current global list of all recognized Odonata species, based on previously published checklists and literature, includes over 5,500 species (Schorr et al. 2002a and 2002b). In addition there are a number of other checklists and databases scattered across different geographic regions and taxonomical groups (International Odonata Research Institute 2002). Systematic mapping of species distribution range has been done in many countries, mostly in Europe, with varying degree of accuracy. However, the knowledge of tropical species is confined to anecdotal reports (Moore 1997).

Although some sampling bias exists, general areas of high diversity can be identified. Based on country-level species lists, tropical countries support the highest biodiversity of dragonflies. The western Amazon Basin and Southeast Asia are, as in so many other species groups, the regions of highest odonate diversity. Mexico, Central America, and the large islands of Indonesia and Malaysia also support high diversity, while northern Queensland and West Africa support moderately high levels of odonate diversity. The eastern United States is another region of relatively high odonate diversity, paralleling diversity in numerous other freshwater groups (Paulson pers. comm. 2002). In addition to these species-rich areas, main centres of endemism include Madagascar, the mountains of Central Africa, the mountains of Myanmar, the Ryukyu Islands of Japan, New Caledonia, and Hawaii (Moore 1997).

Enough knowledge on species distribution to set conservation priorities exists in a few countries in Europe and North America and in Japan and New Zealand. The information on odonates in Australia, India, and South Africa is fragmented (Moore 1997). On the other hand, there is little information as to specific localities with prominent diversity within the tropics. Among the few known localities of high odonate diversity in the tropics are southern Peru and the foothills of the Andes in Ecuador and Peru. Poorly sampled or under-sampled areas are Colombia, Bolivia, large parts of China, and insular Southeast Asia (Paulson pers. comm. 2002).

Of the 107 threatened Odonata species listed in the IUCN Red List, 13 are classified as critically endangered, 55 as endangered, and 39 as vulnerable to extinction. In terms of the geographic distribution of threatened odonates, 27 are reported in North America, 3 in the Caribbean, 20 in Central America, 2 in Brazil, 6 in Europe (incl. former Soviet Union), 6 in West and Central Asia, 18 in Japan, 3 in North Africa, 19 in Sub-Saharan Africa, and 4 in Australia (IUCN 2002).

3.3.2 Coleoptera (beetles)

Of the more than one million described species of insect, at least one-third are beetles, making the Coleoptera the most diverse order of living organisms. Only 10% of the 350,000 described species of beetles are aquatic. There are at least 14 families that

are either entirely or partially aquatic (Mandaville 1999). Of these, the Hydraenidae family (moss beetles) has 1,200 species, the Hydrophilidae (water scavenger beetles) has 2,800 species, and the Dytiscidae (predaceous diving beetles) have 3950 species, and better known than other groups among aquatic Coleoptera. World catalogs for these groups were recently published (Hansen 1998 and 1999; Nilsson 2001 and 2002). Aquatic beetles are found in a variety of habitats and exhibit diverse adaptations to environments including some that even tolerate saline habitats.

Hydraenidae are found in matted vegetation along streams or decaying moss near the shore and swampy places, and have predacious larval stages. Most species of Hydrophilidae are aquatic both as adult and larvae. Although adults are principally scavengers, larvae feed on a variety of aquatic animals. Members of the large group Dytiscidae are found in ponds, lakes, and streams. Both adults and lavae are predators, feeding on a variety of aquatic animals including small fish (Borror and White 1970).

There are many more species to be identified, even within these better-known groups: for example, recent expeditions to China and New Guinea for the sampling of Dytiscidae species have provided many new species, and South America is considered as having a great potantial for producing many more. Modern taxonomical revision of most larger beetle genera in South America would be required (Nilsson pers. comm. 2002).

The status of known species has not been comprehensively assessed. The 17 threatened aquatic beetles listed in the IUCN Red List are almost entirely Dytiscidae species in Europe (IUCN 2002).

3.3.3 Diptera (flies, mosquitoes, and midges)

The Diptera is one of the largest groups of organisms, estimated to contain about 200,000 species worldwide, 120,000 of which have been described so far (Wiegmann and Yeates 1996). Approximately 10% of all dipteran species are aquatic in their egg, larval, and pupae stages. Aquatic dipterans represent some of the best-known insect groups, because many species are particularly important as vectors of human, plant, and livestock diseases. Diptera also play an important role in aquatic environments, including as food for many predators. They are also good indicators of aquatic environmental conditions because, in comparison with other aquatic insects, they are more widely distributed across a range of habitat types and conditions (Mason et al. 1995). Some 32 families contain species whose larvae are either aquatic or semiaquatic, including Chironomidae (midges), Culicidae (mosquitoes), Tipulidae (crane flies), Simuliidae (black flies), and Chaoboridae (phantom midges) (Mandaville 1999). A global database of Diptera is currently being developed (Thompson 2000).

3.3.4 Ephemeroptera (mayflies)

Some aquatic fly groups (Plecoptera, Ephemeroptera, Trichoptera, Megaloptera) are commonly used as biological indicators of stream water quality. These groups express relatively less tolerance to degradation in water quality, such as lowered dissolved oxygen level (USEPA 2001; DeShon 1995). Due to the taxonomic difficulties, the orders Plecoptera and Ephemeroptera are poorly sampled, particularly in the tropics although stone fly distribution is rather restricted to temperate zones and less diverse in the tropics (Miller pers. comm).

There are about 2,000 species of mayflies, most of them associated with running water. The taxonomy of the immature stages is poorly known because the naiads of many species have not yet been associated with adult forms. The order has a cosmopolitan distribution but is absent from the Arctic and Antarctic. They are also absent from oceanic islands, with the exception of New Zealand (Mandaville 1999). The Ephemeroptera is a primitive order, with many families having wide ranges and others having more restricted ones (Banarescu 1990). Checklists for known species are

available for a number of countries (Ephemeroptera Galactica 2001).

3.3.5 Plecoptera (stoneflies)

There are about 1,718 species of stoneflies representing 15 families. The taxonomy of this order, like that of the Ephemeroptera, is poorly known because the naiads of many species have not been associated with adults. Most naiads are restricted to lotic systems of relatively high oxygen concentrations, but some species may be found along the wave-swept shores of large oligotrophic lakes. The high water-quality requirements of naiads make them effective biological indicators of environmental degradation (Mandaville 1999). The Plecoptera are a rather primitive order of insects, with confined distribution to water bodies which makes them biogeographically very significant (Banarescu 1990). The threatened mayflies and stoneflies in the IUCN Red List are all reported from Australia (IUCN 2002)

3.3.6 Trichoptera (caddis flies)

About 10,000 species of caddis flies have been described, but it has been estimated that this group may contain as many as 50,000 species (Holzenthal and Blahnik 1997). Caddis flies have a global distribution and inhabit a wide range of habitats from cool to warm streams, permanent lakes and marshes, and temporary ponds. Although the larvae are found in a wide range of aquatic habitats, the greatest diversity occurs in cool running waters. Among the families represented in both lotic and lentic habitats, the genera exhibiting more ancestral characters tend to be found in cool streams whereas those showing more derived characters tend to occur in warm, lentic waters (Mandaville 1999). This group of species has a large range of pollution tolerance (USEPA 2001). A searchable world checklist exists and is maintained by a group of scientists under the successive International Symposia on Trichoptera (Trichoptera Checklist Coordinating Committee 2002). The database lists 951 records in the Afrotropical bioregion, 1,157 in the Australasian, 1,248 in the eastern Palearctic, 1,558 in the Nearctic, 2,121 in the Neotropical realm, 3,754 in the orient, and 1,807 in the western Palearctic region.

3.3.7 Megaloptera (alderflies)

The Megaloptera consists of about 300 extant species worldwide. The larvae of all Megaloptera species are aquatic and attain the largest size of all aquatic insects. Although they occur throughout most of the world, except for much of Africa, alderflies are very difficult to find in tropical climates and life histories of species in temperate zone are better known (Contreras-Ramos 1997). They express general intolerance to pollution (USEPA 2001).

3.3.8 Heteroptera (bugs)

Among the order Hemiptera, the sub-order Heteroptera, with a total 38,000 species, contains about 3,200 species of hydrophilic insects, representing 15 families worldwide. Hemipterans are generally found in lentic habitats or in backwater or pool areas of streams (Mandaville 1999). Common aquatic families include Corixidae (water boatman), Notonectidae (backswimmers), Nepidae (water scorpions), Belostomatidae (giant water bugs), and Naucoridae (creeping waterbugs) all of which are primarily predaceous. Other groups that are not aquatic in a strict sense but live on the water surface include Gerridae (water striders) and Veriidae (ripple bugs) (Borror and White 1970).

3.4 WATER MITES

Species of *Hydrachnidia* are common in such lentic waters as swamps, marshes, ponds, and the littoral and profundal zones of lakes. They are often associated with vegetation or with the top few millimetres of substrate, but they can also lead a planktonic existence. Water mites are common, too, in the ero-

sional and depositional zones of rivers, and the air-water interface at the margins of various water bodies. Some species are adapted to live in such extreme environments as thermal springs, glacial meltwater rivers, temporary pools, waterfalls, and in groundwater buried within gravel banks of streams (interstitial habitats). A few species can inhabit oceans and inland saline waters, although most are limited to freshwater.

Water mites are among the most abundant and diverse benthic arthropods in many habitats. One square metre of substratum from littoral weed beds in eutrophic lakes may contain as many as 2,000 deutonymphs and adults representing up to 75 species in 25 or more genera (Smith and Cook 1991). Comparable samples from an equivalent area of substratum in rocky riffles of streams often yield over 5,000 individuals of more than 50 species in over 30 genera (including both benthic and hyporheic forms). Mites have coevolved with some of the dominant insect groups in freshwater ecosystems, especially nematocerous *Diptera*, and interact intimately with these insects at all stages of their life histories.

Species of water mites are specialized to exploit narrow ranges of physical and chemical regimes, as well as the particular biologic attributes of the organisms they parasitize and prey upon. Preliminary studies of physicochemical and pollution ecology of the relatively well-known fauna of Europe have demonstrated that water mites are excellent indicators of habitat quality. The results of these studies, along with observations in sampling a wide variety of habitats in North America and elsewhere, lead to the conclusion that water mite diversity is dramatically reduced in habitats that have been degraded by chemical pollution or physical disturbance (Smith and Cook 1991).

3.5 FRESHWATER MOLLUSCS

Information on species diversity is fragmentary. There are a few global overviews of a particular taxon, or freshwater habitat, as well as regional overviews of a particular river or lake system (Cushing et al. 1995; Gopal et al. 2000; Mitsch 1994; Taub 1984). However, these studies are largely descriptive and focus on hydrographics or biomass, rather than provide information on where high species richness and endemism actually occur, and how one region compares to another in terms of their species diversity. A significant amount of research is also devoted to identifying the conditions within each ecosystem that correlate with higher species diversity or abundance rather than identifying specific areas of high species diversity and abundance. (Bornette et al. 1998; Crow 1993; Dillon 2000; Milner et al. 2001; Miserendino 2001; Zedler 2000)

The following section (on molluscs) summarizes existing information on the relatively better-known taxa. Because of the lack of published global overviews, the descriptio relies heavily on expert knowledge.

Molluscs are some of the most ancient animals that inhabit the earth. Their appearance in prehistoric deposits dates from 500 million years ago. During this historical period, molluscs have undergone waves of extinctions, however, today the rate of extinction affecting freshwater molluscs is much faster than previously experienced. The main reasons for this rapid extinction rate is that molluscs are extremely vulnerable to habitat degradation, over-exploitation, and predation by alien species, all pressures that currently and in recent history have affected freshwater ecosystems worldwide. More than half the freshwater molluscan families in North American, for example, are currently extinct or listed as endangered (Kay 1995).

Freshwater molluscs are an integral part of the rich invertebrate phylum mollusca. Brusca and Brusca (1990) present 8 classes of molluscs, of which only two Gastropoda and Bivalvia (or Pelecypoda) contain freshwater species. The approximate numbers of living species, including marine, terrestrial, and freshwater molluscs in these two classes, are 40,000 and 8,000 respectively. The estimated total number of molluscs ranges from 80,000 to 135,000 species (Seddon 2000). There are around

6,000 known species of gastropods and bivalves that live in freshwater habitats. Freshwater bivalves include animals such as clams and mussels, while freshwater gastropods include snails and slugs.

Freshwater molluscs are found all over the world except for Polar Regions, high altitudes and some remote islands. The global species inventory is far from complete, with new species regularly added and described from all regions, including those more thoroughly studied like Europe, the U.S., Japan, and Australia (Hilton-Taylor 2000). The most well studied group is the freshwater mussels with more than 250 species and 47 genera described to date (Kay 1995). Some ancient lakes contain highly diverse and endemic freshwater mussel fauna. For example, it is estimated that Lake Biwa in Japan has 73% of the freshwater mussel species of the country, of which 43% are endemic (Kay 1995). Other spectacular lakes for freshwater mussel endemism are Lake Baikal, Tanganyka and Titicaca (Bos 1979).

There are many lists on freshwater molluscs at national and regional levels, such as those available on the internet (e.g. http://species.enviroweb.org/omull.html; and http://www.worldwideconchology.com/DatabaseWindow.html). These databases, however, are not standardized or comparable; therefore an assessment of the current status and trends of freshwater molluscs at the global level is difficult. Existing lists are also biased towards terrestrial and marine groups.

In terms of the distribution pattern of this group, UNEP-WCMC identified "important areas for freshwater biodiversity" based on existing information and expert consultation, and highlighted 27 known areas of special importance for freshwater mollusc diversity worldwide (Groombridge and Jenkins 1998; CBD 2001). The identified areas comprise a variety of habitats from ancient lakes (Tanganyika, Victoria, Malawi, Biwa, Baikal, Ohrid, Titicaca), to lower river basins (Congo, Volta, Mekong, and La Plata), and springs and underground aquifers (e.g., in Australia, New Caledonia, the Balkans, western US, Florida, and Cuatro Cienegas basin in Mexico). One characteristic of mollusc diversity is that endemism at species level tends to occur within a river basin and, as more detailed data for the U.S. show, species diversity correlates highly with fish species diversity (Bogan pers. comm. 2002)

Assessments of the status of known species have been conducted for a limited number of taxa and regions and the results provide an overview of the threats that this group of animals is facing. The IUCN Red List lists 332 freshwater species of gastropods that are either critically endangered, endangered, or vulnerable, representing over 40% of all gastropods threatened (including terrestrial groups) (IUCN 2002). Springs-inhabiting snails are the most threatened with the numbers of endangered species increasing from 12 to 19% of all threatened molluscs since the 1996 Red List assessment. Of the threatened gastropods, 111 species were reported from the U.S., 81 from Australia, 76 from Sub-Saharan Africa, 53 from Europe, and 5 from Central America. On the other hand, 88 bivalves were listed under these categories with most of them reported from North America (IUCN 2002).

The IUCN Red List also confirmed the extinction of a large number of molluscan species in the eastern U.S. that were previously suspected extinct but were placed under Critically Endangered because of insufficient information. The change in the Table 8 below, therefore, reflects an improvement in the quality of the data rather than a change in the conservation status of these groups.

The alarming rate of extinction of freshwater molluscs in eastern North America deserves special attention. According to the U.S. Federal Register over 30% of freshwater bivalves and 9% of gastropods in the U.S. are threatened, endangered, or extinct (McAllister et al. 2000). Less than 25% of the present freshwater bivalves appear to have stable populations. A number of these endangered species are "functionally-extinct," meaning that individuals of a species are surviving but not reproducing (Bogan 1993). The status of gastropods is

much less known. Of 42 species of extinct gastropods in the U.S., 38 were reported from the Mobile Bay Basin (Bogan 1997).

3.5.1 Bivalvia or Pelecypoda (bivalves)

The taxonomic nomenclature of bivalves is being revised as knowledge on the group improves, and there is currently no scheme that is universally agreed upon. Thus the number and categorization of groups and species used in the descriptions below should be treated with caution. There are two orders that contain most of the freshwater species: Unionoida and Veneroida. The Unionoida are known as pearly freshwater mussels and have 6 representative families that are all restricted to freshwater. The larvae of Unionoida have a parasitic stage to fish, making them sensitive to disturbances of the freshwater ecosystems. Without the host fish the unionoid species is unable to complete its life cycle and faces extinction (Bogan 1993). There are about 165 recognized unionoid genera (Bogan 1993). Of the 6 families, the largest one is the Unionidae, which, along with the Margaritiferidae, are the best-known families with worldwide distribution (Dillon 2000). There are other primarily marine families that include some fresh/brackish water species, but they are poorly known and thus not discussed here.

The small Margaritiferidae family is considered the most primitive of the group and has a holarctic but discontinuous distribution. There are seven recognized species, currently divided into two genera: Margaritifera and Cumberlandia. Species in the genus Margaritifera are found in Eastern Canada and New England, Northern Europe, Asia, Northwestern North America, Southern U.S. (Louisiana and Alabama), Amur basin and Russian Maritime Territory, Kamchatka, Sakhalin rivers, and the Iberian Peninsula.

The Unionidae on the other hand is a large family with worldwide distribution. This group is most diverse in eastern and central North America, and followed by China and Southeast Asia. The group includes North America's most abundant, interesting, and economically valuable shells. Because of their long association with activities of leisure, livelihood, and trade, many have acquired colorful common names. There are about 90 currently recognized genera in the Unionidae. The North American fauna north of Mexico is composed of 278 species and 13 recognized subspecies in 49 genera (Bogan pers. comm.). There are also four subfamilies with a total of 16 genera that are wholly distributed outside North America and found in east and Southeast Asia, India, Afghanistan, Europe, and Africa.

Historically, mussels were used as food by native peoples. In the late nineteenth and early twentieth centuries harvesting for the purpose of making buttons for clothing increased considerably. With the advent of plastics in the 1940s and 50s, this industry came to an end, with the last plant closing in the mid 1960s (Williams and Neves 1995). Soon afterwards unionid mussels came to be used as the nuclei in cultured pearls cultivated in Japan, and it is now estimated that 95% of the world's round cultured pearls contain nuclei from American freshwater mussels. More recently, some of the freshwater mussels themselves have been used for pearl production using modifications of the Japanese techniques.

Table 8. Freshwater Molluscs in the IUCN Red List in 1996 and 2000

	Extinct		CR, EN, VU		Data Deficient	
	1996	2000	1996	2000	1996	2000
Bivalves	12	34	117	96	4	6
Gastropods	14	57	340	340	104	90

Source: McAllister et al. 2000; Hilton-Taylor 2000.

The distribution of species belonging to the other four unionoid families are: Hyriidae—presently with a disjunct distribution in South America, Australia, New Guinea, and New Zealand, with fossils are also known from North America; Mycetopodidae—found in tropical and partly temperate South America through Central America to the central west coast of Mexico; Iridinidae (incl. Mutelidae)—found in tropical Africa and the Nile basin; Etheriidae or river oysters—which include three or four genera, distributed disjunctively in tropical Africa including the Nile, northwestern Madagascar, in the Rio Magdalena drainage in Columbia, the headwaters of the Amazon and in Paraguay, and in southern India, (Banarescu 1990; Bogan pers. comm. 2002).

The Hyriidae found in Australia and the Neotropics are less studied, while Mycetopodidae in the Neotropics and Ethiopian Etheriidae and Mutelidae "remain rather obscure" (Dillon 2000).

North America, including the Rio Grande, by far contains the richest freshwater bivalve diversity in the world—5 Margaritiferidae and 292 Unionidae. Asia, China and South Asia have a high diversity of unionacean mussels second only to east and central North America. There are 38 species described for China, and 54 for Pakistan, India, Sri Lanka, Bangladesh, and Myanmar combined. The freshwater bivalves in Africa include 55 species in 4 families, 28 Mutelidae, 26 Unionidae, 1 Etheriidae, and 1 Margaritiferidae. In Australia there are 17 Hyriidae. Russia and Europe are not particularly species-rich in unionaceans, with only 2 Margaritiferidae and 8 Unionidae documented (Bogan 1993).

Another order of freshwater bivalves is the Veneroida with 3 families: Sphaeriidae, Corbiculidae, and Dreissenidae. The first group is large, and commonly known as pill clams and fingernail clams. This is strictly a freshwater family with worldwide distribution, although all species and most genera have restricted ranges. They inhabit ponds, swamps, and creeks. Within this family there are approximately 75 North American species, but they are also found in Europe, Asia, Africa, and South America. The second group are known as basket clams, and they are widespread and of moderate size, often tinged or colored with violet in their interior. There are 12 genera, including several from brackish waters mostly found in Asia, although some have become invasive in North America, and can also be found in Africa, South and Central America, and Australia (Banarescu, 1990). Finally the third family, the Dreissenidae, is a much less diverse group. Members of this family, including quagga mussels and zebra mussels, are found in both fresh and brackish waters of the Atlantic coast, the Caspian, Black, and Aral Seas and the rivers draining into them, as well as in the Tigris and Euphrates Basin. The notorious zebra mussel, *Dreissena polymorpha* from the Ponto-Caspian and the Aral Sea basins, is now found in North America and Europe where it is causing serious and expensive damage to native species and infrastructure particularly in the Great Lakes region in North America.

3.5.2 Gastropoda (gastropods)

There are about 4,000 freshwater gastropod or snail species known worldwide, found in a variety of habitats including streams, ponds, marshes, and lakes. The knowledge on the geographic pattern of gastropod diversity at the global scale is limited. The U.S., Australia, and Europe are the better-sampled regions but data are still fragmented. Southeast Asia and Latin America are poorly sampled, except for some valuable medicinal species (Seddon pers. comm. 2002).

North America contains 601 freshwater gastropods representing 14 families. Hydrobiidae is by far the most diverse family in this region with 228 species, followed by Pleuroceridae, 156 species. The highest diversity are recorded in Mobile Bay and Ohio-Tennessee rivers, with 118 (110 endemic) and 99 species, respectively.

Regional estimates are not available for the rest of the world. In Asia, only a few localities have estimated numbers of total species. For example, only

the lower 500 km of the Mekong river basin has been well-studied, and so far over 120 species are known—including 92 endemic species of Triculinae and 19 endemic species of Stenothyridae. Much work is required for the rest of tropical Asia. Much of the knowledge on molluscs in South America is still at checklist stage, and more investigations are needed especially at headwaters. Some estimates are available for Parana, Uruguay and La Plata, and Lake Titicaca. The gastropod diversity in Africa is generally not as rich as that of North America or the Mekong. However, East African lakes have relatively high gastropod diversity, especially Lake Tanganyika with 68 species. Another area with rich gastropod fauna is the Congo basin, with 96 species known only downstream of Kinshasa. In Russia, Lake Baikal contains by far the highest richness and endemicity of gastropods, with 147 species of which 114 are endemic (Seddon 2000).

Freshwater gastropods are classified into two subclasses, the Prosobranchia or gilled gastropods and the Pulmonata or lunged gastropods. There are 20 families of gilled gastropods and 7 families of lunged gastropods around the world (Mandaville 1999). The gilled gastropods are more numerous in terms of families and species than the freshwater mussels and tend to occur in large and ancient lakes in tropical regions (Banarescu 1990; Mandaville 1999). Most of these gastropod families have a worldwide distribution. For example, the family Neritidae, one of the most primitive within this group, is found primarily in fresh and brackish water in the tropics. Living species of the family Viviparidae are found throughout the world except South America and much of Oceania. Hydrobiidae is a large family with many genera and species whose taxonomy is still much debated among experts. Hydrobiids have a worldwide distribution and are characterized by their small to almost microscopic size. The Pomatiopsidae family is more abundant, particularly in Southeast and East Asia, but can also be found in India, North America, the upper Paraguay River, southern and western Australia, and southern Africa. Finally, the *Pleuroceridae* family is restricted to freshwater with a centre of diversity in eastern North America. Other families with more restricted ranges include:

- *Valvatidae:* restricted to the northern hemisphere, with southern limits at the Mexican Plateau, south of Sahara, northern India, and northern East Asia;
- *Melanopsidae:* with disjunct distribution confined to the eastern hemisphere;
- *Bithyniidae*: also restricted to the eastern hemisphere and with a center of diversity in Southeast Asia; and
- *Thiaridae* and *Ampullariidae:* which are strictly freshwater species with ranges encompassing the tropical and subtropical zones (Banarescu 1990; Dillon 2000).

The freshwater Pulmonata or lunged snails are best developed in ponds and in small to moderate-sized eutrophic lakes. These animals are of relatively recent origin and found in temperate regions. The systematics of Pulmonata are better known than that of the Prosobranchia, due to their parasitic importance (Banarescu 1990). There are four major freshwater families in this group the Lymnaeidae with a worldwide distribution, the Planorbidae, by far the largest family of aquatic pulmonates with also a global distribution, the Ancylidae (limpets) also worldwide, and the Physidae with a Holarctic distribution.

Gastropods can be used as an indicator of water quality. Considerable research has been done on the ecological and physiological tolerances and requirements of gastropods. Pulmonates tend to be more tolerant to eutrophication than prosobranchs because pulmonates can rise to the surface to obtain oxygen when the dissolved oxygen supply is depleted. Most physids are known to tolerate anoxia for a short period of time but they, like all gastropods, need water well saturated with oxygen for the proper development of their eggs. Similarly, many prosobranchs, like some pleurocerids and viviparids, can tolerate near-anoxia, but only for short periods of time (Mandaville 1999).

3.6 FRESHWATER CRUSTACEANS

There are about 40,000 living crustacean species, of which 10,000 are estimated to occur in freshwater sediment, with 8,000 of these described so far (Palmer et al. 1997). The orders that are almost entirely freshwater include: Anostraca or fairy shrimp and Cladocera or water fleas. Other orders that include freshwater species, although to a lesser degree, are the Amphipoda or side swimmers, the Copepoda and Decapoda (prawns, crayfish and crabs), and the Isopoda (Hebert 2002). Freshwater crustaceans also inhabit subterranean habitats such as caves. These species are usually amphipods and isopods that tend to have extremely restricted distributions—a single species being usually confined to one spring, one cave, or one cenote, and therefore are highly susceptible to extinction (Schotte pers. comm. 2002). IUCN reports 409 freshwater crustacean species as critically endangered, endangered, or vulnerable, including 69 Amphipoda, 8 Anomopoda, 25 Anostraca, 51 Calanoida, 168 Decapoda, 18 Harpacticoida, and 38 Isopoda (IUCN 2002). There are 8 recorded species that have gone extinct. With the exception of the United States, no other country or region has assessed the status of known inland water crustaceans comprehensively.

3.6.1 Amphipoda

Of 7,000 known species, 24% or about 1,700 amphipods species are known to occur in freshwater environments (Bousfield cited in McAllister et al. 1997). Freshwater amphipods can be found in a variety of habitats from shallow, densely vegetated areas, to deep sediments in lakes, sometimes at densities of 10,000 per square metre (Hebert 2002). In general, freshwater species are poorly sampled, and huge data gaps exist for Africa, Southeast Asia, and South America except for Lake Titicaca. In addition, many islands remain unexplored, even most of the Caribbean (Gable pers. comm. 2002).

Some groups are better known than others as exemplified by a database of subterranean amphipod families. This database describes about 900 species representing 35 families found in subterranean habitats, including many that are not freshwater. In addition, over 5,000 specimen records of subterranean amphipods are currently being entered into the database (Holsinger pers. comm. 2002). For some better-sampled groups patterns of distribution are known. For example, type localities for specimens of the family *Bogidiellidae*, which occur worldwide except for boreal, Arctic, and Antarctic regions, indicate an apparent concentration in the Mediterranean region, and to a lesser extent in Central America, South America, and the Caribbean region (Holsinger 2000; Koenemann pers. comm. 2002). Sampling gaps exist in Africa and Central and Eastern Asia (particularly, the Siberian far east and central western China), Middle East, especially in groundwater aquifers in deserts and very dry regions, and some parts of Australia (Koenemann pers. comm. 2002; Holsinger pers. comm. 2002).

3.6.2 Copepoda

Copepods are one of the largest groups of crustaceans with over 14,000 species described to date. These represent as little as 15% of the total number of species that actually exist. Copepods are found in both marine and freshwater systems, but are much more diverse in marine environments (Hebert 2002). They are widely distributed from freshwater to hyper-saline conditions, from the highest mountains to the deepest ocean trenches, and from the cold polar ice-water interface to the hot active hydrothermal vents.

The Smithsonian National Museum of Natural History maintains an on-line bibliographic and specimens database of copepod crustaceans containing over 5,000 records worldwide, including information on type localities (Smithsonian 2002). However, the collection has few African species. European museums on the other hand have a much

larger representation of specimens from Africa and the Japanese and Australian museums have stronger Asian collections (Walter pers. comm. 2002). The information from collections among different museums would have to be synthesized to get a better sense of copepod diversity worldwide.

3.6.3 Isopods

With approximately 10,000 described species, the order Isopoda is the second most diverse group of crustaceans. About 850 freshwater species are known worldwide. Freshwater isopods also known as sowbugs or aquatic pill bugs are widely distributed across freshwater habitats including lakes, rivers, streams, underground aquifers, thermal springs, water held in some tropical plants, and cave habitats where they often display associated specializations (Brusca 1997). The actual ranges of most species are very small with a very high level of endemism.

In general the freshwater isopod fauna has been very poorly sampled worldwide. Distribution of type localities based on one of the best museum collections indicates higher concentrations in Western Europe and North America; however, the current distribution data reflects collection bias rather than a true picture of biodiversity.

Spain, France, Italy, and the eastern U.S. have been well sampled for many years, with apparent high diversity in cave and subterranean habitats. South America seems to be very poorly sampled except for groups representing fish parasites. Many more species are likely to await discovery in Mexico and the Balkans, areas rich in karst habitats, where isopods tend to have particularly restricted ranges. Scandinavia, Asia, western U.S, Canada, and Alaska are very poorly surveyed in general, as are Africa and Madagascar except for some subterranean species in northern Africa and along the perimeter of the continent (Schotte pers. comm. 2002).

The Smithsonian National Museum of Natural History maintains an on-line bibliographic and specimens database of isopod crustaceans containing 10,054 records worldwide, including information on type localities (Smithsonian 2002).

3.6.4 Decapods (prawns, crabs and crayfish)

Freshwater crabs and crayfish each have a circumglobal distribution, but their distributions are for the most part mutually exclusive. Freshwater crabs dominate tropical freshwaters while crayfish abound in temperate regions and although there are some species found in the tropics and subtropics they are much less prevalent in these latitudes (Cumberlidge pers. comm. 2002). Their distribution range is generally not confined to one river basin (Banarescu 1990).

True freshwater crabs are restricted to the tropical and warm temperate zones of Central and South America, Southern Europe, Africa and Madagascar, South and Southeast Asia, China, Japan. The Philippines, New Guinea, and Australia. They are also found in the Gulf of Guinea islands, the Seychelles, Socotra, Sri Lanka, and parts of the West Indies (Banarescu 1990). Freshwater crabs are not found in the U.S., Canada, Northern Europe or Russia. They are also absent from oceanic islands in the Atlantic and Pacific, including New Caledonia, New Zealand, Tahiti, and Hawaii. There are at least 1,000 species worldwide, with high tendency towards endemism. Checklists of species can be compiled for most of the range of this group. Gaps exist for Africa (other than West Africa), India and Burma, and most of the Indonesian archipelago (Cumberlidge pers. comm. 2002).

A freshwater crab (*Hymenosoma lacustris*) confined to lakes in northern New Zealand is reported to have declined following the introductions of salmonids for sport fishing (Fish 1966).

Crayfish generally occur in the freshwater ecosystems in the temperate parts of the world (i.e., Canada, U.S., temperate South America, Europe, China, Korea, Japan, Australia and New Zealand). They are also found in the tropics and subtropics

in Mexico, Cuba, Haiti, The Dominican Republic, Madagascar, New Guinea, New Caledonia and Australia (Banarescu 1990; Cumberlidge pers. comm. 2002). There are almost 600 species worldwide, of which 400 are found in North America. Endemism at the species level is high, especially in the Southeastern United States, Australia, Asia, and Madagascar. There are two centres of freshwater crayfish diversity: southeastern U.S. and Victoria, Australia. A worldwide checklist of species is available on-line (Crandall and Fetzner 2002).

Prawns are a very diverse group in freshwaters and include two major groupings—the Palaemonidae (including the important large river prawns of the genus *Macrobrachium*) and the smaller Caridinidae. Both form the basis of important fisheries in rivers, floodplains, ricefields and other wetlands of tropical regions and are very important in food-webs. River prawns also form the basis of very significant aquaculture globally. Despite this importance, freshwater prawns remain very little studied and details of their biology and taxonomy are fragmentary. Even less information is available on their socio-economic value (except for commercial aquaculture) although they are widely acknowledged to be important.

Nineteen species of freshwater crustaceans belonging to seven genera (Decapoda) are now known from Vanuatu (Marquet et al. 2002). In contrast to Fiji and New Caledonia where endemics represented 12% and 35% of the total respectively, no endemics were found in Vanuatu, which can be explained by the relatively recent formation of this archipelago.

New Caledonia has 34 species of freshwater crustaceans. The New Caledonian freshwater palaemonid fauna (Crustacea) totals ten species in two genera, which is comparable to the 10 species recorded from neighbouring Fiji. All but 1 New Caledonian species, the only endemic (*Macrobrachium caledonicum*) are wide-ranging in the Indo-West Pacific. No large-egged, palaemonids have so far been recorded from New Caledonia or from the other islands of Oceania. This contrasts with the larger continental land mass of Australia, which has 4 of those species plus 1 undescribed (Short and Marquet 1998).

Atyid shrimps have also been surveyed in New Caledonia, yielding 21 species of which ten are endemics. Diversity is higher on the wetter, windward northeast coast. High endemism in the southern part suggests its early geologic isolation (Choy and Marquet 2002).

3.6.5 Cladocera

There are about 600 species of Cladocera, of which the genus *Daphnia* is mostly responsible for algae control in reservoirs. The only *Daphnia* recorded from North America has been examined using molecular taxonomy.

3.7 ROTIFERA

There are over 2,000 species of Rotifers, which are responsible for nitrate and phosphate recycling in freshwaters. Since they recycle nutrients faster than bacteria they play an important part in the eutrophication process. Rotifers are one of the most difficult invertebrate groups to identify and one of the most neglected groups taxonomically. The Rotifera museum collections are fragmentary, lost or damaged.

3.8 FRESHWATER FISH

Most global and regional overviews of freshwater biodiversity include more information on diversity of fishes than any other freshwater group (Cushing et al. 1995; Gopal et al. 2000; Groombridge and Jenkins 1998; Taub 1984). A number of other regional overviews are devoted to the diversity of fishes (e.g., Kottelat and Whitten 1996; Lévêque 1997; Skelton 1994; Snoeks 2000; Stiassny 1996), yet there is still much to be discovered and many of the existing overviews need regular updating—about 200 new fish species are being described annually (Lundberg et al. 2000.)

Of the 25,000 total living fish species described worldwide, the vast majority belong to the group Actinopterygii or ray-finned fish, of which 41% or about 10,000 species, are primarily freshwater species, with an additional 160 species regularly migrating between fresh and salt waters. Fishes are a polyphyletic group—a group containing an ancestor and all of its descendants—thus, both marine and freshwater fishes, are included in other taxonomic groups such as the *Myxini* or hagfishes, with 25 species, the Cephalaspidomorphi or lampreys, with 35 species, the Elasmobranchii or sharks and rays, with 1,200 species, and the Sarcopterygii, which include 1 species of coelacanth and 7 species of lungfishes (Lundberg et al. 2000).

In terms of species numbers and overall distribution, the Otophysi (also known by their former taxonomic name as Ostariophysi) dominate freshwater fish diversity. This group includes the following major orders: Cypriniformes (carps, minnows, barbs, suckers, loaches, with roughly 2,700 species), Characiformes (tetras, piranhas, with at least 1,300 species), Gymnotiformes (electric eels and knifefishes with over 90 species), and Siluriformes (catfishes, with over 1,400 species).

In terms of their geographic distribution pattern, it is estimated that Latin America has over 5,000 species of freshwater fish, followed by tropical Asia and Africa with over 3,000 species each, North America with 1,000 species, and Europe and Australia with several hundred species each. It should be noted however, that there are major differences in the level of knowledge on inland fish fauna across different geographic regions.

With respect to their conservation status, it has been estimated that, in recent decades, more than 20% of the world's 10,000 described freshwater fish species have become extinct, threatened, or endangered (Moyle and Leidy 1992). This figure, however, is considered a major underestimate (Bräutigam 1999). According to the WRI's latest ecosystem assessment, freshwater ecosystems and their dependent species, particularly fish and invertebrates are more severely degraded than forest, grassland, and coastal ecosystems (WRI 2000).

The IUCN Red List includes 627 freshwater fish species classified as critically endangered, endangered, or vulnerable. These include 610 Actinopterygii, 3 Cephalaspidomorphi, and 14 Elasmobranchii (IUCN 2002). In all, over 80% of the total number of threatened fish species are freshwater fish (Hilton-Taylor 2000). The percentage is much higher if freshwater representatives of marine groups are included where they are under threat from conditions in inland waters (e.g., salmonids and sturgeons). Because in-depth assessments of the conservation status of freshwater fish have been limited to a few countries, regional distribution of threatened species is strongly biased towards these countries. This is why more threatened fish species have been found in North America than in other regions of the world. This also applies to a lesser extent to threat status in Sub-Saharan Africa, Central America, the Caribbean, Europe, and certain areas in Southeast Asia.

To assess the validity of the threat status, and test the potential existing biases, Harrison and Stiassny (1999) assessed 245 freshwater fish species representing 2% of the total known freshwater fish species worldwide, which were known to be "potentially extinct or seriously threatened." The assessment results concluded that the geographic and taxonomic representation of the species assessed is biased due to more exhaustive reviews of species' status in some countries and the lack of information for other regions. Of the 245 species assessed, 132 or 54% were cichlids from Lake Victoria, while another seventy were non-cichlid species belonging to 10 taxonomic orders, with salmoniformes and cyprinodontiforms representing a larger percentage of "possible extinctions" than would be expected given the actual size of these taxa. Given these biases, the results of Harrison and Stiassny's study as well as those of other threat assessments do not provide a clear geographic pattern of possible fish species extinctions, but give an unambiguous indication of the

steady increase in the number of possible extinctions over the last 50–100 years.

In South, Southeast, and East Asia combined, there are at least 3,500 freshwater fish species some with very restricted ranges. The majority of the high-fish diversity countries are in the tropics, with Indonesia, India, Thailand, Vietnam, and Malaysia leading the list (Kottelat and Whitten 1996). The dominant groups of fish in this tropical region are: cyprinids (carps and minnows, with close to 1,000 species), loaches from two groups (Balitoridae and Cobitidae) with about 400 species, Bagridae (bagrid catfishes, with 100 species), Perciformes (Osphronemidae or giant gouramies, with 85 species), and the Gobiidae family with 300 species. A distinct feature of fish fauna in tropical Asia is its diversity at family level—121 families have been recorded in inland waters, in comparison to 50 in Africa and about 55 in Latin America (Lundberg et al. 2000).

Species diversity estimates for freshwater fish have also been made by basin for some large river systems of the world (Revenga et al. 1998). The river systems in Asia with the highest number of freshwater fish species include the Mekong River with at least 1,200 species, followed by the Yangtze River in China and the Kapuas River in Indonesia with close to 320 species each. The Xi Jiang or Pearl River, and the Chao Phraya also have rich fish diversity with over 200 species each; while the Song Hong or Red River shared by Vietnam and China, the Huang He or Yellow River, the Indus, the Salween, and Ganges each have over 140 species of freshwater fish. These figures are indicative only and are invariably underestimates. River systems in this region with high occurrence of endemic species are the Xi Jiang (with 43% of endemics), the Mekong, the Salween, and the Tigris and Euphrates (over 25%). Compared to river basins in South America and Africa, Asian river systems may seem less species-rich. However, species richness is often proportional to the size of the basin, and in terms of the number of species per square kilometer of basin area, the Kapuas River ranks among the highest in the world, followed by Chao Phrya. When number of species is calculated relative to basin area these two rivers have by far a higher density of species richness than the Amazon or the Congo basins (McAllister 2000). These estimates provide an overview of the fish species diversity in the region. However, there are significant differences in ichthyological knowledge and nomenclature between regions and countries.

From research and literature review, it is clear that much of the fish fauna of tropical Asia still needs to be explored and discovered. There are considerable data gaps and nomenclature differences among the countries in the region, which makes access and harmonization of information a challenge. Some of the key countries with data gaps include India, Sri Lanka, Laos, Vietnam, Bhutan, Brunei, Myanmar, Cambodia, North and South Korea and remote areas of Indonesia. In these latter countries, problems with outdated nomenclature and poor sampling coverage, are the main causes for the information gap (Kottelat and Whitten 1996; Lundberg et al. 2000). In Bhutan, Brunei, Myanmar, Cambodia, Laos, North and South Korea, comparison of records of fish species with estimated species richness cited by Kottelat and Whitten (1996) indicate that only 30-60% of the fish fauna of these countries has been recorded. China, on the other hand has data holdings on fish species, but because of language and isolated ichthyological research, adequate comparisons with other countries has been and continues to pose a challenge.

A comprehensive assessment of the threatened fishes in Asia does not exist. However, in Japan, where exceptionally good data exist, a 1995 assessment shows that 39 out of total 200 freshwater or brackish fish species (about 20%) are rare, endangered, or vulnerable, and 2 species have gone extinct (Japanese Council of Ministers for Global Environmental Conservation 1995). Other estimates of the conservation status of fish are provided by Moyle and Leidy (1992). For example in Iran, 22% of fish species have severely declining populations and 28% of Sri Lanka's freshwater

fishes are classified as endangered, threatened, or "of special concern." China has 31 species listed as threatened in the IUCN Red List, including many cyprinids and some sturgeons (IUCN 2002), which is a small fraction of the total species that are found in this large country. Indonesia and Philippines also have a significant number of threatened freshwater fishes (57 and 26 species, respectively), reported from relatively limited number of localities. Of the 14 Elasmobranchii species, 7 are freshwater stingrays and sharks found in South and mainland Southeast Asian rivers (IUCN 2002).

Africa is estimated to harbor some 2,850 species, in 40-50 families, depending on the taxonomical convention followed. This number, probably an underestimate because of information and knowledge gaps, is considered low for the size of the continent. However, the African ichthyofauna is highly endemic—almost 100% at species level and 40% at family level—and includes some extraordinary examples of evolutionary phenomena, ranging from "living fossils" to uniquely high speciation and adaptation rates (Lundberg et al. 2000).

More than two-thirds of African freshwater fish species belong to two common groups: Otophysi fishes—Cyprinidae (475 species in 23 genera), characiforms (characins, with 208 species in 39 genera), and siluriforms (catfishes, with 3 families: Clariidae—74 species in 12 genera, Clariteidae—98 species in 18 genera, and Mochokidae—167 species in 10 genera); and fishes from the Cichlidae family with 870 species in 143 genera (Lundberg et al. 2000.) Among these, Cyprinidae, Characidae, and a few siluriform families constitute the primary component of riverine fauna, along with Cyprinodontiforms (killifishes, pupfishes) and Mormyridae (elephantfishes). On the other hand cichlids (Cichlidae) are by far the most abundant and the dominant group in lacustrine environments, particularly East African Great Lakes (Lévêque 1997; Lundberg et al. 2000).

Within Africa, as in Asia, the highest fish species richness is found in large river systems, including their lakes and wetlands, in the tropical regions of the continent. The freshwater systems with the highest number of freshwater fish species are the Congo basin and Lake Tanganyika, with 700 species, Lake Victoria with 343 species, the Niger River with 164 species, and the Volta with 141 species. The Congo basin contains the highest level of endemism (70%) among the major African rivers. Among the African lakes, Lake Victoria and Lake Tanganyika have the highest levels of endemism (90 and 77% respectively). Other systems with high ratio of endemics are: Lake Turkana (39%), Orange River (29%), and the Zambezi and Senegal rivers with over 20% endemics (Revenga et al. 1998).

African fishes have been studied extensively since the colonial period—a series of checklists (Daget et al. 1984, 1986a, 1986b and 1991) and regional overviews of fish diversity are available (Teugels et al. 1994; Stiassny 1996; Lévêque 1997). Yet despite this extensive knowledge, the a great deal of undescribed species still remains. For example, the rate of species discovery for three families—Citharinidae, Mormyridae, and Cichlidae—over the last century shows the steady growth in the cumulative number of species described, which range from 50 to 200 species per decade (Lundberg et al. 2000). Even in well-sampled locations, such as Lake Victoria and in the Cross River in Cameroon and Nigeria, recent studies have found previously unknown species, particularly cichlids. Endemic cichlid fauna in the East African Great Lakes are still largely undescribed. In Lake Malawi, 300 endemic cichlids have been described so far, yet this is considered less than 40% of the estimated total number of cichlids in the lake. The situation is similar in Lakes Tanganyika and Victoria (Snoeks 2000). In general, the most well documented areas are located in West Africa, Southern Africa, Madagascar, and the East African lakes. Areas that are still poorly sampled include: Lower Guinea (coastal rivers of Cameroon to the mouth of Congo River), part of the Congo River basin, the Angolan coastal drainages and the coastal drainages of Mozambique between the Ruvuma and the Zambezi rivers (Lévêque 1997; Skelton 1994).

The status of African fish fauna has not been comprehensively assessed, however, there are a few well-documented cases. The most widely known and frequently cited is the disappearance of over 300 haplochromine cichlids in Lake Victoria and the decline or disappearance of most of the riverine fauna in the east and northeastern forests of Madagascar (Stiassny 1996). There is also documented evidence of the threatened fish fauna of crater lakes in western Cameroon and the South African fish fauna, which has 63% of its species endangered, threatened, or "of special concern" (Lévêque 1997; Moyle and Leidy 1992). The IUCN Red List reflects this assessment bias with 120 threatened fishes included, most of which are reported from East African lakes, South Africa, Madagascar, and Cameroon (Hilton-Taylor 2000).

In South America, the Neotropical ichthyofauna is very large, estimated to contain as many as 5,000-8,000 species. There are five dominant groups of fishes in this region: Characiformes with a total of 1,300-2,000 estimated species and 450 described species between 1950 and 1997, Siluriformes with 1,400-2,000 species, Gymnotiformes with 94 identified species, and an estimated total of over 100, Cyprinodontiformes with close to 375 species, 203 described between 1950 and 1997, and Cichlidae with about 450 species. Neotropical cichlids are not as diverse as their African counterparts, but the number of described species is increasing—about 30% of them have been described since 1974 (Lundberg et al. 2000).

The pattern of diversity based on the number of species by river basin without taking basin area into consideration, shows that the Amazon basin is by far the richest river basin in the world, containing an estimated 3,000 species (Revenga et al. 1998). Other river basins with high number of species are the Orinoco and the Paraná, each with over 300 species, followed by the Magdalena and the Uruguay basin containing over 140 species of freshwater fish. Other major river systems for which no species data were available include Rio Colorado in Argentina, the São Francisco, and the Tocantins, both in Brazil. In terms of endemism, the large river systems in South America, for which data were available, all seem to contain a high percentage of endemic fish. Lakes Titicaca and Salar de Uyuni shared by Bolivia and Peru, for example contain a relatively low number of species, but a high degree of endemism—70%. Of the Amazon's 3,000 species, 60% are endemic, followed by the Orinoco and Uruguay rivers with 28% and 22% endemism respectively. For other important river systems in South America, such as the Magdalena, Paraná, and Parnaiba data on endemics were not available (Revenga et al. 1998). Further north or south within the continent, fish diversity by basin drops sharply. Rivers draining into the Caribbean and the Pacific, or rivers in the southern temperate zone, taxonomic composition of the fauna changes and is less diverse (Lundberg et al. 2000).

There is no comprehensive inventory or assessment for the Neotropical fish fauna (Lundberg et al. 2000). *The Catalog of Fishes* (Eschmeyer 1998) is the most thorough list of the Neotropical ichtyofauna and has substantially improved accessibility of the existing information. Data on new species described between 1950-1997 shows the increase in the number of new species described each year and indicates many previously under-sampled areas and taxa. This increasing trend is expected to continue because there are still areas to be discovered and rediscovered. For example, a 1997 list of Venezuelan freshwater fishes contained 1,065 species—more than twice of what was published in the first comprehensive list in 1970 (Lundberg et al. 2000.) An assessment of the conservation status of fishes has not been conducted in the region except for Mexico, which accounts for 78 species of threatened fishes according to IUCN (IUCN 2002).

Museum collections of South American fishes are far more advanced than that of African and Asian fishes, especially in terms of its accessibility. The Inter-Institutional Database of Fish Biodiversity in the Neotropics (NEODAT) is an international cooperative effort to make available systematic and geographic data on Neotropical

freshwater fish specimens deposited in natural history collections in Europe and the Americas. An on-line database for museum records has compiled nearly 400,000 primary and 120,000 locality records from 24 institutions worldwide. Locality data that include latitude and longitude can also be mapped on-line. This initiative demonstrates the crucial need for geo-referencing the localities, which enables the assessment of species ranges, patterns of richness, and facilitates the identification of data and information gaps.

Three quarters of the world's islands are found in the Pacific Ocean. Included in these are archaic continental remnants like New Zealand and New Caledonia, detached continental islands (New Guinea), isolated archipelagos (Hawaii, Galapagos), galaxies of remote volcanic islands (Societies, Marquesas), and low-lying biologically depauperate atolls (Tuomotus) (Keast 1996). In terms of freshwater fish fauna, these islands are also unique.

Australia and New Guinea have strong biogeographic affinity in freshwater fish fauna because they were connected throughout most of their geological history. The fish fauna of New Guinea-Australia is very different to that of other continental tropical regions such as Southeast Asia, Africa, and South America (Allen 1991). Dominant forms are clupeids, plotosid and ariid catfishes, atherinids, melanotaeniids, ambassids, gobiids, and eleotrids. In contrast to the primary division forms that have evolved entirely in fresh water, they are considered to be secondary division of fishes of marine origin. In fact all of New Guinea-Australia's fish fauna except the lungfish (*Neoceratodus*), bony tongues (*Osteoglossus*), and possibly galaxiids (see below), are considered to be derived from marine ancestors. The very different complexion of the fish fauna compared to other regions is a reflection of the long period of isolation (approximately 500 million years) since the Australian land mass broke away from Antarctica and began drifting northwards towards its present position (Allen 1991).

Despite Australia's size its river network is much less extensive. Nevertheless, Australia harbors a large variety of freshwater habitats ranging from tropical streams to alpine lakes and ephemeral desert lakes. Of the 180 freshwater fish species known in Australia, about 108 are found in the southeast. Of these 86 are native to Australia. In addition to species that are clearly 'freshwater fishes', the fauna includes many that may or must spend a part of their lives in the sea. Some of these belong to the Galaxiidae, an archaic southern group, which has 18 Australian, over 20 New Zealand (many non-migratory species have only been recently described), 1 New Caledonian, and 4 Patagonian-South American species. Reasons why New Zealand has a small freshwater fish fauna has much to do with the country's long and great geographical isolation from other landmasses in the southwestern Pacific region but also much to do with its turbulent geological history. However all but five of the 38 species found in New Zealand freshwaters are known only from New Zealand. The longfin eel, which reaches a length of about 2.0 m and weighs up to about 25 kg, makes it arguably the largest freshwater eel in the world (McDowall 2000).

Fishes found in freshwater described so far in New Guinea number about about 330 species, including close to 100 species which are basically estuarine forms and relatively widespread outside of New Guinea. The remaining species are exclusively freshwater indigenous species. It is this latter group that gives New Guinea its unique "flavour" (Allen 1991). Most of the families and many of the genera have strong Australian affinities. As in Australia, the most diverse taxa in New Guinea are also *Eleotrididae* and *Gobiidae*, with 115 species, followed by *Melanotaeniidae* with 53 species. About 50 species from southern New Guinea also occur in northern Australia and are restricted to these two areas (Lundberg et al. 2000).

The Murray-Darling basin, the largest river system in Australia, contains 33 fish species including 7 endemics. The Fly basin in southern New Guinea has 105 species and Sepik basin, to the north, has 57 species of fish (Revenga et al. 1998). These are

locally important but less diverse relative to other tropical rivers in Asia. Other areas of locally important fish diversity include the Aikwa (Iwaka) River in Irian Jaya, Lake Kutubu and the in the Kikori River in Papua New Guinea, and Tasmania and Southwest Western Australia (Groombridge and Jenkins 1998).

Two closely related families are unique to the Australo-Papuan zoogeographic region: the Melanotaeniidae (rainbowfishes—famous among tropical fish aquarists and naturalists) and Pseudomygilidae (blue-eyes) (Keast 1996). Large New Guinean rivers like the Fly have a high diversity of ecomorphological types of fishes (Roberts 1978). Many of the rainbowfishes appear to be restricted to an isolated lake or small part of a river system, making them very vulnerable to environmental disturbances like logging or dam construction. Lake Sentani in Irian Jaya and Lake Kutubu in Papua New Guinea are two areas that have unique fish faunas that are extremely vulnerable (Allen 1991).

Fiji has a substantial fresh and brackish-water fauna of at least 80 species represented by 28 families (Ryan 1980). This diversity compares well with other neighbouring islands such as Vanuatu (60 species), French Polynesia (32 species—7 endemics (Marquet 1993)) or Palau (40 species) or even the Cape York Peninsula in Australia (30 species). It may be explained by the old age of some of the islands (Vitilevy is at least 40 million years old and has therefore given ample time for both colonisation and speciation. Many of the species have marine larval stages and this influences greatly the level of endemism). It is likely that there are 10 or more endemic gobies accounting for around 30% of the total gobiid fauna and around 12.5% of the total freshwater/brackishwater fauna of these areas (Ryan 1991).

The number of freshwater endemic fish species is also limited in New Caledonia with only 5 endemic genera (out of 26—mainly represented by Eleotrididae and Gobiidae), 15 endemic species (out of 59), i.e. about 30% of endemic species. The explanation here again is the marine origin of all but two families (Séret 1997).

As opposed to North America and Europe, where there have been few fish species discoveries in recent years, in Oceania, over 30% of the total number of species have been identified since 1970. Many more surveys are still needed in some poorly-sampled areas of Australia and New Guinea, particularly Irian Jaya. Taxonomic re-evaluations of more common species are also needed (Lundberg et al. 2000). There are 44 threatened ray-finned fishes according to IUCN, the majority of which are reported from Australia, with Papua New Guinea and New Zealand making up the rest. Many of them are Perciforms and Salmoniforms (Hilton-Taylor 2000).

Europe contains 358 species of freshwater fish, 62 of which are threatened. The IUCN Red List ncludes numerous sturgeons, barbs, and other cyprinid fishes (IUCN 2002). The major groups accounting for 80% of the taxa west of the Ural Mountains are: Cyprinidae (129 species), Salmonidae (54), Coregonidae (whitefish, 43 species), Gobiidae (31 species), Cobitidae (loaches, 21 species), Petromyzontidae (lampreys), Clupeidae (herrings), and Percidae (perches) with 11 species each. Like in North America, it is now uncommon to discover new species of fish in European waters. Recent discoveries have been of very small species (3-10 cm in size), mostly from the Iberian, Italian, and Balkan peninsula (Lundberg et al. 2000). The European fish fauna is less diverse than in temperate North America. The river system that contains the largest number of species is the Danube, with 103 species, followed by the Volga with 88 species. Other major river basins that are smaller in size, contain fish species numbers ranging from 30 to 70. Very few endemics are reported by river basin in Europe (Revenga et al. 1998). These low numbers of species and endemics may also reflect the high degree of modification of European rivers and its impact on their fish fauna.

Over 1,050 freshwater fish species are known to occur in North America, representing 32 prima-

rily freshwater families and 24 marine families that contain a few freshwater members. The dominant groups that constitute about 80% of the total species are Cyprinidae (305 species), Percidae (172 species), Poeciliidae (livebearing poeciliids, 75 species), Castomidae (suckers, 68 species), Ictaluridae (catfishes, 48), Goodeidae (livebearing fishes, 40), Fundulidae (topminnows and killifishes 37), Centrarchidae (sunfishes, 32), Atherinidae (silversides 35), Cottidae (sculpins, 27), and Cichlidae (cichlids, 21). The continent's fish fauna contains 9 families and 128 genera endemic to the region (Lundberg et al. 2000). The Mississippi basin is an outstanding centre of ichtyofauna diversity, harboring 375 species of which over 30% are thought to be endemic. The Rio Grande, Colorado, Alabama, and Susquehanna River systems have very diverse fish fauna for a temperate region, each containing over 120 species. Fish endemicity is also very high in the Rio Grande (57%), Colorado (35%), and Usmacinta basins (59%) (Revenga et al. 1998).

Freshwater fishes of North America have been thoroughly explored in the last two centuries. Except for Mexico and Central America, there are few unknown species. Species distribution is well documented at regional, provincial, and state level. Assessments of the conservation status of freshwater fishes are extensive: of the 645 ray-finned fishes listed as threatened in the IUCN Red List, 119 are found in the U.S. and 78 in Mexico (IUCN 2002).

3.8 AMPHIBIANS

Amphibians are strictly freshwater animals, unable to tolerate salt water. They are found in all types of freshwater habitats from ponds, streams, and wetlands, to leaf litter, on the tree canopy, underground, and in vernal pools. Although some amphibians thrive in cold or dry conditions, the group reaches its highest diversity and numbers in warm, humid climates (Hebert 2002). Amphibians are classified into 3 orders: *Anura* (frogs and toads), *Caudata* (newts and salamanders), and *Gymnophiona* (caecilians). Estimates of the actual number of extant amphibian species vary among taxonomists and authors. Duellman (1993) lists 4,522 species of amphibians, based on data and information available in 1992. The on-line resource AmphibiaWeb lists almost 5,500 species. Diversity and distribution of the group is better known in the developed world. A total of 74 amphibians are known in Europe, with the highest numbers occurring in France, Italy, Spain, and former Yugoslavia (20-30 species each) (Corbett 1989). Approximately 230 species of amphibians occur in the continental United States, including 140 salamander species and 90 anurans. The ranges for most endemic species in the western United States (26 species) are widely dispersed while endemics in the eastern and southeastern U.S. (25 species) tend to be clustered in centers of endemism, such as in the Edwards Plateau in Texas, the Interior Ozark Highlands in Arkansas and Oklahoma, the Atlantic Coastal Plain from Texas to Virginia, and the uplands or mountaintops in the Appalachian Mountains (Bury et al. 1995). In Japan a total of 59 amphibians have been described to date, many of which are salamanders (Japanese Council of Ministers for Global Environmental Conservation 1995). The American Museum of Natural History maintains an on-line catalog of the world's amphibian species with a bibliography containing over 7,100 references (Frost 2000). Although still incomplete, this is the most comprehensive and up-to-date global list that currently exists.

Duellman's 1993 classification provides an overview of the distribution of species between the 3 orders. However, because of constant updating and revision of taxonomic names and new species being identified, these figures may not accurately reflect the current state of knowledge of amphibian systematics. Of Duellman's estimated 4,522 species of amphibians, the majority (3,967) belongs to the order *Anura*, 392 species are newts and salamanders and 163 species belong to the order Gymnophiona (Duellman 1993).

The IUCN *Red List of Threatened Animals* (IUCN 2002) lists 142 "freshwater-dependent" amphibian species as either critically endangered,

endangered, or vulnerable to extinction, of which 113 are frogs or toads and 27 are newts or salamanders. Two additional caecilian species are reported as threatened in the Philippines. The threatened *Anura* species include 34 in Australia, 21 in the Philippines, 15 in South America, 15 in African, 8 in the Caribbean, 8 in the U.S., and 4 in Japan. There are as many as 67 species still listed as "data deficient" that are potentially threatened, the majority of which are found in South America. Some global data for declines in Amphibia are shown in Map 4 *(see Appendix A, page 120)*.

Of the 27 species of newts and salamanders listed as threatened, 9 are found in the U.S., 8 in the Caribbean, 6 in Japan, and 4 in Europe. There are 7 additional species listed as "data deficient" that are potentially threatened.

In addition to the conservation assessments carried out by IUCN for the Red List, research to date shows that globally over 200 amphibian species have experienced recent population declines while 32 are reported extinct (Blaustein and Wake 1990, Alford and Richards 1999, Houlahan et al. 2000). Experts believe that the population declines are due to multiple factors including habitat destruction, climate change, ultraviolet radiation (because of the reduction of the ozone layer), contaminants, introduced species, infectious bacteria, fungi and viruses. Most alarming is that many of these declines have occurred in pristine protected areas (Amphibia Web 2002). Due to the lack of long-term monitoring of amphibian populations, the evidence of these declines is mostly anecdotal. The Declining Amphibian Populations Task Force of the IUCN/Species Survival Commission has assessed these documented incidents worldwide. Although the cases of amphibian declines are not evaluated with standard criteria, the results show marked declines in the populations of eastern Australia, southeastern Brazil, Central America, and at higher altitudes in the U.S. and Canada (Revenga et al. 2000).

In response to this global phenomenon, the German Federal Ministry of Education and Research and the Zoology Department of Mainz University, in collaboration with local organizations have founded the Global Amphibian Diversity Analysis Group (GADAG) under their BIOLOG program. GADAG has initiated long-term monitoring projects and has other activities planned at a number of localities in East and West Africa, Southeast Asia, South America, and Madagascar (GADAG 2002). IUCN and Conservation International have also initiated a global amphibian assessment, the results of which will be published in early 2004.

3.9 REPTILES

3.9.1 Freshwater Turtles

There are around 200 species of freshwater turtles throughout the warm temperate and tropical regions of the world (IUCN/SSC Tortoise and Freshwater Turtle Specialist Group 1991). They play an important role as scavengers (eating carrion, weeds, insects and snails) and therefore contributing to the maintenance of the ecosystem. Turtles are harvested and used by humans throughout their range. Most turtle species are edible and are especially valuable as food (both flesh and eggs) in many developing and some developed countries. Turtles are also used for products such as souvenirs, traditional medicines, aphrodisiacs and the international pet trade. These pressures in combination with habitat loss are causing declines in turtle populations worldwide (van Dijk et al. 2000).

There are two taxonomic suborders of living turtles. One comprises the Pleurodira or side-necked turtles, which are only found in the Southern Hemisphere, and are characterized by folding their neck to the side rather than draw it into the shell between the shoulder blades. The side-necked turtles are primitive, semi-aquatic turtles that include two distinct taxonomic families. The Chelidae with 36 species distributed throughout Australia, New Guinea, and South America, and the Pelomedusidae with 23 species, found in

Africa and South America. (Ernst and Barbour 1989; Meylan and Ganko 1997). In terms of their conservation status, IUCN lists 2 Pelomedusidae species, the Madagascar big-headed turtle in Madagascar and the Magdalena River turtle in Colombia, as endangered and 6 species as vulnerable to extinction (IUCN 2002). Within the Chelidae family, there are 3 species considered critically endangered, 1 is found in Indonesia, 1 in Colombia and 1 in Australia. Four more species are classified as endangered, including 1 species in Brazil, 2 in Australia and 1 in Papua New Guinea: *Chelodina pritchardi* the only endemic turtle found in Papua New Guinea, and illegally hunted for the pet trade. There are 6 additional Chelidae species listed as vulnerable to extinction (IUCN 2002).

The other taxonomic suborder, the Cryptodira or hidden-necked turtles, includes all the remaining living turtles of the world, including freshwater and marine turtles, and land tortoises. All members of this suborder can retract the neck and most of them also the head into the shell between the shoulder blades. Of the 12 living families of turtles, 10 families are cryptodirans and 2 side-necked turtles.[5] The Cryptodira include snapping turtles, sea turtles, soft-shelled turtles, mud and musk turtles, pond, box and water turtles, land tortoises, and the two single species of two relictual families, the Fly River or Pig-nosed turtle found in New Guinea and Australia and the Tortuga Blanca or Central American river turtle found in Mexico, Belize, Guatemala and Honduras (Ernst and Barbour 1989; Meylan and Ganko 1997; Uetz and Etzold 1996). These last two species are considered vulnerable and endangered respectively, primarily from habitat loss and exploitation (IUCN 2002).

The snapping turtles (Chelydridae) contain only 3 species in three monotypic genera. They include the alligator snapping turtle (*Macrochelys temminckii*), the heaviest freshwater turtle in the world (up to 80 kg), which is endemic to the U.S. and found exclusively in rivers draining to the Gulf of Mexico (Ernst and Barbour 1989). This species is considered vulnerable, mainly due to habitat loss and degradation, and exploitation (meat) for international and domestic markets (IUCN 2002). The common American snapping turtle (*Chelydra serpentina)* is found in North America and as far south as Peru, in both fresh and brackish water (Ernst and Barbour 1989). The third species of snapping turtle, the big-headed turtle (*Platysternon megacephalum)*, is found in China and Southeast Asia, where it inhabits cool mountainous rocky streams. This turtle has "a head so large that it cannot be withdrawn into the shell" (Ernst and Barbour 1989). This species is considered endangered mostly because of trade (IUCN 2002). Ernst and Barbour (1989) consider this species to be the only representative of a separate taxonomic family, the Platysternidae.

The Trionychidae or soft-shelled turtles are semi-aquatic flat turtles with leathery shells, paddlelike-limbs, and usually a long snout. They are distributed in Africa, Asia, Indonesia, Australia and North America. This group contains 14 genera and 22 species (Ernst and Barbour 1989). There are 14 species of soft-shell turtles listed as critically endangered, endangered or vulnerable to extinction by IUCN (2002). Some of the critically endangered species, such as the Cuatro Ciénagas softshell, have very restricted ranges, Therefore minor changes to their habitat can have devastating effects on the population. The food and pet trade, particularly in Southeast Asia, threaten many of these species. Even species that are commercially farmed in large numbers (up to several millions per year) for the food trade, such as *Pelodiscus sinensis,* are threatened in the wild due to overexploitation (IUCN 2002).

The mud and musk turtles are small and medium sized, aquatic and semi-aquatic turtles belonging to the family Kinosternidae. There are 3 genera and 22 species found exclusively on the American continent (Ernst and Barbour 1989). IUCN lists 4 species as vulnerable to extinction, 2 of which are found in the U.S and Mexico, 1 in Central America and 1 in Colombia (IUCN 2002).

5 Some authors classify the living turtles into 13 families instead of 12 (Meylan and Ganko 1997).

Pond, box and water turtles belong to the family Emydidae. Many authors, including Ernst and Barbour (1989), classify the Emydidae turtles into two subfamilies: Batagurinae or old world pond turtles and Emydinae or new world pond turtles. However, several authors consider the batagurs as a complete separate family (Bataguridae) (Uetz and Etzold 1996, IUCN 2002). The pond turtles and their allies are the most diverse group, represented in all parts of the world except for Australia and Antarctica. They are mostly aquatic or semiaquatic freshwater turtles, with the exception of two species (*Callagur borneoensis* and *Malaclemys terrapin*), which nest on beaches or inhabit brackish marshes along the coast. They also contain several terrestrial genera. There are 91 living species of pond turtles, belonging to 33 genera (Ernst and Barbour 1989; Uetz and Etzold 1996). There are 13 threatened species of new world pond turtles, the majority of which are restricted to areas in the U.S. and Mexico, with a few species being native to Brazil, Jamaica, and Haiti (IUCN 2002). With respect to old world pond turtles, IUCN lists 40 species as threatened, of which 12 are critically endangered, 18 endangered and the rest classified as vulnerable to extinction (IUCN 2002). The major threat to all these species is trade either for food or as pets. Several species are still traded even though they are listed in CITES Appendix I (IUCN 2002).

The number of critically endangered freshwater turtles has more than doubled in just the last 4 years, according to IUCN, Trade Records Analysis of Flora and Fauna in Commerce (TRAFFIC), Wildlife Conservation Society (WCS), WWF, and other conservation groups (van Dijk et al. 2000). Three-quarters of Asia's freshwater turtles are listed as threatened, and over half considered endangered. Imports of turtle shells into Taiwan alone, for example, comprise on average over 30 metric tons per year, and the total trade may add up to several times this amount (TRAFFIC 2002). According to the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group and the Asian Turtle Trade Working Group, of the 90 species of Asian freshwater turtles and tortoises, 74% are considered threatened. Over half of Asian freshwater turtle and tortoise species are endangered, including 18 critically endangered species, and one that is already extinct: the Yunnan box turtle *Cuora yunnanensis* (van Dijk et al. 2000). The increase in trade of turtle species and their continuing population declines prompted China, Germany, India and the United States to submit proposals for inclusion of several freshwater turtle species under Appendix II of CITES in order to control their trade. At the last CITES Conference of the Parties, held in Santiago de Chile, November 2002, 11 of these proposals were accepted by concensus. The accepted proposals include listing in CITES Appendix II the following freshwater turtles: the big-headed turtle, the Annam pond turtle, the yellow-headed temple turtle, all *Kachuga* species except for *K. tecta*, the yellow pond turtle, the Malaysian giant turtle, the Sulawesi forest turtle, the keeled box turtle, the black marsh turtle, the giant softshell turtle, and all the softshell turtles in the genus *Chitra* (CITES 2002). In addition and to aid in curbing the illegal trade in turtles and tortoises, Environment Canada and collaborators have produced a manual on the identification of turtles and tortoises as part of their *CITES Identification Guide* series (CITES 2002).

Southeast Asia harbors a great variety of freshwater and semi-aquatic turtle species comprising approximately 39 species. The two most diverse groups of turtles in this region are the pond turtles, with 27 species and the softshells with 15 species found in tropical Asia, and nine of these specifically in Southeast Asia (Jenkins 1995). All freshwater turtles are traded throughout SE Asia for use as food, in traditional medicine, as souvenirs, aphrodisiacs and in the international pet trade. Softshells are used throughout the region as food, and in Chinese medicines. Pond turtles are less marketable as food than the softshell turtles, instead they are used more in medicines (Jenkins 1995).

The conservation status of softshells in the region varies from one country to another. The limited amount of information for Cambodia and

Laos PDR, for instance, indicates that softshells are exported regularly, mostly to Vietnam, and in most cases are further exported. Experts believe that most of the time the final destination for the trade is China. In Indonesia and Thailand, export and consumption of softshells is widespread and has increased in recent years. In Thailand, much of the trade is illegal, given that current laws in the country protect all softshell species. Since the early 1990s, trade in softshells in Thailand seems to have declined, but the cause of this decline is not clear. Thailand is also a major breeding center for softshells, especially for the Chinese market, Japan, Korea, Taiwan and Hong Kong. This trade was estimated in 1995 to be around US$3-6 million per year (Jenkins 1995).

In the Peninsula of Malaysia there are 15 species of freshwater and semi-aquatic turtles. The main threats to these species are: loss and degradation of nesting habitat in coastal and riverine areas, alteration of habitat (drainage of wetlands, etc.), harvest and consumption of eggs, and exploitation for food. A few species are commercialized for the pet trade. There are 13 turtle species classified as critically endangered, endangered or vulnerable to extinction by IUCN (IUCN 2002). In Malaysia consumption seems to have decreased, but this may be related to a shortage of supply rather than to a change in food preference. In Myanmar, trade in turtles is forbidden, but they are extensively harvested for food in certain parts of the country and some illegal trade is suspected (Jenkins 1995; Sharma 1999).

Finally a third group of turtles, highly threatened in the region and among the most threatened in the world are the large-river terrapins. Not much information is available on the exploitation or status of this group across SE Asia, however, it seems that in places, like Indonesia trade is increasing (Jenkins 1995).

Another area for which information on the status of turtles is available is India. There are 22 species of freshwater and semi-aquatic turtles in India, 15 of which are critically endangered, endangered or vulnerable according to IUCN (IUCN 2002). The major regions of the country where a high diversity of turtle species can be found are the floodplains of the Brahmaputra, Ganges, and the Mahanadi watersheds. The species found in the Ganges and Mahanadi as well as the ones in northeastern India, for example, have been heavily affected by exploitation and habitat destruction. Two brackish-water species have been practically wiped out (Choudhury and Bhupathy 1993). Exploitation of turtles in India is mostly geared towards food, traditional medicine, religious rites, and the pet trade.

Information on location and distribution of individual species of freshwater and land turtles of the world is available through the World Turtle Database, compiled by the Geosciences Department of Oregon State University (OSU) in Corvallis, Oregon (World Turtle Database http://emys.geo.orst.edu/). The database contains maps of all the known localities of every land and freshwater turtle species "that has been collected by a museum, private individual, or referenced in a publication." The information provided on the website is from Iverson (1992), *Revised Checklist with Distribution Maps of the Turtles of the World*.

3.9.2 Crocodilians

Crocodiles, alligators, caimans and gharials are widespread throughout tropical and subtropical aquatic habitats. There are 23 species of crocodilians distributed in tropical America, Africa, South Asia, and Oceania. They are top predators in freshwater habitats and therefore are key to maintaining ecosystem functions, including selective predation of certain fishes, nutrient recycling, and maintenance of wet refugia during drought periods (Ross 1998). Crocodilians usually live in wetlands, marshes, swamps, rivers and lagoons and the majority of the species require large areas (hundreds of square kilometers) of undisturbed wetlands to maintain large populations.

In the Americas, there are 10 species of crocodilians: the American alligator (*Alligator mississippi-*

ensis) found in Southeast US, along the Atlantic coastal plain through southern Florida and west along the coast to eastern Texas; the common caiman (*Caiman cocodrilus*), which has a wide distribution along most of tropical Central and South America; the black caiman (*Malanosuchus niger*) found in the Amazon basin and coastal rivers of Brazil, Guyana and French Guiana; the broad-snouted caiman (*Caiman latirostris*), which can be found in coastal streams and swamps along the southern part of Brazil, and in some inland river basins like the São Francisco, Doce, Paraiba, Paraná and Paraguay in Brazil and Argentina; Cuvier's dwarf caiman (*Paleosuchus palpebro*sus), which is distributed throughout the Orinoco, Amazon, São Francisco river basins and the upper reaches of the Paraná and Praguay rivers; Schnieder's dwarf caiman (*Paleosuchus trigonatus*) found in the forested regions of the Amazon and the Orinoco, and in the Guyana region; the Cuban crocodile (*Crocodylus rhombifer*) restricted to a 500 km^2 area in southwestern part of the island, in the Zapata Swamp. It is being bred in captivity and has been re-introduced into the Isle of Pines (IUCN/SSC Crocodile Specialist Group 2002); Morelet's crocodile (*Crocodylus moreletii*) found throughout the Yucatan Peninsula, to Chiapas, Belize and the Peten region in Guatemala; the American crocodile (*Crocodylus acutus*) found from southern Florida, throughout the Caribbean and the coasts of Central America to Colombia and Venezuela; and the Orinoco crocodile (*Crocodylus intermedius*) restricted to the freshwater reaches of the Orinoco River.

Africa has 3 crocodilian species, including the African slender-snouted crocodile (*Crocodylus cataphractus*), the Nile crocodile (*Crocodylus niloticus*), and the African dwarf crocodile (*Osteolaemus tetrapsis*). The Nile crocodile is the most widespread of the 3 species found throughout tropical and southern Africa, including Madagascar. It also used to be found in the Nile delta and throughout parts of the Mediterranean coast and in some inland lakes in Mauritania, Chad and the Sahara Desert. The African slender-snouted crocodile and the dwarf crocodile on the other hand are limited to tropical forest regions in Africa. The slender-snouted crocodile can be found throughout central Africa, including Zambia, and eastern Tanzania, while the dwarf crocodile can only be found from Senegal to Angola, and Northeastern Zaire and Uganda.

In Asia and Oceania, there are 9 species of crocodilians, including the true gharial (*Gavialis gangeticus*), and the single Asian alligator species, the Chinese alligator (*Alligator sinensis*). The gharial is found exclusively in the northern part of the Indian subcontinent, although historically it could be found in the rivers of Pakistan, Nepal, India, Bangladesh, Bhutan and Myanmar. The Chinese alligator is restricted to a small area in the lower Yangtze River. The remaining 7 species are all crocodiles. These include, the Johnston's crocodile (*Crocodylus johnsoni*) found in the northern tropical areas of Australia; the Philippine crocodile (*Crocodylus mindorensis*), which used to be found throughout the Philippine archipelago but has been eliminated from 80% of its former range. Currently, the only remnant population is in Mindanao with some individuals scattered on other islands (IUCN/SSC Crocodile Specialist Group 2002); the New Guinea crocodile (*Crocodylus novaeguineae*) found exclusively in Papua New Guinea and Irian Jaya; the saltwater crocodile or Indopacific crocodile (*Crocodylus porosus*) whose distribution extends throughout the tropical regions of Asia and the Pacific, which has the most commercially valuable hide of any crocodilian; and the Siamese crocodile (*Crocodylus siamensis*) which is only found in small populations in Laos, Vietnam, and Indonesia. It has been eradicated from much of its former range and has practically disappeared from Thailand (IUCN/SSC Crocodile Specialist Group 2002); the marsh or broad-snouted crocodile (*Crocodylus palustris*) which is distributed throughout the Indian subcontinent; and the false gharial (*Tomistoma schlegelii*), confined to a few areas, including the Malay Peninsula, Sumatra, Borneo, Java and possibly Sulawesi (Ross 1989).

Of the 23 species, 15 are traded commercially for their skin and all 23 species are listed in CITES Appendices. The historical peak of the crocodile skin trade was in the 1950s and 1960s when 500,000 skins were traded per year. This quantity declined during the two following decades due to overexploitation of the wild populations. In the 1980s, and after CITES entered into force, management of crocodiles and alligators by farming and ranching developed. Today, trade has not reached the high levels of the 1950s. In 1990 for example, around 220,000 skins were traded legally. The legal international trade in crocodile skins is worth US$500 million per year, with Europe and Japan being the two most important markets.

The two major threats to crocodilians worldwide are habitat loss and degradation, and overexploitation. Habitat degradation is caused by pollution, drainage of wetlands, deforestation, and conversion of wetlands to cropland. The deliberate destruction of nests and killing of adults by humans as well as the illegal hunting for their skin also pose a threat to some species. These are frequently reported from Madagascar, Philippines, China, and Bangladesh. Of the 23 species of crocodilians, 4 are critically endangered, 3 are endangered, and 3 vulnerable. The most threatened crocodilian is the Chinese alligator, whose distribution has been restricted to small areas in the lower reaches of the Yangtze River and its tributaries. Pressure from land use change, agriculture, pollution, deforestation, water extraction, etc., further reduces the little habitat available. It is estimated that less than 150 individuals remain in the wild (IUCN/SSC Crocodile Specialist Group 2002 and Ross per. comm. 2002). The other 3 species that are critically endangered are the Philippine and Siamese crocodiles in Asia, and the Orinoco crocodile in South America. The 3 endangered species include the gharial, the false gharial, and the Cuban crocodile. Finally the vulnerable species include the American crocodile, the marsh or broad-snouted crocodile with less than 2,500 adults remaining in the wild, and the African dwarf crocodile (IUCN 2002). The African slender-snouted crocodile is considered data deficient. The other species are estimated to be at lower risk of extinction although depleted locally in some places (Ross 1998).

3.9.3 Freshwater Snakes

There are several species of freshwater snakes in the world. The members of the family Acrochordidae also known as wart or file snakes, for example, are adapted to aquatic life by having dorsal eyes, valvular nostrils, and a flap for closing the lingual opening of the mouth (Uetz and Etzold 1996). This family has 3 species, two adapted to freshwater habitats, the file snake (*Acrochordus arafurae*) and the Javan wart snake (*A. javanicus*), and one adapted to the marine environment. Both freshwater species are found in the Indo-Pacific region. File snakes continue to be important food for Aboriginal communities in northern Australia (Shine 1991 as cited in the Animal Diversity Web 2002). There is not much information on their conservation status.

The Javan wart snake lives in brackish water of rivers and estuaries, along coastal India, Sri Lanka, and across the Indo-Pacific islands as far as the Solomons. This species can also make short incursions into the sea. A major threat to the species is hunting for its skin, which is used in the manufacturing of leather goods. The Javan wart snake is becoming increasingly rare (Animal Diversity Web 2002).

In addition to these two strictly freshwater species there are snakes that are semi-aquatic. These include many colubrids, such as Mud snakes, Garter snakes, and species belonging to the genus *Helicops* and *Hydrodynastes*. *Helicops* and *Hydronastes* species are found in wetland habitats in South America, from French Guyana to the Chaco region in Argentina. The Western mud snake (*Farancia abacura reinwardtii*) is found in and around stagnant, muddy waters along the coast of the Gulf of Mexico in the U.S., while the Rainbow snake (*Farancia erythrogramma*) is found in rivers in the southeastern U.S. (Animal Diversity Web 2002).

The large-headed water snake (*Natrix megalocephala*) found in Azerbaijan, Georgia, Russia and Turkey is listed as vulnerable to extinction (IUCN 2002). The Giant garter snake (*Thamnophis gigas*) is found in freshwater habitats in the U.S and considered vulnerable. The Brown water snake (*Nerodia taxispilota*) of the U.S., is found in coastal rivers from Virginia to Florida and Alabama. This species is quite common and currently not threatened. The cottonmouth (*Agkistrodon piscivorus*) is found in brackish waters, swamps, streams, marshes and drainage ditches in the southeastern United States. The Green anaconda (*Eunectes murinus*), one of the largest snakes in the world and the Yellow anaconda *(Eunectes notaeus)* belonging to the *Boidae* family are also aquatic. The Green anaconda is found mainly in slow running or still waters of the Amazon and Orinoco River basins, but also in rivers of the Guiana Shield (Animal Diversity Web 2002). The Yellow anaconda is distributed from northern Argentina, to Bolivia, Brazil and Paraguay. It inhabits swampy savanna habitats along the Paraguay and Parana Rivers (Mattison 1986). These species are listed in CITES Appendix II, and although their trade is prohibited in most South American countries some are periodically exported for zoos, research and the pet trade. There is also some illegal trade in anaconda skins, but this is not threatening the species' survival. Other pressures on anacondas are habitat destruction and killing by local people because they are perceived as dangerous to the local population (Animal Diversity Web 2002). These species are not listed as threatened by IUCN.

3.10 BIRDS

Birds can be useful indicator species to assess habitat condition. Because of the historical and ongoing interest of hunters, scientists, birdwatchers, and others they have been studied and monitored more consistently and for longer periods of time than many other taxa. Waterbirds (bird species that are ecologically dependent on wetlands) and particularly migratory waterbirds are probably "the most comprehensively studied group of animals on earth" (Rose and Scott 1997). For some parts of the world, notably North America and Northwestern Europe, time-series data on trends are available for a period of over 30 years.

Given the vast amount of information on birds in general, and waterbirds in particular, this section provides only an overview of the status and trends of waterbird populations primarily at the global level. In addition, for some waterbird taxa information is available at the flyway scale. The information is presented by taxonomic family followed by a summary section of trends in waterfowl populations by geographic region. All families with a large number of wetland-dependent species are included, even though some species within particular families may not be considered waterbirds. Many waterbirds are dependent on inland waters at some stage of the year, but it should be noted that some species in the families included in this section are predominantly coastal, although parts of such populations may utilise inland waters.

Importantly, global information on the status and trends of waterbirds is available for biogeographic populations, rather than just at the species level. A population is defined as a "distinct assemblage of individuals that does not experience significant emigration or immigration" (Rose and Scott 1997). Information on biogeographic populations therefore provides a better understanding of the overall condition of a species at the global level. For migratory waterbirds this is particularly important since many species are widely distributed but with different populations following distinct and different migratory pathways (flyways), and the status and trends of these populations within a species can differ greatly.

Global information on waterbird population status and trends is compiled and regularly updated by Wetlands International through its International Waterbird Census (IWC), and published as *Waterbird Population Estimates.* Population status and trend information presented here

are from the third edition of *Waterbird Population Estimates* published in September 2002 (Wetlands International 2002).

Detailed information is also available for waterbird species in North America, compiled by the U.S. Geological Service, and for the Western Palaearctic and South-West Asia by Wetlands International (e.g. Delany et al. 1999). For African-Eurasian waterbird populations, comprehensive analyses have been compiled for Anatidae (ducks, geese and swans) (e.g., Scott and Rose 1996) and waders (Charadrii) (e.g., Stroud et al. 2002). Europe-wide national population trends for all bird species, including waterbirds, have been compiled by BirdLife International (BirdLife International/European Bird Census Council 2000). For other regions, although distributional data are available, comprehensive information on status and trends of waterbirds is generally lacking.

3.10.1 Gaviidae (loons, divers)

All populations of the 5 *Gavia* species are found in temperate regions (i.e. North America, Europe and Asia). None of the 5 species are considered threatened under the IUCN criteria. Trend information for the 5 species is available for only 5 of the 13 identified populations.The North American population of *G. pacifica* and part of the North American population of *Gavia immer* are stable, while the arctic population of *G. artica* and the Northwestern European and North American populations of *G. stellata* are decreasing (Wetlands International 2002).

3.10.2 Podicipedidae (grebes)

Grebes include 22 species distributed throughout all continents, although they are more predominant in the temperate to subtropical climatic zones. The status of grebes is summarized in Table 9.

Two species of grebes, the Colombian grebe and the Giant or Atitlan grebe, went extinct ca. 1970. The other possibly extinct species is Delacour's little grebe from Madagascar. Although this species is listed as critically endangered by IUCN, scientists currently believe that it is more likely that this species is already extinct (O'Donnel and Jon Fjeldsa 1997). The two critically endangered species are Delacour's little grebe and the Junin grebe, the latter of which is endemic and restricted to one single lake in Peru and whose population has undergone significant decline. Only a very small number of adults remains.

The major threats to grebes are habitat loss, particularly because of conversion to agricultural land and water abstraction for irrigation, domestic and industrial use. Additional threats include

Table 9. Grebe Species and Subspecies according to IUCN Threat Categories and their Geographical Distribution

	Africa	Eurasia	N. America	C. and S. America	SE Asia and China	Australasia/ Oceania	Total
Total taxa*	5	6	6	21	9	8	55
Extinct	1 (?)			2			3
Critically Endangered	1 (?)			1			2
Endangered				1			1
Vulnerable	1	1		4	3	5	14
Total Threatened	5	1	0	10	7	6	29

* Includes species and subspecies of grebes.

Source: O'Donnel and Jon Fjeldsa 1997

pollution from pesticides, eutrophication, siltation, recreation activities in lakes and wetlands, and the introduction of fish and other predators and competitors. The regions where the pressures on grebes and their habitats are greatest are Central and South America, followed by Southeast Asia and Australasia.

The IUCN/SSC Grebe Specialist Group has created a "Global Conservation Strategy to ensure the successful recovery of grebe populations and the management of wetlands." This Strategy includes 8 priority areas ranging from the immediate development and implementation of recovery plans for critically endangered grebe species and subspecies including lake restoration, public awareness campaigns, further assessment of grebe species listed as "data deficient," monitoring key grebe populations listed as vulnerable, and the development of methods for using grebes as keystone indicator species for monitoring wetland health and biodiversity (O'Donnel and Fjeldsa 1997). In terms of grebe population trends, out of a total of 73 identified populations, 12 populations are decreasing, 9 are increasing and 17 are stable. Trend information for the remainder of the populations is not available. It is however possible to highlight some regional trends. For example, of the decreasing populations, the majority are found in the Andean region, particularly populations in Peru and Bolivia, and in Africa, particularly in Madagascar (Wetlands International 2002).

3.10.3 Pelecanidae (pelicans)

There are 8 species of pelicans with 20 distinct populations, the majority of which are found in Asia, Africa, and the neotropics and fewer populations in North America, Eastern Europe, and Australasia. Because the available information does not separate the inland water populations from coastal or marine ones, we have included all populations in the trends analysis. In terms of the conservation and threat status of pelican species, IUCN lists only one species, the spot-billed pelican (*Pelecanus philippensis*) as vulnerable (IUCN 2002). There are 5 increasing populations all in the western hemisphere, 5 declining populations and 5 stable populations. Information on the remainder of the populations is not available (Wetlands International 2002).

3.10.4 Phalacrocoracidae (cormorants)

There are 40 species of cormorants and 77 identified populations worldwide. None of the freshwater dependent species within this family is listed as threatened by IUCN, however there are 10 species of marine cormorants that are threatened and one species, the Palla's cormorant (*Phalacrocorax perspicillatus*), that is extinct. The Pallas cormorant inhabited the Commander Islands in the Bering Sea and it went extinct in the late 1800s (IUCN 2002). Information on trends for other populations indicates that there are a total of 21 stable cormorant populations, 9 increasing and 8 decreasing (Wetlands International 2002).

3.10.5 Anhingidae (darters)

There are 4 species of darters, and nine distinct populations. No darter species is currently listed as threatened by IUCN. In terms of population trends there is information for only 7 populations, 5 of which are decreasing (Wetlands International 2002).

3.10.6 Ardeidae (herons, egrets and bitterns)

There are 65 species of herons and 261 populations distributed in all regions of the world. IUCN currently lists 8 species as either endangered or vulnerable. There are also 4 species that have gone extinct, including the New Zealand little bittern, the Réunion night heron, the Mauritius night heron and the Rodrigues night heron (IUCN 2002). Thirty-six populations are decreasing, 18 are increasing, and 42 are stable (Wetlands International 2002).

3.10.7 Balaenicipitidae (shoebill)

The single species in this group, *Balaenices rex*, is found exclusively in tropical Central Africa. The species is listed as near threatened by IUCN (IUCN 2002). The current population estimate is around 5,000-8,000 individuals with a decreasing population trend (Wetlands International 2002).

3.10.8 Scopidae (hammerkop)

This is also a single-species family found in Africa. There are 3 distinct populations of *Scopus umbretta* or hammerkop, however population trend information is only available for Madagascar. The Malagassy population, estimated at 60,000 to 90,000 individuals, is believed to be stable or possibly increasing (Wetlands International 2002). The species is not listed as threatened by IUCN.

3.10.9 Ciconiidae (storks)

There are 19 species of storks and 39 distinct populations. In terms of their conservation status, there are 3 species listed as endangered and 2 as vulnerable (IUCN 2002). The endangered species include the Japanese white stork (*Ciconia biyciana*), Storm's stork (*C. stormi*) and the greater adjutant (*Leptoptilos dubius*). The two vulnerable species are the lesser adjutant (*L. javanicus*) and the milky stork (*Mycteria cinerea*). Information on population trends is available for 29 of the 39 populations; of these 17 are decreasing, 4 are increasing and 8 are stable (Wetlands International 2002). Many of the decreasing populations are found in Southeast Asia and China, while most of the increasing populations are in Southern Africa and Europe.

3.10.10 Threskiornithidae (ibises and spoonbills)

There are 39 species of ibises and spoonbills and 67 identified populations. One wetland-dependent species, the Réunion flightless ibis (*Threskiornis solitarius)* has already gone extinct. Four other freshwater dependent species are threatened. These include 2 endangered species in Asia: the Japanese crested ibis (*Nipponia nippon)* and the Black-faced spoonbill (*Platalea minor)*; and 2 critically endangered species found in Southeast Asia: the White shouldered ibis (*Pseudibis davisoni)*, and the Giant ibis (*Thaumatibis gigantean)* (IUCN 2002). Of the populations for which there is trend information, 19 are decreasing, 16 are stable and 4 increasing.

3.10.11 Phoenicopteridae (flamingoes)

There are 5 species of flamingoes and 17 identified populations, most of them in Africa and the neotropics. Only 1 species, the Andean flamingo (*Phoenicoparrus andinus*) is listed as vulnerable to extinction (IUCN 2002). Of the populations, 3 are known to be decreasing, 6 increasing and 8 stable (Wetlands International 2002).

3.10.12 Anhimidae (screamers)

There are 3 species and 3 populations within this family. None of the species is listed as threatened by IUCN, but 2 of the populations are decreasing, while 1 is stable (Wetlands International 2002).

3.10.13 Anatidae (ducks, geese and swans)

There are 164 species and 462 identified populations within this family. With regard to their conservation status, IUCN lists 25 freshwater-dependent species as threatened and 5 as extinct. The extinct species include the Mauritian shelduck, the Mauritian duck, the Amsterdam Island duck, the Réunion shelduck and the Auckland Island merganser. There is also an additional marine species that has gone extinct, the Labrador duck. Among the threatened species, there are 5 critically endangered, three of which are probably extinct;

these include the Pink-headed duck (*Rhodonessa caryophyllacea*), the Madagascar pochard (*Aythya innotata*), and the Crested shelduck (*Tadorna cristata*). The critically endangered Campbell Island teal from New Zealand (*Anas nesiostis)* has a stable population, while the Brazilian merganser (*Mergus octosetaceus*) has a declining population (Wetlands International 2002). There are also 9 duck species considered endangered by IUCN, all of them with declining populations; these are the Madagascar teal (*Anas bernieri*), the Brown teal (*Anas chlorotis*), Meller's duck (*Anas melleri*), the Hawaiian duck (*Anas wyvilliana*), the Swan goose (*Anser cygnoides*), the White-winged wood duck (*Cairina scutulata*), the Blue duck (*Hymenolaimus malacorhynchos*), the Chinese merganser (*Mergus squamatus*) and the White-headed duck (*Oxyura leucocephala*) (IUCN 2002). Finally there are 11 species of freshwater ducks listed as vulnerable to extinction. Of the vulnerable species, the Auckland Island teal in New Zealand has a stable population, while the Laysan duck found in the Hawaiian Islands has an increasing population. The remaining vulnerable species, however, all have declining populations (IUCN 2002).

Looking at trend data for all duck populations, not just the threatened species, there are 130 decreasing populations, 75 increasing populations, and 121 stable populations (Wetlands International 2002).

3.10.14 Pedionomidae (plains-wanderer)

This is a single-species family. The Plains-wanderer (*Pedionomus torquatus)* is a species endemic to eastern Australia and although considered a grassland species it is highly dependent on water. It is classified as endangered by IUCN due to its small and declining population (IUCN 2002). The major threats to the species are the expansion of agriculture, the introduction of alien invasive species and land-based water pollution. The single population of plains-wanderer is decreasing with an estimated population between 2,500 and 8,000 birds (Wetlands International 2002).

3.10.15 Gruidae (cranes)

The 15 extant crane species are widely distributed throughout the world. They can be found in all continents except Antarctica and South America. They inhabit a wide range of climates from habitats in northern latitudes, like the Asian tundra, to the tropical regions of the world. East Asia is the most species-rich region, with 7 species of cranes occurring on a regular basis. The Indian subcontinent follows with 5 species occuring during the year. Africa has 4 species year-round, with 2 additional species during wintering periods (Meine and Archibald 1996). There are 49 identified populations of cranes, many of which are closely monitored because of their threatened status.

Cranes are among the world's most endangered families of birds, with 9 species listed as threatened by IUCN. The Siberian crane is critically endangered. The major threat to this species is habitat loss, in particular the destruction and degradation of wetlands in its passage and wintering grounds. The rich mudflats of Poyang Lake in China, constitutes its major wintering site, holding 95% of the population. This seasonal lake depends on annual flooding from the Yangtze River. The Three Gorges Dam, which has changed the hydrological regime of the lake, poses a major threat to the species. The Red-crown crane and the Whooping crane are both considered endangered, while the Sarus, Wattled, Hooded, Black-necked, Blue, and the White-naped cranes are all listed as vulnerable to extinction (IUCN 2002).

Information is available for 43 out of the 49 identified populations. Of these, 9 populations are increasing, 14 are stable and 20 are decreasing (Wetlands International 2002).

3.10.16 Aramidae (limpkins)

This is also a single-species family with 4 identified populations. Limpkins are found in the Western Hemisphere. There is only information for one of the populations in South America, which seems to be stable (Wetlands International 2002).

3.10.17 Rallidae (rails, gallinuls and coots)

There are 154 species of rails, gallinuls and coots, and 352 identified populations. The available information on population trends indicates that there are 30 extinct, 63 decreasing, 8 increasing, and 25 stable populations (Wetlands International 2002). In terms of their conservation status, IUCN lists 7 species as extinct, 1 as critically endangered, 7 as endangered, and 6 as vulnerable (IUCN 2002). The extinct species include the Red rail (*Aphanapteryx bonasia*), the Rodrigues rail (*Aphanapteryx leguati*), the Mascarene coot (*Fulica newtoni*), Dieffenbach's rail (*Gallirallus dieffenbachia*), the Tahiti rail (*Gallirallus pacificus*), the Lord Howe swamphen (*Porphyrio albus*), and the Laysan crake (*Porzana palmeri*). Madagascar's Olivier's crake (*Amaurornis olivieri*) is the only species listed as critically endangered, while the endangered species include the Zapata rail (*Cyanolimnas cerverai*), the Rusty-flanked crake (*Laterallus levraudi*), the Junín rail (*Laterallus tuerosi*), the Bogotá rail (*Rallus semiplumbeus*), the Plain-flanked rail (*Rallus wetmorei*), the White-winged crake (*Sarothrura ayresi*), and the Slender-billed flufftail (*Sarothrura watersi*). Finally, the 6 vulnerable species are the Brown wood-rail (*Aramides wolfi*), the Asian yellow rail or Siberian crake (*Coturnicops exquisitus*), the Hawaiian coot (*Fulica alai*), the Rufous-faced crake (*Laterallus xenopterus*), Woodford's rail (*Nesoclopeus woodfordi*), and the Austral rail (*Rallus antarcticus*).

3.10.18 Heliornithidae (finfoots)

This small family of odd aquatic birds is distributed in the tropical regions of the world. There are 3 species—each in a monotypic genus—and each fills a niche in the major tropical regions of the world. Seven distinct populations have been described. There is only 1 species threatened, the Asian finfoot (*Heliopais personata*), which is classified as vulnerable (IUCN 2002). This species is found in South and Southeast Asia, where the loss of wetland habitat is causing a decline in the population. Trend information is only available for one other population, the African finfoot population in Angola, which is also in decline (Wetlands International 2002).

3.10.19 Eurypygidae (sunbitterns)

The Sunbittern is a water-edge bird found in the Neotropics, from Guatemala to the Pantanal region of southern Brazil and Paraguay. There is only 1 species within the family and 3 identified and distinct populations. There is no population trend information and the species is not listed as threatened by IUCN.

3.10.20 Jacanidae (jacanas)

There are 8 species and 17 populations of jacanas. Information on population trends is available for 4 populations. The populations of Madagascar and Southeast Asia are both declining, while the one in Western Colombia and Venzuela and in Sub-Saharan Africa are stable (Wetlands International 2002). There are no *Jacanidae* species listed as threatened by IUCN.

3.10.21 Rostratulidae (painted-snipes)

The painted-snipes are a small family of shorebirds. The family is composed of just two species: the Greater painted-snipe (*Rostratula benghalensis*) distributed over the warmer parts of the Old World, including sub-Saharan Africa, tropical Asia, and eastern Australia, and the South American painted-snipe (*Nycticryphes semicollaris*) which is found throughout the southern third of South America. There are 4 populations of painted-snipes, however, information on trends is only available for the Eastern Australian population, which is decreasing (Wetlands International 2002). There are no species listed as threatened within this family.

3.10.22 Dromadidae (crab plover)

The crab plover is a wader of tidal mudflats from the NorthWest Indian Ocean, to the Red Sea, and the Persian Gulf where it breeds. There is only one species and one population (*Dromas aredeola)*. The species is not threatened and its stable population is estimated at 60,000-80,000 individuals. The population's non-breeding range extends to areas in coastal East Africa to Madagascar, and from coastal Pakistan to West India.

3.10.23 Haematopodidae (oystercatchers)

The Oystercatchers are a small family of shorebirds that have specialized bills for dealing with oysters, mussels, and limpets. There are 12 species and 21 distinct populations of oystercatchers. One species of oystercatcher, the Canary Islands black oystercatcher (*Haematopus meadewaldoi*), has become extinct and 1 species, the Chatham Island oystercatcher (*Haematopus unicolor*), is classified as endangered (IUCN 2002). Trend information is only available for 8 populations; five of which are increasing while 3 are stable (Wetlands International 2002).

3.10.24 Ibidorhynchidae (ibisbill)

This family has a single species, the Ibisbill (*Ibidorhyncha struthersii*). It is a unique wader inhabiting shallow, stony rivers at high-altitudes. The species is distributed across the central Asian highlands from Kazakhstan to Northwest China and south to northern India, including the Himalayan valleys and Tibetan Plateau. The species is not listed as threatened and information on its population is not available.

3.10.25 Recurvirostridae (stilts and avocets)

There are 10 species and 25 populations of stilts and avocets in all regions of the world. There is only one species listed as threatened, New Zealand's black stilt (*Himantopus novaezelandiae*), which is classified as critically endangered. Despite 20 years of intensive conservation and captive breeding efforts, this species remains one of the most threatened shorebirds in the world. Its current population is estimated at only 40 birds. The annual release of substantial numbers of captive-bred birds and predator control has probably prevented it from becoming extinct in the wild, but the numbers and productivity of wild pairs still urgently need to be increased (IUCN 2002). In terms of their population trends, there are 8 stable populations, 4 increasing, and 2 decreasing (Wetlands International 2002).

3.10.26 Burhinidae (thick-knees)

The thick-knees are a small family of birds that are predominantly terrestrial. There are 9 species and 25 identified populations. None of the species is classified as threatened by IUCN. Data on population trends are only available for 5 populations, all of which are decreasing (Wetlands International 2002).

3.10.27 Glareolidae (coursers and pratincoles)

This family of birds includes 17 species, with 46 distinct populations restricted to the Old World. Some of the species in this family, the coursers, are generally restricted to short-grass plains or deserts, often far from water. However most pratincoles are water edge birds inhabiting muddy margins of lakes or estuaries. The only species within this group listed as threatened by IUCN is Jerdon's courser (*Rhinoptilus bitorquatus*), which is critically endangered; this species is considered terrestrial (IUCN 2002). There is only trend information available for 12 out of the 46 populations, of which 4 are freshwater-dependent birds. These include the Black-winged pratincole population that breeds in Romania, Ukraine, southwestern Russia, and Kazakhstan, which is declining; the Madagascar pranticole population which is declining, the Black

Sea and eastern Mediterranean breeding population of Collared pranticoles, which is also declining; and the western Mediterranean breeding population of Collared pranticoles, which is stable.

3.10.28 Charadriidae (plovers)

The plovers include 67 species and 156 distinct populations. There are 31 plover populations decreasing, 12 increasing, and 18 that are stable (Wetlands International 2002). Several freshwater species within this family are listed as threatened by IUCN. These include one critically endangered species, the Javanese lapwing (*Vanellus macropterus*); one endangered species, the Saint Helena plover (*Charadrius sanctaehelenae*), and two vulnerable species, the Wrybill (*Anarhynchus frontalis*) and the Piping plover (*Charadrius melodus*) (IUCN 2002).

3.10.29 Scolopacidae (snipes, sandpipers and phalaropes)

Sandpipers are a highly diverse family, which includes some waterbirds but also ground-dwelling birds like the snipes and woodcocks, and highly pelagic birds like the Red phalarope. There are 90 species and 221 populations within the sandpiper family. In terms of their conservation status this family has 10 species classified as threatened by IUCN and two that have already gone extinct. Not all the species considered threatened are strictly freshwater species. Most inhabit grasslands, tundra or agricultural lands, and some, like the woodcocks, are considered terrestrial.

The 2 extinct species are the White-winged sandpiper (*Prosobonia ellisi*) and the Tahitian sandpiper (*Prosobonia leucoptera*). There are 2 species, the Eskimo curlew (*Numenius borealis*) and the Slender-billed curlew (*Numenius tenuirostris*) that are considered critically endangered. Among the species classified as endangered there are 2 predominantly terrestrial species, the Moluccan woodcock (*Scolopax rochussenii*), and the Sharp-billed sandpiper (*Prosobonia cancellata*), and 1 that is considered a freshwater species, the Spotted greenshank or Nordmann's greenshank (*Tringa guttifer*). The Spotted greenshank, found throughout Asia, has a very small, declining population as a result of the development of coastal wetlands throughout its range, principally for industry, infrastructure projects and aquaculture (IUCN 2002). Finally there are 5 vulnerable species. These include the Chatham Island snipe (*Coenocorypha pusilla*), the Spoon-billed sandpiper (*Eurynorhynchus pygmeus*), the Wood snipe (*Gallinago nemoricola*), the Bristle-thighed curlew (*Numenius tahitiensis*), and the Amami woodcock (*Scolopax mira*) (IUCN 2002). There are 51 decreasing populations, 12 that are increasing and 43 that are stable (Wetlands International 2002).

3.10.30 Thinocoridae (seedsnipes)

Seedsnipes comprise a small family of birds adapted to open habitats in South America. The family is comprised of 4 species and 10 distinct populations. There is no information on population trends and none of the 4 species is listed as threatened by IUCN.

3.10.31 Laridae (gulls)

Gulls comprise a large family of shorebirds, containing 52 species and 103 identified populations. Gulls are generally found along shorelines around the world, except in some tropical regions, but because of their high adaptive capacity they also occupy many man-made habitats. Most species are migratory to some extent. They are gregarious and not particularly territorial animals found usually in large numbers. There are 9 populations that are decreasing, 23 that are increasing, and 15 that are stable (Wetlands International 2002). In terms of their conservation status there are 6 species listed as vulnerable to extinction by IUCN, but none listed as endangered or critically endangered. The vulnerable species include Olrog's gull (*Larus atlanticus*), the Black-billed gull (*Larus bulleri*),

the Lava gull (*Larus fuliginosus*), the Relict gull (*Larus relictus*), the Chinese black-headed gull or Saunders's gull (*Larus saundersi*), and the Red-legged kittiwake (*Rissa brevirostris*) (IUCN 2002).

3.10.32 Sternidae (terns)

Terns are slim and graceful waterbirds, related to gulls. In fact, most authors place gulls and terns within the same family, Laridae. However, we have followed the nomenclature set forth by Wetlands International (2002), which considers terns as a separate family. There are 45 species of terns and 173 distinct populations. In terms of population trends, there are 23 populations decreasing, 11 increasing, and 23 that are stable (Wetlands International 2002). Only 1 species within this group, the Chinese crested tern (*Sterna bernsteini*) is listed as critically endangered by IUCN, another, the Black-fronted tern (*Chlidonias albostriatus*), is listed as endangered (IUCN 2002).

3.10.33 Rhyncopidae (skimmers)

The skimmers are a small family (3 species) of specialized shorebirds found in North and South America, Africa, and India. There is 1 species in each continent; the Black skimmer (*Rhynchops niger*) found in the Western Hemisphere with 4 distinct populations, the African Skimmer (*Rhynchops flavirostris*) with 2 populations, and the Indian skimmer (*Rhynchops albicollis*) with a single population. The African and Indian skimmer populations are both decreasing, while 1 population of Black skimmers in South America is stable and another in the United States is increasing (Wetlands International 2002). The Indian skimmer is considered vulnerable to extinction by IUCN. The major threat is degradation of rivers and lakes (IUCN 2002).

3.10.34 Waterbirds Population Trends Summary by Geographic Region and Flyways

The information on waterbird population trends by geographic region presented below is from the 3rd Edition of the *Waterbirds Population Estimates* (Wetlands International 2002). The geographic regions correspond to the six regional groupings of countries under the Ramsar Convention on Wetlands.

The trends in waterbird populations are better known in Europe, North America and Africa than in Asia, Oceania, and the Neotropics. The improved knowledge of waterbird populations in

Table 10. Waterbird Population Trends by Geographic Region

Geographic Region	Population Trend				Number of Populations		
	No. Stable	No. Increasing	No. Decreasing	No. Extinct	With Known Trend	Lacking Trend	Total Number
Africa	141	62	172	18*	384	227	611
Europe	83	81	100	0	257	89	346
Asia	65	44	164	6	279	418	697
Oceania	51	11	42	28	138	241	379
Neotropics	100	39	88	6	234	306	540
North America	88	62	68	2	220	124	344
Global Total[1]	404	216	461	60	1,138	1,133	2,271

[1] Global totals do not equal the sum of the column because a population is often distributed in more than one Ramsar Region.

* Most extinctions in Africa have been on associated islands.

Africa is apparent if compared to previous waterbird assessments and reflects the efforts by Wetlands International and BirdLife International in the 1990s to survey and assess waterbird populations in this continent. Overall, however, the number of populations for which there is no trend information remains high; therefore the numbers presented in Table 10 have to be interpreted with caution. In every region, the proportion of populations in decline exceeds those that are increasing. Nonetheless, it is important to note that detailed information is more readily available for smaller populations, which are more likely to be in decline. Asia and Oceania are the regions of highest concern for the conservation of waterbirds. Both regions have the highest number of known populations with decreasing trends, while at the same time trend information is lacking for most of the populations in these regions. Oceania also has the largest percentage of extinct populations, mostly small island endemic populations. In Africa and the Neotropics more than twice as many known populations are decreasing than increasing. In Europe and North America waterbird population numbers seem to be more equally distributed among the 3 categories (stable, increasing and decreasing). But at the global level, 41% of known populations are decreasing, 36% are stable and 19% are increasing. There is an urgent need to reverse these trends and increase the conservation efforts for freshwater-dependent birds.

Whilst analysis of population status by geopolitical region is informative, status assessment of biogeographical populations using the same migratory flyways can provide clearer insights into where and why certain populations are under threat or of special concern, as an essential basis to guide conservation actions. However, detailed analyses at the biogeographic population level for most waterbird taxa for the different flyways are not readily available. The following section presents a trend analysis of the wader (shorebird) species[6] with migratory populations using three African-Eurasian flyways[7], as an example of a biogeographic trend assessment. This type of analysis could be done for other regions of the world and other taxa based on existing population trend data.

Stroud et al. (2003) have assessed the change in the overall status of migratory wader populations since the late 1980s by comparing current information with trend estimates from the 2nd Edition of *Waterbird Population Estimates* (Rose and Scott 1997). The following section presents the results from this analysis. Almost all these populations are dependent on inland water systems for at least part of their annual cycle.

Of the 131 wader populations of 55 belonging to species which use these three African-Eurasian flyways population sizes were estimated for 125 populations and trend assessments made for 72 populations belonging to 32 species. Of these 72 populations, nine are increasing, five are stable or increasing, 15 are stable, two are stable or decreasing and 27 are decreasing. Overall, almost four times as many populations are decreasing than increasing.

Direct comparison of more recent (1990s) with earlier (1980s) trends was possible for only 32 of these populations. Of these, the status of 17 is unchanged (or probably unchanged) since the mid-1980s. Three populations, all on the East Atlantic flyway, are undergoing a long-term increase; 6 populations are long-term stable and 8 populations are in long-term, and sometimes serious, decline (see Table 11).

Based on this analysis, Stroud et al. (2003) concluded that there has been little change in overall status of migratory waders in Africa-Eurasia over the last 15-20 years. However, this overall pattern masks substantial changes in the status of individual populations. For some populations, notably those on the East Atlantic flyway, status is improving. However a significant num-

6 Species in families *Dromadidae, Haematopodidae, Recurvirostridae, Burhinidae, Glareolidae, Charadriidae and Scolopacidae.*
7 East Atlantic; Black Sea/Mediterranean; and West Africa/East Africa flyways.

ber of other populations, spread across all flyways, are in decline or have a deteriorating status (from increasing to stable).

In addition to populations in decline, populations can also be of conservation concern if they are small or if their status is deteriorating (from increasing to stable or from stable to decreasing). Further analysis using these criteria show that of the total of 115 populations of migratory wader species in Africa-Eurasia, 31 can be regarded as being at risk, because their populations are in decline and/or are small (see Table 11). A further 3 populations are also of concern since their population status has deteriorated from previous trend estimates, and 8 populations appear to be in long-term decline.

Of the populations at risk, 7 can be classified as being of major conservation concern because they have a small population of less than 25,000 birds, which is in decline. The best documented case is the Slender-billed curlew, which is now on the verge of extinction. The other 6 species are the Sociable plover with a rapidly declining population of only about 2,000 birds, the Baltic-breeding population of *schinzii* dunlin, the Black Sea/East Mediterranean population of Collared pratincole, the Black Sea/East Mediterranean population of Kentish plover, and the two small resident populations of Stone curlew in the Canary Islands.

Five further populations, all on the West Asian/East African flyway, are of concern as their populations are small (<25,000 birds), but there is no information on trends (see Table 11). Establishing the status of these populations should be considered a priority.

Only four small (<25,000 birds) populations of African-Eurasian migratory wader species are considered stable or increasing. These are the West African/East African population of Oystercatcher, West Mediterranean Collared pratincole and Avocets of the West Asian/East African and Southern African populations (see Table 11).

Also of conservation concern are 19 larger populations that are declining or possibly declining (see Table 11). Of these, the Kentish plover, Bar-tailed godwit, and *canutus* red knot populations on the East Atlantic flyway are of particular concern as they have undergone sharp declines. Likewise the Black-winged pratincole, breeding in West and Central Asia, is undergoing a significant decline.

Comparison of the characteristics of populations of conservation concern provides some insights into the possible reasons for decline or deteriorating status. Many of the most severely declining populations breed in the arid and semi-arid areas of the Middle East, west and central Asia, and the Mediterranean Basin, or primarily in European wet grassland habitats maintained through agricultural practices. Continuing loss of steppe breeding habitat through intensification of agriculture and irrigation schemes, coupled with increasing frequency and severity of drought and desertification, are considered as likely drivers behind the decline of breeding populations such as those of the Sociable plover and Black-winged pratincole.

According to Stroud et al. (2003) the reasons for the decline of certain populations on the East Atlantic flyway (Kentish plover, Bar-tailed godwit, and *canutus* red knot) are not yet clear. Because the declining populations are observed in different breeding areas, changes occurring in the breeding grounds seem unlikely. On the other hand, if the cause lies on wintering grounds it is unclear why these populations are in decline while other populations wintering in the same area of coastal West Africa are either stable or increasing (e.g. Curlew sandpiper). Further assessment of possible causes of decline, should be a priority for the long-term conservation of these migratory species and the habitats upon which they depend, perhaps focusing on the ecological status of migratory staging areas.

Likewise, the reasons for the increase of some populations are also unclear. None of these are in the West Asia/East African flyway, and most (six populations) are on the East Atlantic flyway. Some of the increasing populations use the same breeding and overwintering areas as other populations in decline. Different increasing populations use almost all parts of the wintering range on the flyway, and

come from different arctic and sub-arctic breeding areas (although none are wholly temperate zone breeders). The possibility of a link between population increase and different migratory strategies and/or extent of dependence on particular migratory staging areas requires further investigation.

3.11 MAMMALS

Although all terrestrial mammals depend on freshwater for their survival and many feed and drink in rivers and lakes or live in close proximity to freshwater ecosystems, only a small number of

Table 11. Populations of African-Eurasian Migratory Wader Species that are of Conservation Concern

Population Status and Trend	East Atlantic flyway	Black Sea/ Mediterranean flyway	West Asian/ East African flyway	Africa residents
Small declining populations:				
	Dunlin	Collared pranticole [Kentish plover] **Slender-billed curlew*	*Sociable plover*	*Stone curlew* (2 populations)
Small populations with unknown trend:				
			Black-winged stilt Greater sand plover (Black Sea/East Mediterranean and South-west Asia populations) Whimbrel Great knot	
Small populations not in decline:				
		Collared pranticole	Oystercatcher Avocet	Avocet
Large declining populations:				
	Golden plover **Kentish plover* *Bar-tailed godwit* Common redshank (2 populations) *Red knot* Dunlin	Stone curlew (2 populations) *Common snipe [*Jack snipe] *Black-tailed godwit (2 populations) [*Wood sandpiper] [Little stint]	**Black-winged Pranticole* [*Great snipe] [Eurasian curlew] [Ruff]	
Populations with deteriorating status (formerly stable, currently declining):				
	Red knot	[Little stint]		
Populations with deteriorating status (formerly increasing, currently stable):				
	Black-winged stilt Black-tailed godwit Bar-tailed godwit			

Source: Stroud et al. (2002)

Notes: Species in square brackets […] are those for which the population trend is possible but uncertain. Species in italic text are those that are in strong or very strong decline. Populations in long-term decline (i.e. also cited as declining in Rose and Scott (1997) are indicated with an asterisk (*)

mammals are considered aquatic or semi-aquatic. The following paragraphs provide a compilation of aquatic and semi-aquatic mammals by taxonomic order and geographic region. The mammals presented spend a considerable amount of time in freshwater and usually live in the riparian vegetation close to rivers, lakes, lagoons, ponds, etc. or in marshes and swamps, although they may forage and sleep on land.

3.11.1 Order Monotremata (monotremes)

One of the better-known and probably the oddest freshwater mammal is the Duck-billed platypus (*Ornithorhynchus anatinus*). It is the single species within its taxonomic family and one of the 3 species of living monotremes in the world. This group consists of egg-laying mammals, and the eggs are incubated outside the mother's body (Nowak 1991). The platypus lives in streams, lakes, and lagoons in eastern Australia and Tasmania. Historically, the platypus was hunted for its pelt, and consequently almost extirpated from its range. Government conservation strategies have allowed the species to recover, although river fragmentation from dams, habitat degradation from pollution and irrigation schemes, and entrapment with fishing gear still pose a threat to the species (Nowak 1991).

3.11.2 Order Marsupialia (marsupials)

In South America, there is a semi-aquatic marsupial, the water opossum (*Chironectes minimus*). This is the only marsupial adapted to semi-aquatic life, and the only opossum with webbed feet. Both sexes have a well-developed pouch, but, as opposed to other pouched mammals, in the female water opossum, the pouch opens towards the tail-end of the animal and a sphincter muscle closes the pouch to create a watertight compartment for the young (Emmons 1997). The species is categorized by IUCN as near threatened (IUCN 2002). The main reason for this conservation status is the inferred reduction in the population based on the decline in the quality of its habitat, mostly due to pollution (Ojeda and Giannoni 2000). Water possums live in and near rivers and stream, all over the neotropics, but there is very little information on their status, population trends, or threats to the species.

3.11.3 Order Chiroptera (bats)

Although many species of bats are associated with freshwater, only one group of fishing bats is included in this summary. These are the bulldog bats or fishing bats belonging to the family Noctilionidae. Two species from the genus *Noctilio* make up this family: the lesser bulldog bat (*Noctilio albiventris*) and greater bulldog bat (*Noctilio leporinus*). Both species feed on aquatic insects, and *N. leporinus* eats fish, frogs, and crustaceans as well. Fish-eating in bats are thought to have evolved from catching floating or swimming insects off the water. To capture fish, these bats fly within 20-50 cm of the water surface over ponds, rivers, strems and saltwater lagoons listening for prey. They use echolocation to detect ripples on the water surface made by swimming fish, crustaceans or amphibians. They then drag their hind claws, which are unusually large and sharp, through the water and catch the fish. Noctilionids are relatively large bats, often brightly colored (varying from bright red or orange in males to gray-brown in females) and with strong muscle structure. If knocked into the water, fishing bats can swim using their wings as oars, and are capable of taking flight from water (Animal Diversity Web 2002). They are found in tropical and subtropical parts of the Central and South America, including the Greater and Lesser Antilles. Their range extends from Southern Mexico to Northern Argentina and Southeastern Brazil. Both species are widespread and common.

3.11.4 Order Insectivora (insectivores)

This group of species includes the water-dependent shrews. In North America there are several species

of water shrews. Two of these (*Sorex palustris* and *Sorex bendirii*) extend throughout most of Canada, down to Northeast California, Utah, through the Great Lakes region and from New England all the way down the Appalachian Mountains to North Carolina. There is also an isolated population in the Arizona mountain region. One particular species is also found in Glacier Bay, Alaska (*Sorex alaskanus*) (Whitaker 1991). Water shrews are found along streams and lakes, or in wet forests. Many other shrew species also inhabit moist forests, or are close to streams, marsh, and swamp areas but are not considered water shrews. The fourth North American water-dependent shrew is the Swamp short-tailed shrew (*Blarina telmalestes*), which is found in Virginia (Whitaker 1991). These species are not listed as threatened by IUCN.

In Europe and Asia, there are also several species of water shrews. Three species belonging to the genus *Neomys* are found in Western and Southern Europe, Western Siberia and Pacific Siberian coast, Armenia and Georgia. Other species include the Elegant or Tibetan water shrew (*Nectogale elegans*), and six species of Asiatic water shrews (*Chimarrogale ssp.*) that inhabit streams in mountain regions at altitudes of up to 3300 m (Stone 1995). The Tibetan water shrew is distributed in mountain streams from southwest China to southeast Tibet, and the Himalayas to eastern Nepal (Stone 1995). Although very limited information is available on these species, two of them, the Malayan and the Sumatran water shrew are considered critically endangered, while a third species, the Borneo water shrew is considered endangered (IUCN 2002).

A particular and unique group of aquatic insectivores found in Europe are the desmans. There are two species *Desmana moschata* or Russian desman, which inhabits rivers in southwestern Russia, Belarus, Kazakstan, and Ukraine and the Pyrenean desman (*Galemys pyrenaicus*) found in the Pyrenees and the mountain regions of northern-central Spain, and northern Portugal (Nowak 1991). Both species are listed as vulnerable to extinction by IUCN (2002). The Russian species inhabits slow-flowing rivers, lakes, and ponds and is semi-aquatic, while the Pyrenean species is strictly aquatic and requires fast-flowing streams. The total population of Russian desmans is estimated to be between 40,000 and 50,000 individuals, while the population for the Pyrenean desman is not known (Nowak 1991; Stone 1995). The major threats to the Russian desman are hunting, water pollution, creation of impoundments, clearance of riparian vegetation, entanglement in fishing nets and competition for breeding sites with other exotic species (e.g. nutria and muskrat). For the Pyrenean species the major threats are water pollution and habitat fragmentation. Other threats are direct persecution from fishermen who incorrectly believe this species to be a threat to fish stocks, especially trout, or from eager collectors (Stone 1995). Finally the escape of North American mink from fur farms in northern Iberia is thought to have a negative impact on the species (Stone 1995).

A unique and threatened group of aquatic shrews found in Africa are the otter shrews. Otter shrews are the only survivals of a prehistoric group of animals that used to be widespread. They are closely related to the tenrecs, which are only found in Madagascar. There are 3 species of otter shrews, all with a very restricted distribution within the Congo basin, and west-central Africa (Kingdon 1997). The largest one, the Giant otter shrew (*Potamogale velox)* is found from Nigeria to western Kenya and southwards to central Angola and northern Zambia. The species inhabits slow flowing streams, forest pools, and stream banks in mountain areas and is endangered according to the IUCN Red List (IUCN 2002). Because it depends on its sight for hunting prey, soil erosion caused by deforestation and loss of riparian habitat are major threats to the species. Water turbidity from siltation is especially a problem in Cameroon (IUCN 2002). Other important threats affecting the species are hunting for its skin, entrapment with fishing gear, and fragmentation of the population (IUCN 2002). The other two species of otter shrews, the

Mount Nimba and Ruwenzori otter shrews, are much smaller and also endangered. They are both being heavily affected by water pollution especially from mining operations. The Mount Nimba otter shrew is found in Cote d'Ivoire, Guinea and Liberia and the Ruwenzori otter in Congo and Uganda (IUCN 2002).

In Madagascar there is a group of semi-aquatic insectivores called ternecs. Some of the Malagasy tenrecs, like the 3 species of rice tenrecs, are usually found in marsh areas and on the banks of rice paddies, where they burrow. Finally the Aquatic or Web-footed tenrec (*Limnogale mergulus*) from eastern Madagascar is considered to be endangered (2002). The major threat is siltation and soil erosion caused by deforestation because the species requires clear, fast flowing water (Nowak 1991).

3.11.5 Order Lagomorpha (rabbits and hares)

The semi-aquatic freshwater mammals within this order are primarily found in North America. These are the Marsh and Swamp rabbits, *Sylvilgus palustris* and *Sylvilgus aquaticus* (Whitaker 1991). These species live in swamps, marshes, lake borders and coastal waterways. Marsh rabbits are found in the Southeast of the U.S. (Florida and up the coast to Southeast Virginia). Swamp rabbits are found from eastern Texas and Oklahoma, to South Illinois and North Georgia (Whitaker 1991). Neither species is considered endangered by IUCN, although a subspecies of marsh rabbit, the Lower Keys marsh rabbit, has been listed as endangered since 1990 by the U.S. Fish and Wildlife Service (USFWS 2002).

There is also a riverine rabbit in South Africa (*Bunolagus monticularis*). This species, habituated to seasonal rivers, is one of the most threatened species in South Africa. It inhabits dense riverine scrub along seasonal rivers in the central Karoo Desert of South Africa's Cape Province. This species is classified as endangered (IUCN 2002). The major threat to the species is habitat loss from conversion to agriculture, firewood collection and overgrazing by sheep. Other threats include hunting with dogs, predation from uncontrolled dogs, trapping, and dam construction, which alters the river flow. There are several organizations involved in the conservation of the species including WWF-South Africa, Cape Nature Conservation, Northern Cape Nature Conservation, and the Society for the Conservation of Species and Populations of South Africa (Riverine Rabbit Conservation Project Web Site 2002).

3.11.6 Order Rodentia (rodents)

Some of the best known semi-aquatic mammals are the beavers. The North American beaver (*Castor canadensis*) is found only in North America and it is one of the two species within the Castoridae family. It extends throughout freshwater habitats all over North America with the exception of Florida, Nevada and southern California (Whitaker 1991). The other beaver species (*Castor fiber*) is found in Europe and Asia, except for the Mediterranean region and Japan. These semi-aquatic mammals are among the largest rodents in the world. Both beaver species used to be widely distributed but their populations declined drastically from hunting for the fur trade and the modification and fragmentation of rivers (Nowak 1991). By early 1900 only a few small and scattered populations of beavers remained in Europe and North America. Some conservation measures in both regions, including introductions, have allowed the species to recover especially in Scandinavia and some parts of North America. Currently the major threats to the species are water pollution, wetland drainage, and hydroelectric plants (Nowak 1991; Whitaker 1991).

Other groups of rodents that live in freshwater habitats, especially freshwater marshes, are the rice rats, muskrats, and water voles. In North America there are 2 species of rice rats, the Marsh rat (*Oryzomis palustris)* and the Key or Silver rice rat (*O. argentatus*) (Whitaker 1991). The first species is found throughout Southeast U.S. and part of the Mid-Atlantic States, the second one is

found only in Cudjoe Key, Florida. The North American water vole (*Arvicola richardsoni*) is found along upland streams and lakes, from southeastern and southwestern British Columbia, southwestern Alberta, to central and eastern Washington and Oregon, North Idaho, North-Central Utah, western Wyoming and western Montana (Whitaker 1991). The North American muskrat species include the Florida water rat (*Neofiber alleni*) found in South Georgia and Florida, and the Common muskrat (*Ondatra zibethicus*) found in most of North America, except southern part of theU.S. (Florida through Texas, California and Georgia) (Whitaker 1991). Finally the Nutria (*Myocastor coypus*), which is native to South and Central America, has been introduced to North America and can be found especially in the Southeast, but also in the Mid-Atlantic region, in the Great Plains and the Pacific Northwest (Whitaker 1991).

The aquatic and semi-aquatic rodents in Africa include different species of water rats. The Marsh cane rat (*Thryonomys swinderianus*) is found throughout central Africa, parts of western Africa and down the coast in east Africa in waterlogged valley bottoms with abundant grasses and reeds. This species is not endangered (Kingdon 1997). The shaggy swamp rats, which live in swamps, marshes, and wet grassy areas of sub-Saharan Africa, especially at high altitudes (i.e., in moss bogs) and include 5 species from the genus *Dasymys* (Kingdon 1997). There is very little information on these species, 3 of which are classified as data deficient by IUCN and one, *D. montanus* as vulnerable to extinction (IUCN 2002). According to Kingdon (1997) the genus requires taxonomic revision. Other semi-aquatic rodents found in Africa are the creek rats (5 species of the genus *Pelomys*). These live in marshes, reed beds, lakeshores and mountain bogs in central and eastern Africa. There are 2 species in these genus found in Uganda and Rwanda that are considered vulnerable by IUCN because of their restricted distribution and habitat, although information on these species is very limited (IUCN 2002). Finally, there are 4 species of long-eared marsh rats in Africa in the genus *Malacomys* that are found in thick vegetation near water (Nowak 1991).

The best-known aquatic rodents in Central and South America are the Capybara (*Hydrochaeris hydrochaeris*) and the Nutria (*Myocastor coypus*). The Capybara is a large rodent that lives in vegetated areas near rivers, lakes, ponds, and other wetlands. It is hunted throughout its range for its meat, hide, fat (which is used in medicines), and teeth (for use as ornaments by local populations), and sometimes deliberately killed because it is considered an agricultural pest. The populations in Venezuela and Peru have declined considerably, but it is still common in other areas, and is sometimes raised in ranches for commercial purposes (Nowak 1991). The nutria is native to Southern Brazil, Bolivia, Paraguay, Uruguay, Argentina and Chile and lives in marshes, lakeshores, and slow-flowing streams (Nowak 1991). Its major threat is hunting for its fur and meat, which continues throughout its range and seems to have affected the populations in South America. The species has extended its range through intentional or accidental introductions and is now found in North America, and parts of Europe and Asia, including Japan. In South and Central America, there are also numerous species of semi-aquatic rodents usually called water rats, swamp rats, water mice, etc. Among the species commonly known as water rats there are:

- three species from the genus *Nectomys*, which are widespread and common throughout tropical areas of Latin America, except for *N. parvipes*, which is restricted to French Guiana and is critically endangered (IUCN 2002);
- the single species of its genus, *Scapteromys tumidus,* found from southern Paraguay and Brazil to Uruguay and northeastern Argentina;
- the single species *Anotomys lenader* or Fish-eating rat, from the Andes region north of Ecuador;
- four species of web-footed rats or marsh rats in the genus *Holochilus* distributed throughout the wetter areas of South America; and

- the Andean swamp rat (*Neotomys ebriosus*), which can be found from central Peru, Bolivia to the northern parts of Chile and Argentina (Emmons 1997; Nowak 1991).

South and Central America also have 4 species of crab-eating rats (*Ichthyomys spp.*). Crab eating rats are always found near freshwater (not salt or brackish water) and require clear and fast flowing streams. The species are not very well known, and usually found in small streams in hilly or forested areas. Crab-eating rats have been recorded in the eastern slope of the Andes in Ecuador and Peru, the western slope of the Andes from Panama to Ecuador, and in the coastal mountain range in Venezuela (Emmons 1997). One species, *I. pittieri*, found in Venezuela is vulnerable to extinction (IUCN 2002).

There are also 5 species of water mice in Central America (*Rheomys spp*.) and 4 species of South American water mice (*Neusticomys spp*.) but there is little information on these species. All species are considered rare or difficult to capture (for further study) and the 4 South American species found in Peru, Venezuela, and the Guyana Shield, are considered endangered by IUCN because of their restricted habitat (Emmons 1997; IUCN 2002).

In Europe there are 2 species of water voles that have aquatic and non-aquatic populations (*Arvicola sapidus and A. terrestris*). The aquatic populations of *A. terrestris* are found mostly in Western Europe, while *A. sapidus* is only found in France, Spain, and Portugal. *A. sapidus* is classified by IUCN as being at lower risk of extinction, but under the category of "near threatened," meaning that the species is close to qualifying for a threatened status (Nowak 1991, IUCN 2002).

In Oceania, there are 4 species of beaver rats in the genus *Hydromys*, which are large aquatic rats, found in marshes, swamps and other wetland areas from Papua New Guinea to Australia and some of the South Pacific islands (Nowak 1991). One species from Papua New Guinea, *H. neobrittanicus,* is vulnerable (IUCN 2002). There are also 2 unique species in Papua New Guinea that inhabit riparian areas along mountain streams, the Mountain water rat (*Parahydromys asper*), and the Earless water rat (*Crossomys moncktoni*), both found at high elevations on the island (Nowak 1991).

3.11.7 Order Carnivora (carnivores)

3.11.7.1 Otters and other mustelids

Although many North American carnivores fish in rivers and lakes, or live in close proximity to freshwater ecosystems, only a few are characterized as freshwater-dependent mammals. These include the American Mink (*Mustela vison*) and the river otter (*Lutra canadensis*). The Mink is found almost taxonomic throughout North America, except for the more arid areas ofsouthern California, Arizona, southern Utah and New Mexico, and western Texas. The River otter is distributed throughout most of Canada and south to northern California and Utah. It is also found in the East from New Foundland south to Florida, with the exception of the Midwest, where is has disappeared (Whitaker 1991).

Another mustelid found in Europe is the European mink (*Mustela lutreola*). Like the American mink, this species lives in dense vegetation on the banks of rivers, lakes and streams. This species has been hunted and trapped for its fur for centuries, its habitat has been heavily affected by dams and canals, as well as water pollution, and more recently the species has suffered from competition from exotic species, particularly from the American mink. The American mink was introduced to Europe originally as part of the establishment of fur farms. However, individuals quickly escaped from farms or were accidently released into the wild, where they adapted very well to the European environment, to a point where they displaced and outcompeted the native species throughout much of the continent. It is estimated that the European mink only survives in Finland, eastern Poland, parts of the Balkans, south-western France and northern Spain, as well as in Russia, where its population has declined to around 40,000

(Nowak 1991). The species is considered endangered (IUCN 2002).

In Africa there are 4 species of otters: the Congo claw-less otter (*Aonyx congica*), the Capeclaw-less otter (*Aonyx capensis*), the Common or Eurasian otter (*Lutra lutra*), and the Spot-necked otter (*Lutra maculicollis*) (Kingdom 1997). All otters in Africa are hunted for their fur and meat, or because they are perceived by rural communities and fishers as competitors for food (fish). Habitat degradation, deforestation, siltation, water pollution, wetlands drainage, water diversions, and river fragmentation, have all affected the habitat and distribution of otters in Africa. In addition, entrapment with fishing gear is also a cause of high otter mortality. Otter populations are declining throughout Africa (Nel and Somers 1998). However, the current knowledge and understanding of the biology, status and distribution of the three sub-Saharan otter species is very poor. The two claw-less otters are hunted because of their soft fur. The Congo claw-less otter occurs in central Africa, particularly in the Congo River basin, as well as the forests and wetland areas of Rwanda, Burundi, and southwestern Uganda. This species is the least known of the three African otter species, and no detailed ecological study on this species is believed to have been published (Nel 1998). In spite of its name the Common otter is almost extinct in Africa and considered vulnerable to extinction by IUCN. Its range used to extend from Morocco to Tunisia. Hunting, water pollution, habitat fragmentation and degradation, and siltation of rivers due to deforestation are the main causes for its disappearance. The Spot-necked otter requires clear water to hunt. The major threat to this species, which is distributed throughout the wetter parts of central and western Africa and parts of South Africa, is the increased silt load (turbidity) in many African rivers resulting from deforestation and agricultural activities. Populations are declining throughout its range, especially in South Africa, and it is considered vulnerable to extinction (IUCN 2002; Kingdon 1997).

In South and Central America there are 3 species of freshwater otters. The Neotropical otter, which is widely distributed from Mexico to northern Argentina (*Lutra longicaudis*), the Southern river otter or Huillin (*Lutra provocax*) found in southern Chile and western Argentina, and the Giant Brazilian otter (*Pteronura brasiliensis*) found from Venezuela to northern Argentina, and from the headwaters of some Amazon tributaries to the Pantanal region (Foster-Turley et al. 1990). The Southern river otter used to have an extensive distribution from the Cauquenes and Cachapoal Rivers to the Magellan region in Chile. Its current population, however, is restricted to just seven isolated areas from Cautín to Futaleufú. This population decline is driven by habitat loss, deforestation, removal of river bank vegetation, river and stream canalization and dredging, dams, and poaching—especially in southern Chile. The remaining populations are highly fragmented, and therefore more susceptible to local extinctions. *L. provocax* is considered endangered by IUCN and listed in the *Chilean Red Data Book of Vertebrates* as being in danger of extinction. It is also listed as endangered in the *Argentine National Wildlife List* (IUCN 2002).

The Giant Brazilian otter is the largest of all the 13 otter species and is endemic to the rainforests and wetlands of South America. It is known to inhabit large rivers, streams, lakes and swamps of the lowland areas with gentle flow and oxbow lakes with high fish densities. The distribution of *Pteronura brasiliensis* has declined dramatically in its former range and estimates suggest that it has probably already been extirpated from Uruguay and Argentina. Deforestation, soil erosion, decrease of prey abundance, over-fishing and illegal hunting of otters are the major threats to the species. Canine diseases, such as parvovirus and distemper, transferred through the domestic stock are also a threat. Finally, mining operations that contaminate rivers and fish with mercury also have a negative impact on the species. The species is listed as endangered (IUCN 2002).

In Europe and Asia, the most widely distributed species is the Eurasian otter (*Lutra lutra*), but many populations are declining and today it is considered vulnerable to extinction (IUCN 2002). The Eurasian otter has the widest distribution of all otter species. Its range covers parts of three continents: Europe, Asia and Africa. Originally the species was widespread throughout Europe. Little is known about the original distribution in Africa and Asia. In Europe, otters inhabit many different types of aquatic habitats, including lakes, rivers, streams, marshes, swamp forests and coastal areas. The aquatic habitats of otters have been modified and destroyed throughout its range. The building of canals, dams, the draining of wetlands, and aquaculture activities have all impacted the otter populations negatively. In addition water pollution and acidification pose major threats, particularly in western and central Europe. Illegal hunting continues to be a problem in many parts of its distribution range. In several European countries political pressure, especially by fishermen, has resulted in granting of licenses for killing otters (IUCN 2002).

In Asia there are 3 additional species of otters, the Hairy-nosed otter (*L. sumatrana*), the Smooth-coated otter (*L. perspicilata*) and the Oriental small-clawed otter (*Amblonyx cinereus*), which is the smallest species (Foster-Turley et al. 1990). Little is known about the biology and distribution of the Hairy-nosed otter, which is classified as data deficient by IUCN. The Hairy-nosed otter is endemic to Southeast Asia and has been reported from Java, Borneo, Sumatra, Malaysia, Thailand and Indochina. Major threats to this species are habitat destruction, depletion of its prey base, and road kills. The oriental small-clawed otter is found in India, the Himalayan foothills, and eastwards throughout Southeast Asia to the Philippines (IUCN 2002). It inhabits freshwater and peat swamp forests, rice fields, lakes, streams, reservoirs, canals, mangroves and coastal areas. Like with other otter species, the major threat is habitat degradation from agriculture, development activities, aquaculture, water pollution, overexploitation of fish, and siltation of streams due to deforestation. Increased influx of pesticides into the streams from the plantations reduces the quality of the habitats. The Smooth-coated otter is found from Iraq through South and Southeast Asia and southern China. In general it inhabits large rivers and lakes, peat swamp forests, mangrove forests along the coast and estuaries, and even rice paddies in Southeast Asia. The major threats are loss of wetland habitats due to construction of large-scale hydroelectric projects, reclamation of wetlands for settlements and agriculture, reduction in prey biomass, poaching and contamination of waterways by pesticides. The species is listed as vulnerable to extinction (IUCN 2002).

3.11.7.2 Viverrids

The Marsh mongoose (*Atilax paludinosus*) lives in rivers and lakeshores throughout the wet areas of sub-Saharan Africa (Kingdon 1997). The species is still believed to be widespread and common, although its populations have drastically declined from hunting and habitat loss in the last decades (Nowak 1991). Other mongooses, such as the Malgassy mongoose in Madagascar and the West-Bangal marsh mongoose in India, are however endangered (IUCN 2002).

The Otter civet (*Cynogale bennettii*), found near streams and swamps in northern Vietnam, Borneo, Sumatra and the Malay Peninsula (Nowak 1991), is also considered endangered by IUCN (2002).The Aquatic genet (*Osbornictis piscivora*) lives in the shallow headwaters of streams within forested areas, where the water is clear. It is reported from the upper reaches of the Congo tributaries. It is an extremely rare carnivore and likely to become vulnerable, but not enough information on the species is available to assess its status (Kingdon 1997). The Crab-eating mongoose is also a semi-aquatic mammal found in Asia, from Nepal to Thailand and Indonesia (Lekagul and McNeely 1988).

3.11.7.3 Felines

Two feline species that are strongly associated with wetlands and spend most of their time hunting for fish, amphibians and invertebrates near rivers, swamps, marshes, and mangroves are the Fishing cat (*Prionailurus viverrinus*) and the Flat-headed cat (*Prionailurus planiceps*), both species with webbed toes that allows them to hunt in water. The Fishing cat is found from Pakistan to Southeast Asia, including Sri Lanka, Sumatra and Java, but its distribution is very discontinuous, with presence in some of the Indonesian islands, but absent in much of the Malay Penninsula (Nowak 1991; Nowell and Jackson 1996; IUCN 2002). In India, the Fishing cat is found in the valleys of the Ganges and Brahmaputra rivers, and along the upper part of the east coast. In Pakistan, it is mainly found along the lower reaches of the Indus River, and in Java it seems to be confined to a few coastal wetlands. The major threats to the species are habitat loss by human encroachment, conversion of wetlands for agriculture, clearing of mangroves for aquaculture, and water pollution by pesticides. A review of the condition of wetlands in Asia for wild cats, for example, shows that half of more than 700 wetland sites were highly or moderately threatened by human activities (IUCN/SSC Cat Specialist Group 2002). More field studies and information is needed on this species. The species is considered vulnerable to extinction, and it is highly threatened in some localities such as the south-western coast of India, the deltas of the Irrawaddy, Indus, Mekong and Red Rivers, and in Java, where the fishing cats are "probably on the verge of extinction" (Nowell and Jackson 1996; IUCN/SSC Cat Specialist Group 2002). The species is listed in CITES Appendix II and legally protected over most of its range (Nowell and Jackson 1996).

The Flat-headed cat is very rare, and not much information on this species particularly in the wild is available. The species is classified as vulnerable to extinction and believed to inhabit areas in Malaysia, Indonesia, Myanmar, Brunei Darussalam, and Thailand (IUCN 2002). The major threat to the Flat-headed cat throughout its range is water pollution, with toxic elements accumulating in the fatty tissue of its prey. Of special concern is pollution by oil, organochlorines, and heavy metals associated with agricultural run-off and logging activities (Nowell and Jackson 1996). In addition, habitat loss and degradation contribute to the reduction of population and put pressure on the species. The Flat-headed cat is included on CITES Appendix I. The species is fully protected by national legislation over most of its range, with hunting and trade prohibited in Indonesia, Malaysia, Myanmar and Thailand, and hunting regulated in Singapore (Nowell and Jackson 1996).

3.11.7.4 Freshwater seals

There are several species and subspecies of freshwater seals belonging to the family Phocidae also known as true seals or earless seals. These include the Lake Baikal seal (*Phoca sibirica*) and the Lake Ladoga seal in Russia and the Lake Saimaa seal in Finland. The two later are subspecies of *P. hispida (P. h. ladogensis and P. h. saimensis*) (Reijnders et al. 1993).

The Lake Baikal seal is the only pinniped that is restricted to freshwater and is found only in Lake Baikal, Russia. It was heavily hunted in the first part of the century for meat, oil and pelt and as a consequence the population declined drastically in the 1930s. The current population is estimated at 60,000-70,000 individuals, with an annual allowed commercial kill of 5,000-6,000 seals (Nowak 1991; Reijnders et al. 1993). The threats to, and pressures on, these seals are stemming mostly from pollution from pulp and paper mills and from the manner in which they are harvested. Many seals are shot but left to die. Others, mostly pups, are affected by disturbance from boats and gunners when on shore, causing high mortality rates. In 1981, for example, close to 10,000 pups died because of disturbance. It is estimated that mortality from hunting is 20-40% higher than the commercial records

indicate and that the focus on hunting young seals for their pelt is causing a change in the population structure that may have consequences (Reijnders et al. 1993).

The Lake Ladoga seal is only found in this lake in the region of Karelia in Russia. The estimated population in 1992 was between 10,500 and 12,500 individuals (Reijnders et al. 1993). The species is considered as vulnerable to extinction (IUCN 2002). The species is legally protected and cannot be harvested, although 200-300 individuals are caught annually as bycatch in the local fisheries (Reijnders et al. 1993). The other subspecies of *P. hispida* is found exclusively in the Finish Lake Saimaa. This species is classified as endangered (IUCN 2002). The greatest threats are entanglement in fishing gear, pollution, and increasingly lakeshore development, boating, tourism and water level control for a power plant. This last threat causes the ice sheets to break, which during breeding season leads to many deaths of newborn pups. Even though the species has been protected since 1955, and fisheries have been banned from main breeding areas, as of 1991, only 160-180 individuals remain (Reijnders et al. 1993.)

Finally, there is a population or a subspecies (depending on the author consulted) of the Common or Harbor seal that is found in freshwater: the *Phoca vitulina mellonae* or Ungava seal (Reijnders et al. 1993). This seal is also known as Seal Lake seal and Lac des Loups Marins seal because of its distribution in several lakes in the Canadian province of Quebec. The species' status has not been assessed because of insufficient information. However, hydroelectric development in the Nastapoca River will most likely cause a change in the water level of the area lakes posing a threat to the species.

3.11.8 Order Sirenia (manatees)

Sirenians are aquatic mammals that live in coastal and freshwater regions of the tropics. There are 4 species of sirenians in the world, the dugong, a marine mammal found in the Indian Ocean and the South Pacific, and three species of manatees: 1 in the coastal waters and some rivers of Central-West Africa, 1 in the Amazon basin and 1 in South America and the shores of the Caribbean, including Florida (Nowak 1991). This latter species is known as the West Indian manatee (*Trichechus manatus)*. It is vulnerable to extinction according to IUCN, and even rare or extinct throughout much of its range (IUCN 2002). This is the only sirenian species in North America, where it can be found along the Southeast coast of the U.S. up to North Carolina (Nowak 1991; Whitaker 1991). It lives in coastal waters, bays, rivers and lakes. It is hunted in South and Central America for meat, while in the U.S. the biggest threat is accidental killing with boat propellers. Currently the U.S. government is trying to restore the species in the US, where it performs an important ecosystem service by reducing the amount of water hyacinth that chokes many waterways (Whitaker 1991).

Trichechus inunguis lives in areas with dense aquatic vegetation in the Amazon River and lower reaches of its tributaries. This is the only manatee that lives exclusively in freshwater. It used to be common but its populations have collapsed due to hunting for their meat and skin. The Amazon manatee is vulnerable to extinction and legally protected, but still continues to be hunted (Nowak 1991; IUCN 2002).

The third manatee species is the West African manatee (*Trichechus senegalensis)*, which lives in coastal water and rivers from Senegal to Angola and is also considered vulnerable to extinction (Nowak 1991; IUCN 2002).

3.11.9 Order Artiodactyla (even-toed ungulates or hoofed mammals)

The most well known freshwater mammals in this order are the hippopotami, which only occur in Africa. There are two living species, the common hippopotamus (*Hippopotamus amphibius*) and the pygmy hippopotamus (*Hexaprotodon liberiensis*)

(IUCN/SSC Hippo Specialist Subgroup 2003). Historically the range of the common hippopotamus extended throughout Africa from the Nile delta all the way to the Cape, wherever there was permanent water and grazing area (Nowak 1991). Currently its distribution is limited and in 1993 the estimated population in Africa was around 157,000, the largest population being in Zambia with 40,000 individuals (IUCN/SSC Pigs and Peccaries Specialist Group, and the IUCN/SSC Hippo Specialist Group 1993). The major threats to these animals are habitat loss from water reclamation and diversion for agricultural and large scale development projects, which are increasing in Africa with population growth and competition for water resources, and illegal hunting for meat and ivory (Lewison pers. comm. 2002). Legal and illegal trade in hippo teeth (ivory) has increased in recent years. Illegal hunting for meat has also occurred extensively in areas with civil unrest (e.g., in Uganda and the Democratic Republic of Congo) (Kingdon 1997; Lewison pers. comm. 2002; IUCN 2002). The international trade ban on elephant ivory has encouraged the poaching and hunting of hippopotamus for their teeth, as an alternative. The annual export of hippo teeth for example, increased by 530% within two years of the ivory ban taking effect (IUCN/SSC Hippo Specialist Subgroup 2003). The last population trend estimates for this species published in 1993, showed that the species was declining in 18 countries, was stable in 6 or 7, and increasing only in 2: Congo and Zambia. For eight additional countries the population trend in common hippos is not known, and it is thought that it has disappeared from 2 countries: Liberia and Mauritania (IUCN/SSC Hippo Specialist Subgroup 2003). The hippo is not listed as threatened by IUCN, however the subspecies from Chad and Niger is listed as vulnerable (IUCN 2002).

The pygmy hippo inhabits forested waterways, and today is only found in isolated populations in very restricted locations near river deltas in coastal West Africa (Kingdon 1997). IUCN lists the pygmy hippopotamus as vulnerable to extinction in Côte d'Ivoire, Guinea, Liberia, and Sierra Leone. The subspecies found in Nigeria is considered critically endangered (IUCN 2002). Information on this species, however, is limited. The SSC Hippo Specialist Subgroup estimates that "at best, 3000 pygmy hippos may still remain" in the wild and that only "isolated populations may exist in the neighboring countries of Cote d'Ivoire and Sierra Leone, however these groups may be numbered in no more than the dozens" (IUCN/SSC Hippo Specialist Subgroup 2003). The major threats to pygmy hippos are deforestation and habitat fragmentation, pollution especially from oil, and hunting (IUCN/SSC Pigs and Peccaries Specialist Group, and the IUCN/SSC Hippo Specialist Group 1993).

Other freshwater-dependent ungulates not classified strictly as freshwater mammals but that spend considerable time foraging in or around freshwater are also included in this section. One such mammal is the moose or elk (*Alces alces*), which is distributed throughout Canada, Alaska, the Rocky Mountains, and into Maine and Minnesota in the United States, as well as in Northern Europe, the Caucasus, and eastern Siberia (Whitaker 1991). This species is not endangered.

Similarly, in Asia there are two deer species that spend considerable time foraging among reeds and rushes along rivers, and in and around swamps and marshes. These are the Chinese water deer (*Hydropotes inermis*), which inhabits the lower reaches of the Yangtze basin, Korea, and has been introduced into France and the United Kingdom (Nowak 1991) and Père David's deer (*Elaphurus davidianus*), which originally was found in northeastern and east-central China, but has disappeared from the wild. Today it is only found in zoological parks and reserves around the world, or in small re-introduced populations. According to WWF and WCMC (1997) in 1992, a re-introduced herd in DaFeng Reserve, Jiangsu Province, numbered 122 animals. This species is considered critically endangered (IUCN 2002). The Chinese water deer is classified as lower risk, but close to becoming vulnerable (Wemmer 1998).

Another water-dependent ungulate found in the region is the Asian water buffalo (*Bubalus bubalis*). This species ranges from India and Nepal to Malaysia and Vietnam and lives in wet grasslands, swamps and densely vegetated river valleys (Nowak 1991). The wild Asian water buffalo is considered endangered with an estimated total population of less than 4,000 animals. Some estimates suggest that this number is much lower, closer to 200 animals, and that most are probably not purebred. However, IUCN points out the difficulty in assessing the status of this species because of the problems distinguishing domesticated buffalos, feral buffalos, hybrids and their wild relatives (IUCN 2002). The major threats to the species are interbreeding with domestic and/or feral buffalo, hunting, and habitat loss.

There are also some semi-aquatic ungulates in Africa. One example is the sitatunga (*Tragelaphus spekei*), which spends most of its time in grass beds within swamps. It is distributed from Gambia to southern Sudan, and south to northern Bostwana. The species is not endangered. There is also an African water chevrotain, but information on this species is very scarce (Wemmer 1998). The other group of ungulates that depends highly on water resources are the 5 species from the genus *Kobus.* This group includes the waterbuck, two species of lechwes, the kob, and the puku. These animals usually live in swamp areas, moist savannahs and floodplains (Nowak 1991). All species are considered at lower risk of extinction, except for two subspecies of lechwes that are listed as vulnerable, the Kafue lechwe and the Black lechwe, both found in the Kafue flats in Zambia (IUCN 2002).

In South America, from southern Brazil and Peru to northeast Argentina and Urugay, the Marsh deer (*Blastocerus dichotomus*) lives in marshes, wet savannahs, and damp forest edges. It is considered vulnerable to extinction mainly from habitat loss and competition from exotic species (Nowak 1991; Wemmer 1998; IUCN 2002).

3.11.10 Order Cetacea (freshwater dolphins)

River dolphins and porpoises are among the most threatened mammals in the world. There are 5 species of river dolphins, and one of freshwater porpoise living in large rivers in southern Asia and South America. Populations of river cetaceans have declined rapidly in recent years and much of their habitat has been degraded. The Asian species in particular, are highly threatened. Threats to these animals include loss of habitat, siltation and pollution of rivers, fragmentation of rivers by levees, dams and canals, depletion of their food source from overfishing by humans, accidental deaths from boat collisions, and entrapment with nets and other fishing gear. Four out of the 5 species of Asian freshwater cetacean are either critically endangered or endangered according to IUCN's Red List of Threatened Species. The fifth species, the Irrawaddy River dolphin, is listed as data deficient. The single South American freshwater cetacean species, the Amazon River dolphin, is listed as vulnerable (IUCN 2002).

There are 5 species of freshwater cetaceans in Asia: the Yangtze River dolphin, the Yangtze River finless porpoise, the Indus River dolphin, the Ganges River dolphin, and the Irrawaddy River dolphin.

The Yangtze River dolphin or baiji (*Lipotes vexillifer*) is the world's most critically threatened cetacean with only a few tens of individuals remaining. According to experts there is "little hope for the survival of this species." (Reeves et al. 2000). Prior to 1900 there were a few thousand dolphins in the Yangtze basin (Ellis et al. 1993). The historic distribution included lower and middle reaches of the Yangtze River as well as some tributaries and lakes in the basin. The Three Gorges marked the upper limit of the baiji's distribution. By 1980 an estimated 400 individuals remained and by 1993 only 150 remained with their range substantially reduced (Ellis et al.1993). Today, the few remaining individuals can be found just in the mainstream of the Yangtze River (Reeves et al. 2000).

The main pressures on the baiji are the degradation of its habitat mostly from pollution, water diversions, dams, overfishing of their prey, and from accidental deaths due to ship collisions, blasting and entrapment in fishing gear. The Three Gorges Dam has exacerbated the pressures on the remaining population of dolphins.

Another cetacean found in the Yangtze, the finless porpoise (*Neophocaena phocaenoides*) is the world's only freshwater-adapted porpoise, and its population is reported to be declining rapidly. These animals are also classified as endangered (IUCN 2002). The most recent population estimate gives an average of 2,700 individuals for the period 1978-1991. Additional surveys carried out in 1991-1996 at separate locations throughout its range show a sharp decline in population numbers, but a total population estimate was not provided (Reeves et al. 2000).

The other 3 freshwater cetacean species in Asia are the Indus River dolphin (*Platanista minor*), the Ganges River dolphin (*Platanista gangetica*), two species that are closely related, and the Irrawaddy River dolphin (*Orcaella brevirostris*). The Indus River dolphin or bhulan is found in the Indus basin from the Himalayan foothills to the estuarine portion of the river leading into the Arabian Sea. Originally, this species was abundant and could be found throughout the tributaries of the Indus River in Pakistan and India. Today, the range and population numbers are in decline, and most of the remaining population, estimated at less than 1,000 individuals, is concentrated in the Indus River Dolphin Reserve, which was established by the Sind provincial government in 1974. This reserve is located between the Sukkur and Guddu barrage (Reeves and Chaudhry 1998). The major cause for the decline of the Indus dolphin was the extensive dam and barrage construction in the 1930s, which altered migration patterns, isolated populations and changed the flow and sediment regime of the river. Today, accidental entrapment in fishing gear, hunting for meat, oil and traditional medicine, and pollution is also impacting on the species (Reeves et al., 2000). IUCN has classified the species as endangered (IUCN 2002).

The Ganges River dolphin or susu is found in the slowly flowing waters of the Ganges, Brahmaputra, Meghna and Karnaphuli-Sangu rivers, from the foot of the Himalayas downstream to the upper limits of the tidal zone, in Bangladesh, Bhutan, India and Nepal (Sinha et al. 2000). This area also coincides with one of the most densely populated and food-poor areas of the world. Historically this species was quite abundant and found in large groups throughout its range. Close to 5,000 individuals were estimated to live in the Indus river system (WWF India 2002). Populations have severely declined since historical times, with an estimated 1,200-1,500 remaining today and an annual mortality rate of 10% (WWF India 2002). This species is classified as endangered (IUCN 2000, Reeves et al. 2000). Like the baiji, the major threats to the Ganges dolphin is the high level of river fragmentation due to dams, canals, etc., accidental killings from ships and fishing gear, direct harvest for oil and traditional medicines, pollution, and overfishing of its food source (Sinha et al. 2000).

The status and biology of the Irrawaddy dolphin is not well known. The species is found mainly in the Irrawaddy (Myanmar), the Mekong (Vietnam, Cambodia, and Laos) and the Mahakam (Kalimantan, Indonesia) river basins. This species was assessed by IUCN in 1996 and classified as data deficient. The Mahakam subpopulation of this species was assessed by IUCN in the year 2000, and classified as critically endangered. Only 33-50 individuals are estimated to be left in the middle reaches of the main river (Kreb 2000 as cited in IUCN 2002). The major causes of death of the Mahakan subpopulation dolphins are collisions with vessels, deliberate killings and live-capture for ocean aquaria, bycatch and deaths because of other fishing practices in the region (e.g., gillnets, electricity and poison), and the accidental introduction of an exotic piscivorous fish that has contributed to deplete the dolphins' prey. In addition, siltation,

pollution and dams also contribute to the decline of this species (Krebs 2000 as cited in IUCN 2002).

River dolphins also occur in South America but are not considered as endangered as their Asian relatives. The Amazon River dolphin (*Inia geoffrensis)* is the largest of the river dolphins. The known populations are distributed in the Orinoco basin, the Amazon basin, and in the Beni basin in Bolivia (IWC 2000). Threats include interactions with fisheries, hydroelectric development, deforestation, and pollution from agriculture, industry and mining. Hydroelectric development poses the biggest threat. The current status of the Amazon River dolphin is vulnerable according to IUCN. Because of habitat degradation and the current levels of exploitation in the region, there has been an estimated population decline of at least 20% over the last ten years (IUCN 2002). The other dolphin species in Latin America is the Tucuxi or gray dolphin (*Sotalia fluviatilis*). It is found in both fresh and saltwater, mostly in the Amazon basin and in the coastal waters from the Amazon delta to Panama.

4. INLAND WATER ECOSYSTEMS AND HABITATS IDENTIFIED AS HIGH CONSERVATION PRIORITY

Conservation organizations, international environmental agencies and many national governments have identified or designated habitats and ecosystems as conservation priority areas. These priority setting exercises are based on a number of different approaches, but many times they are driven by high species richness and endemism, or the uniqueness of the landscape or habitat. Sometimes the focus is a particular group of species, other times the conservation priority methodology is adapted to multiple taxa.

Much of the prioritizing work for conservation purposes done to date has focused on terrestrial ecosystems and species; one well-known example are Conservation International's hot spots, which are mostly based on centres of high plant diversity and highlight many tropical regions of the world as being of high conservation concern. Methodologies to set conservation priorities for freshwater ecosystems have been lagging behind, but recently they too have become more prevalent, with some internationally recognized conservation organizations, such as WWF-US and The Nature Conservancy, taking the lead at global, regional, subregional and even local levels. Because of the increasing concern about the conservation status and the high extinction rates of many inland water species, more and more conservation groups are beginning to look at inland waters as key ecosystems for conservation. To further the work in this area, IUCN held a workshop in Gland, Switzerland, in June 2002 to develop a site prioritization methodology for inland water ecosystems. The workshop brought together 24 participants from a range of organizations experienced in the field of site prioritization schemes, freshwater taxa, environmental impact assessments and other technologies. The objective of IUCN's workshop was to develop a methodology, building on existing approaches, which will enable any party working on the management, development or conservation of inland waters to identify important areas for conservation of freshwater biodiversity. Specific qualifiers of the methodology were that it should be (a) simple to use, (b) transparent in its rationale, (c) meet the needs of a diverse range of potential end users, and (d) have the flexibility to operate on different geographic scales. A summary of the conclusions and outcomes of this workshop is given below.

4.1 SUMMARY OF THE IUCN METHOD FOR PRIORITIZING IMPORTANT AREAS FOR FRESHWATER BIODIVERSITY

As a result of the workshop held by IUCN, a priorization methodology was outlined, which will be refined and adjusted over time, based on field-testing excercises. The methodology developed and presented here is primarily driven by species-based information, since this is the major strength of IUCN's Species Programme and its associated Species Survival Commission network of experts. The IUCN Species Programme initially intends to employ the tool to help develop the biodiversity component of a number of regional wetlands projects being co-ordinated through the IUCN Water and Nature Initiative (WANI) and the IUCN regional offices. The tool is also intended to make a contribution to the programme of work of the Convention on Biological Diversity (CBD) on inland water biological diversity and to the joint workplan between CBD and the Ramsar Convention. Hopefully, it will also help Parties to the Convention on Wetlands to identify new sites of international importance.

The following steps outline the prioritizing process.

Step 1: Define the geographic boundaries within which to identify important areas or sites.

Step 2: Define the wider ecological context of the designated assessment area.

Step 3: Identify and map the distribution of inland water habitat types.

Step 4: Assemble an inventory of the distribution and conservation status of priority aquatic taxa.

Step 5: Apply species based site selection criteria.

Step 6: Ensure full representation of inland water habitats among those sites selected.

Step 7: Ensure inclusion of keystone species.

The selection criteria applied in Step 5 are based on threatened species, restricted range species, richness of biogeographically restricted species, importance to critical life history stages, and significant numbers of congregatory species.

Guidelines for application of the criteria, and definitions of taxon-specific thresholds will be developed and elaborated through an ongoing process of consultation with workshop participants and field trials with regional users. Once the modifications have been agreed upon, training on its use will be provided through a series of regional workshops.

4.2 HABITATS IDENTIFIED AS HIGH CONSERVATION PRIORITY FOR BIRDS

BirdLife International has identified 218 Endemic Bird Areas (EBAs) worldwide—areas which encompass overlapping breeding ranges of restricted-range bird species—some of which include wetlands as a key habitat component (Stattersfield et al. 1998). Because most restricted-range birds occur in forests, the number of EBAs with wetland ecosystems is limited: 5 in North and Central America, 5 in South America, 4 in Africa and the Middle East, 1 in South Asia, 2 in Indonesia and Papua New Guinea, and 4 in the South Pacific Islands. BirdLife has also identified, or is in the process of identifying, another category of priority areas for bird conservation: Important Bird Areas (IBAs). Whereas EBAs tend to be broadly defined regions across the globe, IBAs are particular sites of international significance for the conservation of birds at the global, continental and sub-continental level. So far, 5,647 IBAs have been identified across Africa, Europe and the Middle East, of which 1,239 (22%) are inland wetlands of global significance for the conservation of wetland-dependent bird species (BirdLife International World Bird Database, as of June 2002). Identification of IBAs elsewhere in the world is well advanced, and completion of the global IBA inventory, which will comprise up to 12,000 sites, is scheduled for 2005.

4.3 HABITATS IDENTIFIED AS HIGH CONSERVATION PRIORITY FOR MULTIPLE TAXA

4.3.1 Priority Setting Exercises by NGOs for Freshwater Habitats

The WWF-U.S. identified 53 areas of global importance for freshwater biodiversity in 1998, as part of the Global 200 inititative—WWF's conservation priority areas—based on species richness, species endemism, unique higher taxa, unusual ecological or evolutionary phenomena, and global rarity of major habitat types (Olson and Dinerstein 1998). WWF-US is currently conducting an assessment for Africa of "Freshwater Ecoregions" in terms of their biological distinctiveness and the level of threats with more detailed data on fish, mussel, crayfish, and herpetofauna. The study for North and Latin America has been completed and published (Abell et al. 2000; Olson et al. 1998).

A 1998 study by WCMC entitled *Freshwater Biodiversity: a preliminary global assessment* summarized existing information on the diversity of freshwater taxa, including freshwater fish, molluscs, crayfish, crabs, and fairy shrimp. "Important areas for freshwater biodiversity" were identified based on existing information and expert consultation on overall diversity of an area to each of these taxa. Of the total 136 important freshwater biodiversity areas identified, 23 contain overlapping diversity of more than one of the assessed taxa (Groombridge and Jenkins 1998). Table 12 summarizes WWF's and UNEP-WCMC's important areas for freshwater biodiversity.

4.3.2 Internationally Recognized Protected Areas

As of June 2003, 1,288 wetlands have been designated as Ramsar sites—wetlands of international importance under the Convention on Wetlands. The cumulative number of Ramsar sites has doubled in the last decade, although many of these sites

are of relatively small size and located in developed countries. Wetlands International maintains the Ramsar database, which includes for each site, general location information (with geographic coordinates), site designation criteria, and the wetland habitat type represented. The Strategic Framework and the guidelines for future development of the List of Wetlands of International Importance were adopted at the 7th Conference of the Parties in 1999. The framework and guidelines specifically categorize the site designation criteria into 8 types including the importance for fish and bird diversity. A brief summary of the criteria is listed in Table 13.

Table 12. Areas of High Freshwater Biodiversity

	WWF Global 200 Freshwater Ecoregions	WCMC Hotspots (areas important for more than one taxa)	WCMC Important areas for at least one of the 5 taxa assessed
Africa	9	7	32
Eurasia	13	9	45
Australasia	15	2	14
North America	7	3	18
South America	9	2	27

Sources: Olson and Dinerstein 1999; summarized from Groombridge and Jenkins 1998.

Table 13. Summary of Criteria for Identifying Wetlands of International Importance

Group A Criteria • ***Sites containing representative, rare or unique wetland types***	
Criterion 1:	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B Criteria • ***Sites of international importance for conserving biological diversity***	
Criterion 2:	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3:	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4:	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Criterion 5:	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6:	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Criterion 7:	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8:	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Source: Ramsar Convention Web site at: http://www.ramsar.org/key_criteria.htm

In many instances, wetland areas have also been selected for protection as part of the *World Heritage Convention* and the *Man and the Biosphere Programme* of the United Nations Educational Scientific and Cultural Organisation (UNESCO). There are 149 *World Heritage sites* designated on

Table 14. Number of Ramsar Sites and Habitat Representation

Ramsar Region	Total	Marine/Coastal	Inland	Manmade	Unclassified
Africa	113	49	95	26	2
Asia	153	62	103	41	7
Europe[1]	778	348	641	260	11
North America	62	33	53	13	0
Neotropics	111	56	87	19	4
Oceania	71	38	57	7	0
Grand total	1288	586	1036	366	24

[1] Europe includes overseas territories and dependencies. Note: Many sites have a combination of coastal, inland, and manmade wetlands represented and counted as such. Therefore the figures for the 4 categories do not add up to the figures in the total.

Source: Ramsar Sites Database, June 2003.

Table 15. Number of Ramsar Sites and Primary Wetland Types[1]

Wetland type(s)	Primary wetland type
Estuarine waters (F)	82
Intertidal mud, sand, or salt flats (G), and/or Intertidal marshes (H)	156
Intertidal forested wetlands (I)	48
Coastal brackish/saline lagoons (J)	114
Coastal freshwater lagoons (K)	17
Inland deltas (L)	23
Permanent and/or seasonal rivers/streams/creeks (M and/or N)	82
Permanent and/or seasonal freshwater lakes (O and/or P)	273
Permanent and/or seasonal saline/brackish/alkaline lakes and flats (Q and/or R)	80
Permanent and/or seasonal saline/brackish/alkaline marshes/pools (Sp and/or Ss)	32
Permanent and/or seasonal freshwater marshes/pools (Tp and/or Ts)	148
Peatlands, non-forested and/or forested (U and/or Xp)	151
Alpine wetlands (Va)	1
Tundra wetlands (Vt)	16
Shrub-dominated wetlands (W)	16
Freshwater, tree-dominated wetlands (Xf)	53
Freshwater springs; oases (Y)	2
Geothermal wetlands (Zg)	1
Subterranean karst and cave hydrological systems (Zk)	4

Source: Ramsar Sites Database, July 2003

[1] Many sites have several wetland types listed as the primary wetland type and that therefore the total is not equal to the total number of Ramsar sites (1291 sites)

the basis of natural properties or mixed natural-cultural properties and 440 Man and the Biosphere reserves. Some internationally protected areas simultaneously encompass areas protected under other systems. For example, as of November 2002 there were 72 biosphere reserves that are wholly or partially World Heritage sites; 24 sites are inscribed as both Ramsar and the World Heritage sites.

In addition, IUCN, in collaboration with UNEP-WCMC, assessed those World Heritage sites that had a wetland component (Thorsell et al. 1997). According to this study, among the 721 World Heritage sites worldwide existing at the time, 77 contained major or secondary wetland habitats. These 77 sites represented 50 countries and ranged in size from 19 hectares, Aldabra Atoll in the Seychelles, to a 140,000-hectare Sundarbans mangrove forest in Bangladesh and the 3.15 million hectare Lake Baikal in Russia (UNESCO 2003).

5. DATA GAPS AND INFORMATION NEEDS

The indicators and information presented in the previous sections show that human activities have severely affected the condition of inland water ecosystems all over the world. Habitat degradation, invasive species, overexploitation, and pollution, are all stressing the capacity of inland water ecosystems to support biodiversity, with many species facing rapid population declines or extinction. Critical freshwater habitats, such as wetlands, rivers and streams, are also getting increased pressures and demands on their use, causing the disappearance of some of the remaining refuges for many species as well as areas for food production and water availability for local communities, particularly the poor.

Although physical alteration to inland waterways have increased the amount of water available for human use, for example through reservoirs, it has been estimated that today more than 2 billion people are affected by water shortages over 40 countries (WWDR 2003). In addition, surface and groundwater is being degraded in almost all regions of the world by intensive agriculture and rapid urbanization, aggravating the water scarcity problem.

Although many of the options available to improve water resources management to benefit both people and nature fall within the economic and political realm, ongoing monitoring and assessment of inland water ecosystems is crucial to informing and guiding policy or economic action. Governments, international agencies, NGOs, river basin authorities, and civil society need data and information on the condition of inland water resources, their ecosystem functions, their dependent species and the livelihoods of people dependent upon them, in order to formulate and implement policy options that are sustainable. For example, better information on actual stream and river discharge, and the amount of water withdrawn and consumed in each basin, would increase our ability to manage freshwater systems more efficiently and evaluate trade-offs. However, information and data on freshwater resources at the global level are scarce. To fill in the gaps, much effort and financial commitment would have to be made. However, the rewards for doing so are significant.

In general, all areas related to inland water ecosystems require more data and information, from water availability and quality to the status and population trends of freshwater species. Because adopting such an information gathering effort at the global level would be a daunting task, we have selected areas where an incremental amount of effort would produce fruitful results. These suggested areas build on ongoing or planned assessments and information gathering activities.

5.1 HABITAT INVENTORY AND INDICATORS OF CONDITION AND CHANGE

Among the different datasets on land cover, there is currently a lack of biogeographic characterization and standard classification schemes, especially as it relates to wetland ecosystems. Remote sensing technology, for example, has not been very successful in mapping wetlands. Part of the problem is the coarse resolution of most satellite imagery, although this is improving every year. The other more problematic area is the difficulty in mapping seasonal wetlands and forested wetlands. Radar, which can sense flooding underneath vegetation and can penetrate cloud cover, is probably the best alternative for developing a global wetland database. Because of its high resolution and sensitivity to water, radar data reveal a much finer wetland texture, particularly in areas of flooded forests, than other remotely sensed data. However work in this area is minimal with most remote sensing groups focusing on terrestrial habitats. The European Space Agency has initiated a programme to assess the application of earth observation products *inter alia* for managing wetlands, especially those designated under the Ramsar Convention. Results from this programme can prove useful to the wider water resources community.

There is also hope that the launch of Landsat 7 in 1999, which includes a 15-meter resolution panchromatic band sensor, in addition to five 30-meter resolution optical and infrared bands, can be used to resolve more detailed land-cover features. In an attempt to maximize use of these data, the price per image has also been reduced from US$4,200 to US$600. Higher quality data, available on a regular basis and at modest cost, should allow more accurate mapping of the general extent of large permanent wetlands. However, to map other smaller, seasonal, and forested wetlands, a resolution of less than 15 meters may be needed (USGS Landsat 7 Web site available at: http://landsat7.usgs.gov/).

5.2 SPECIES INFORMATION

In general, information on biodiversity at the species level in most freshwaters is poor. Some groups, for example birds, are better covered but for most others the cover is poor. Even economically important groups such as fish tend to be poorly covered at the global scale although some countries have better inventories. Information on freshwater biodiversity is often not readily available. For example, in most countries' reports, MSc and PhD theses are produced in the national language and may be hidden in archives. The usual language barriers to information access and dissemination are also evident. In addition, the existing species inventories are organized by taxonomic group and not by ecosystem type, which makes it hard to assess the condition of inland water ecosystems. Freshwater species have traditionally been neglected, and because of their distribution within water bodies they are more difficult to map than terrestrial species. The above mentioned problems make it very difficult to assess threats to species, and therefore the overall condition of ecosystems. Currently the trend is shifting from single-species oriented conservation to ecosystem or habitat-level conservation and activities.

Because monitoring and assessing all freshwater species is a daunting task, countries and institutions are encouraged to monitor key indicator species for freshwater systems, as well as monitoring the presence or introduction of exotic species and their impacts on native fauna and flora. There are several new initiatives that may help identify, catalogue, and map species around the world. Some of these activities include IUCN's freshwater biodiversity assessment and Species Information Service, the work of BirdLife international on the location, distribution and population status of birds, the OECD's Global Biodiversity Information Facility (GBIF) and the Global Taxonomy Initiative of the Convention on Biological Diversity. This knowledge and monitoring would allow for a more complete assessment of the condition of freshwater systems.

There is also great potential to improve the available information on species distribution and richness by drawing from the existing museum collections and databases around the world. These databases contain detailed information that would allow the mapping of species distribution range, the identification of areas of high diversity, as well as the existing data gaps. Overall, museum collections in Europe, North America, Australia, and Japan contain many specimens and information from poorly sampled areas in the tropics. Mobilizing the data and integrating them into a satandard format could help fill many of the existing gaps. In general, accessibility to museum collections depends on the particular institution, while the usability of the data and information depends on the species group and the level of taxonomic knowledge on the groups. An effort to mainstream the use of these vast amounts of information, however, is encouraged.

Another important monitoring area that is missing not only for freshwater, but for most terrestrial and marine species, is trends in species' populations. Here only quantitative data may be of value. The existing data are patchy even for a simple assessment of the current status of a species. There are very few cases where baseline data information on abundance and distribution of a species is available. However, without population trends of

species, it is hard to assess the effects of pressures or the risk of extinction of species.

Finally, because of the large impact that introduced species can have on inland water ecosystems, information on the location of introduced species as well as the presence or absence of invasive species is urgently needed. Regarding information on fish introductions, the FAO DIAS compiles and maintains information on the degree of international introductions by country, which, as of 1998, contains 3,150 records worldwide. The largest percentage of these introductions (35.5%) took place between 1940 and 1979 (FAO 1998). It should be noted however, that the DIAS database considers only species introduced from one country to another and not within-country introductions or translocations. Another example of a global initiative that tries to document the occurrence of invasive species is Global Invasive Species Database, being developed and maintained by the IUCN/SSC Invasive Species Specialist Group (ISSG) and Global Invasive Species Programme (GISP). This database currently list only 3 well-known invasives by the habitat category "water": Zebra mussel (*Dreissena polymorpha*), Water hyacinth (*Eichhornia crassipes*), and Chinese mitten crab (*Eriocheir sinensis*).

Regional or national monitoring programmes often have more detailed information specific to the region. For example, the Group on Aquatic Alien Species (GAAS) in Russia has compiled documentation on 6 aquatic invasive invertebrates found in enclosed seas of Europe and the Great Lakes region of North America, including a mapped range of original and current occurrence (GAAS 2002). Detailed information and distribution maps of a number of nonindigenous aquatic species including vertebrates, invertebrates, and plants, are also available for the U.S. (USGS 2001).

5.3 WATER RESOURCE INFORMATION

Although water is essential for human survival, information of this resource is lacking in many parts of the world. Most data on water availability and use are only available at the national level, which makes management of river basins, especially those that cross national borders, almost impossible. Data and information on basic variables, such as river flow, water withdrawals, aquifer recharge rates, etc. are not often available at the basin level. Most of the current data available are based on models developed from climate and precipitation data, and then validated with some observed data.

If information on water availability and use is lacking, the amount of information on water quality is even more depressing. Better information on water quality can provide nations with immediate benefits because of the direct connection between water quality and human health. But gathering such information generally requires expensive monitoring networks that are beyond the reach of many developing countries. Even though surface water monitoring programmes are well developed in most countries of the Organization for Economic Cooperation and Development (OECD), water quality monitoring in most parts of the world is rudimentary or nonexistent. Even those developed countries that have water quality monitoring programmes in place focus on chemical parameters that leave out important biological information. One of the biggest challenges in future water monitoring programmes is the integration of chemical and biological measures of water quality. National governments are encouraged to establish water quality monitoring programmes that combine chemical and biological measures for both surface and groundwater.

If surface water monitoring is lacking in many countries, the situation for groundwater is even worse. Most nations lack groundwater monitoring, both in terms of its quantity and quality. Information on groundwater quality, as well as on storage capacity and use, is urgently needed. Currently there are two proposed initiatives that could help fill in the information gap on groundwater resources as well as promote their sound management. One of these initiatives is the Groundwater Management Advisory Team, coor-

dinated by the World Bank and the Global Water Partnership. The aim of this team is to promote increased knowledge and efficient management of groundwater resources around the world. The second proposed initiative is to create an International Groundwater Resources Assessment Center, which will collect data on and monitor groundwater resources worldwide. This initiative is being undertaken by UNESCO and WMO.

5.4 SOCIO-ECONOMIC DATA

In addition to ecosystem-specific datasets, greatly improved socio-economic information at all levels is essential for a more integrated approach to water resource management. Some socio-economic variables needed at the basin level include: population density and distribution in relation to water resources; income distribution; the degree of dependence on inland waters and the biodiversity they support; food production from inland waters, etc.

6. REFERENCES

Abell, R.A., D.M. Olson, E. Dinerstein, P.T. Hurley, J.T. Diggs, W. Eichbaum, S. Walters, W. Wettengel, T. Allnutt, C.J. Loucks, and P. Hedao. 2000. *Freshwater Ecoregions of North America: A Conservation Assessment*, World Wildlife Fund-United States, Washington, DC, U.S.

Alford, R. A., and S. J. Richards. 1999. "Global amphibian declines: A problem in applied ecology." *Annual Review of Ecology and Systematics* 30:133-165.

Allen, G.R. 1991. *Field Guide to the Freshwater fishes of New Guinea*. Publication No. 9. Madang, Papua New Guinea: Christensen Research Institute.

AmphibiaWeb: Information on amphibian biology and conservation. 2002. Berkeley, California. Available on-line at: http://amphibiaweb.org/. Accessed May 2002.

Animal Diversity Web, University of Michigan, available on-line at: http://animaldiversity.ummz.umich.edu. Accessed June 2002 and May 2003.

Aselmann, I. and P.J. Crutzen. 1989. Global distribution of natural and freshwater wetlands and rice paddies, and their Net Primary Productivity, seasonality and possible methane emissions. *Journal of Atmospheric Chemistry* 8: 307-358.

Avakyan, A.B. and V.B. Iakovleva. 1998. "Status of Global Reservoirs: The Position in the Late Twentieth Century." *Lakes & Reservoirs: Research and Management* 3: 45-52.

Ballatore, Thomas. International Lake Environment Committee, Kusatsu, Japan. Personal communication, April 23, 2002.

Banarescu, P. 1990. *Zoogeography of Fresh Waters. Volume 1: General Distribution and Dispersal of Freshwater Animals*. Wiesbaden, Germany: Aula-Verlag.

Baumgartner, A. and E. Reichel. 1975. *The World Water Balance: Mean Annual Global, Continental, and Maritime Precipitation, Evaporation, and Runoff*. Amsterdam, The Netherlands: Elsevier Science Publishers.

Bayliss, B., K. Brenman, I. Elliot, M. Finlayson, R. Hall, T. House, B. Pidgeon, D. Walden, and P. Waterman.1997. *Vulnerability Assessment of Predicted Climate Change and Sea Level Rise in the Alligator Rivers Region, Northern Territory Australia*. Canberra, Australia: Supervising Scientist Report 123, Supervising Scientist, 134 pp.

BirdLife International. 2000. *Threatened birds of the world.* Barcelona, Spain/Cambridge, U.K.:Lynx Edicions/BirdLife International.

BirdLife International. 2001. Global Overview at BirdLife International Web page. Available on-line at: http://www.birdlife.net/sites/index.cfm.

Blaustein, A. R., and Wake, D. B. 1990. "Declining amphibian populations: A global phenomenon?" *Trends in Ecology and Evolution*, 5(7), 203-204.

Bogan, A.E. 1993. "Freshwater bivalve extinctions: search for a cause." *American Zoologist* 33: 599-609.

Bogan, A.E. 1997. "The silent extinction." *American Paleontologist* 5(1):2-4.

Bogan, Arthur. Curator of Aquatic Invertebrates, North Carolina State Museum of Natural Sciences. Personal communication, April 16, 2002.

Bornette, G., C. Amoros, and N. Lamouroux. 1998. "Aquatic plant diversity in riverine wetlands: the role of connectivity." *Freshwater Biology* 39: 267-283.

Borror, D.J. and R.E. White. 1970. *A Field Guide to Insects: America North of Mexico*. Boston and New York, U.S.A: Houghton Mifflin Company.

Bos, R. 1997. "The human health impact of aquatic weeds," in E.S. Delfosse and N.R. Spencer, eds., *Proceedings of the International Water Hyacinth Consortium.* Washington DC, U.S.A.: World Bank. Available on-line at:

http//www.sidney.ars.usda.gov/scientists/nspencer/water_h/appendix4.htm.

Bräutigam, A. 1999. "The freshwater crisis." *World Conservation* 30 (2): 4-5.

Breukelaar A. W., Lammens H. E. R. R., Klein Breteler J. G. P., Tatrai I. 1994, "Effects of benthivorous bream (*Abramis brama*) and carp (*Cyprinus carpio*) on sediment resuspension and concentrations of nutrients and chlorophyll a." *Freshwat. Biol.* 32; 113-121.

Brusca, R. 1997. Isopoda page in D.R. Maddison, ed. The Tree of Life Web Project. Available on-line at: http://tolweb.org/tree?group=Isopoda&contgroup=Peracarida.

Brusca, R. C. and G. J. Brusca. 1990. *Invertebrates.* Sunderland, Massachusetts, U.S.A: Sinauer Associates, Inc., Publishers.

Burkett V and Kusler J 2000. "Climate change: Potential impacts and interactions in wetlands of the United States." *Journal of the American Water Resources Association* 36(2): 313-320.

Burke, L., Y. Kura, K. Kassem, C. Revenga, M. Spalding, and D. McAllister. 2001. *Pilot Analysis of Global Ecosystems: Coastal Ecosystems*. Washington DC, U.S.A: World Resources Institute.

Bury, R.B., P.S. Corn, C.K. Dodd Jr., R.W. McDiarmid, and N.J. Scott Jr. 1995. Pages 124-126 in LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. 1995. *Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems.* Washington, DC, U.S.A.: U.S. Department of the Interior, National Biological Service, Available on-line at: http://biology.usgs.gov/s+t/index.htm.

Butler, R.W. and R.G. Vennesland. 2000. "Integrating climate change and predation risk with wading bird conservation research in North America." *Waterbirds* 23(3), 535-540.

Carvalho L. and B. Moss. 1995. "The current status of a sample of English Sites of Special Scientific Interest subject to eutrophication." *Aquatic Conservation: Marine and Freshwater Ecosystems* 5: 191-204.

CBD (Convention on Biological Diversity) Secretariat. 2001. *Global Biodiversity Outlook*. Montreal, Canada: CBD Secretariat.

Choudhury, B.C. and S. Bhupathy. 1993. *Turtle Trade in India: A Study of Tortoises and Freshwater Turtles*. New Delhi, India: TRAFFIC. 50pp.

Choy S. C. and G. Marquet. 2002. Biodiversity and zoogeography of atyid shrimps (Crustacea : Decapoda : Nantantia) of New Caledonia in : Najt J and P. Grandcolas (eds.), Zoologia Neocaledonica 5. Systématique et endémisme en Nouvelle-Calédonie. Mémoires du Muséum national d'Histoire naturelle 187 : 207-222.

CITES (Convention on International Trade of Endangered Species of Wild Fauna and Flora). 2002. *CITES World.* Issue No. 10. December 2002. Geneva, Switzerland: CITES Secretariat.

Contreras-Ramos, Atilano. 1997. Megaloptera page in D.R. Maddison, ed. The Tree of Life Web Project. Available on-line at: http://tolweb.org/tree?group=Megaloptera&contgroup=Endopterygota.

Cook, C.D.K. 1990. *Aquatic Plant Book*. The Hague, The Netherlands: SPB Academic Publisher.

Corbett, K. 1989. *The Conservation of European Reptiles and Amphibians*. Kent, U.K.: Christopher Helm Ltd. 274pp.

Crandall, K.A. and J.W. Fetzner Jr. 2002. Crayfish homepage. Provo, Utah, U.S.A.: Brigham Young University. Available on-line at: http://zoology.byu.edu/crandall_lab/crayfish/ crayhome.htm.

Crow, G.E. 1993. "Species diversity in aquatic angiosperms: latitudinal patterns." *Aquatic Botany* 44: 229-258.

Cumberlidge, Neil. Professor and Head, Department of Biology, Northern Michigan

University. Personal communication, April 17, 2002.

Cushing, C.E., K.W. Cummins, and G.W. Minshall. 1995. *Ecosystems of the World 22: Rivers and Stream Ecosystems*. Amsterdam, The Netherlands: Elsevier Science Publishers.

Daget, J., J. P. Gosse, and D. F. E. Thys van den Audenaerde, editors. 1984. *Check-list of the freshwater fishes of Africa, Vol. 1.* Belgium: ORSTOM-MRAC.

Daget, J., J. P. Gosse, and D. F. E. Thys van den Audenaerde, editors. 1986a. *Check-list of the freshwater fishes of Africa, Vol. 2.* Belgium: ORSTOM-MRAC.

Daget, J., J. P. Gosse, and D. F. E. Thys van den Audenaerde, editors. 1986b. *Check-list of the freshwater fishes of Africa, Vol. 3*. Belgium: ORSTOM-MRAC.

Daget, J., J. P. Gosse, and D. F. E. Thys van den Audenaerde, editors. 1991. *Check-list of the freshwater fishes of Africa, Vol. 4.* Belgium: ORSTOM-MRAC.

Davies, D.A.L. and P. Tobin. 1984. "The dragonflies of the world: A systematic list of the extant species of Odonata: vol. 1. Zygoptera, Anisozygoptera." Utrecht, The Netherlands: *Societas Internationalis Odonatologica Rapid Comm.* (Suppl.) No. 3.

Davies, D.A.L. and P. Tobin. 1985. "The dragonflies of the world: a systematic list of extant species of Odonata: vol. 2. Anisoptera." Utrecht, The Netherlands: *Societas Internationalis Odonatologica Rapid Comm.* (Suppl.) No. 5.

De Groote, H., O. Ajuonu, S. Attignon, R. Djussou and P. Neuenschwander. 2003. Economic impact of biological control of water hyacinth in Southern Benin. *Ecological Economics* 45(1): 105-117.

Delany, S.N., C. Reyes, E. Hubert, S. Pihl, E. Rees, L. Haanstra, and A. van Strien. 1999. *Results from the International Waterbird Census in the Western Palearctic and Southwest Asia, 1995 and 1996*. Wetlands International Publication No. 54. Wageningen, The Netherlands: Wetlands International.

DeShon, J.E. 1995. "Development and application of the Invertebrate Community Index (ICI)." pp 217-243 in W.S. Davis and T. Simon, eds. *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*. Boca Raton, Florida, U.S.A.: Lewis Publishers.

Dillon, R.T. Jr. 2000. *The Ecology of Freshwater Molluscs*. Cambridge, U.K.: Cambridge University Press.

Dudgeon, D. 2000. "Large-scale hydrological changes in tropical Asia: prospects for riverine biodiversity." *BioScience* 50(9): 793-806.

Duellman, W.E. 1993. *Amphibian species of the world: additions and corrections.* Lawrence, Kansas, U.S.A.: University of Kansas.

Duker, L. and L. Borre 2001. "Biodiversity conservation of the world's lakes: A preliminary framework for identifying priorities." LakeNet Report Series, Number 2. Annapolis, Maryland U.S.A.: Monitor International. Available on-line at: http://www.worldlakes.org/biodiversity_LakeNet_report.htm

Dynesius, M. and C. Nilsson. 1994. "Fragmentation and Flow Regulation of River Systems in the Northern Third of the World." *Science* 266: 753-762.

Ellis, S., S. Leatherwood, M. Bruford, K. Zhou, and U. Seal. 1993. "Baiji (*Lipotes vexillifer*) population and habitat viability assessment. Preliminary report." *Species* 20:25-28.

Ephemeroptera Galactica. 2001. Catalogs of Ephemeroptera page, at the Official Web Site of the Permanent Committee of the International Conferences on Ephemeroptera. Tallahassee, Florida, U.S.A: Florida A&M University. Available on-line at: http://www.famu.org/mayfly/cats.html

Emmons, L. 1997. *Neotropical Rainforest Mammals: A Field Guide. 2nd Edition*. Chicago, U.S.A.: The University of Chicago Press, 307 pp.

Ernst, C. H. and R.W. Barbour. 1989. *Turtles of the world.* Washington D.C., U.S.A.: Smithsonian Institution Press, 313 pp.

Eschmeyer, W.N., (ed.). 1998. *Catalog of Fishes*. San Francisco, California, USA: California Academy of Sciences.

ESRI (Environmental Systems Research Institute, Inc). 1992. ArcWorld 1:3M. Continental Coverage. CD-ROM. Redlands, CA: ESRI.

Evans, M.I. Ed. 1994. *Important Bird Areas in the Middle East*. Cambridge, U.K.: BirdLife International.

Falkenmark, M. and C. Widstrand. 1992. "Population and Water Resources: A Delicate Balance." *Population Bulletin* 47 (3): 1-36.

FAO (Food and Agriculture Organization of the United Nations). 1996. "Malawi Fishery Country Profile." FAO Fisheries Department Web site available on-line at: http://www.fao.org/fi/fcp/malawie.htm. Viewed 6/27/00.

FAO (Food and Agriculture Organization of the United Nations). 1998. Data base on Introduction of Aquatic Species (DIAS). Rome, Italy: FAO. On-line at: http://www.fao.org/fi/statist/fisoft/dias/index.htm

FAO (Food and Agriculture Organization of the United Nations). 1999a. *Review of the State of World Fishery Resources: Inland Fisheries.* FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division, FAO Fisheries Circular No. 942. Rome, Italy: FAO.

FAO (Food and Agriculture Organization of the United Nations). 1999b. *The State of World Fisheries and Aquaculture 1998.* Rome, Italy: FAO Fisheries Department.

Fekete, B., C. J. Vörösmarty, and W. Grabs. 1999. "Global, Composite Runoff Fields Based on Observed River Discharge and Simulated Water Balance." World Meteorological Organization Global Runoff Data Center Report No. 22. Koblenz, Germany: WMO-GRDC.

Fernando, C.H. 1991. "Impacts of fish introductions in tropical Asia and America." *Canadian Journal of Fisheries and Aquatic Sciences* 48(Suppl. 1): 24-32.

Feuerer, T. 2002. "Checklists of lichens and lichenicolous fungi." Version 1, February 2002. On-line at: http://www.checklists.de.

Finlayson, C.M. and N.C. Davidson. 1999. "Global review of wetland resources and priorities for wetland inventory: summary report." In Finlayson, C.M. and A.G. Spiers eds. *Global review of wetland resources and priorities for wetland inventory. 2nd edition.* Wageningen, The Netherlands and Jabiru, Australia: Wetlands International and Environmental Research Institute of the Supervising Scientists. On-line at: http://www.wetlands.org/inventory&/GRoWI/welcome.html

Fish, G. R. 1966. An artificially maintained trout population in a Northland Lake. *NZ J. Sci.* 9:200-210.

Fishpool, L.F. and Evans, M.I. Eds. 2001. *Important Bird Areas in Africa and Associated Islands.* Cambridge/Newbury, U.K.: BirdLife International/Pisces Publications.

Foster, S., J. Chilton, M. Moench, F. Cardy, and M. Schiffler. 2000. *Groundwater in Rural Development: Facing the Challenges of Supply and Resource Sustainability.* World Bank Technical Paper No. 463. Washington, DC: The World Bank.

Foster-Turley, P., S. Macdonald, and C. Mason. 1990. *Otters: An Action Plan for their Conservation.* IUCN/SSC Otter Specialist Group. Gland, Switzerland and Cambridge U.K: IUCN-The World Cosnervation Union.

Frost, D.R. 2000. *Amphibian Species of the World: An On-line Referenc*e. V2.20 (1 September 2000). New York, U.S.A: American Museum of Natural History. Available on-line at: http://research.amnh.org/herpetology/amphibia/index.html

GAAS (Group on Aquatic Alien Species). 2002. Illustrated database of Aquatic Invasive Species in Europe. St.Petersburg, Russia: Zoological Institute, Russian Academy of Sciences. Available on-line at: http://www.zin.ru/projects/invasions/gaas/aa_idb.htm

Gable, Michael, ed. 2000. "Alpha-taxonomy workshop on the world-wide status of Amphipoda." In the proceeding of the 10th International Colloquium on Amphipoda, Heraklion, Crete, Greece 16-21 April, 2000. Polskie Archiwum Hydrobiologii 47 (3-4): 681-704.

Gable, Michael. Department of Biology, Eastern Connecticut State University. Personal communication of April 23, 2002.

GADAG (Global Amphibian Diversity Analysis Group). 2002. Global Amphibian Diversity Analysis Group Web site. Available on-line at: http://www.gadag.org/index.php. Accessed June 11, 2002.

Garibaldi, L. and D. M. Bartley, 1998. The data base on introductions of aquatic species (DIAS). Food and Agriculture Organization of the United Nations (FAO) *Aquaculture Newsletter* (FAN), no. 20. Available on the Web at http://www.fao.org/fi/statist/fisoft/dias/index.htm.

Gitay, H., Brown, S., Easterling, W., Jallow, B. et al. 2001. "Chapter 5. Ecosystems and Their Goods and Services." In: *Climate Change 2001: Impacts, Adaptations, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the International Panel on Climate Change.* McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (eds). pp. 235-342. IPCC/Cambridge University Publication Press.

GLCCD (Global Land Cover Characteristics Data base), Version 1.2. 1998. Loveland, T.R., B.C. Reed, J.F. Brown, D.O. Ohlen, Z. Zhu, L. Yang, and J. Merchant. 2000. "Development of a Global Land Cover Characteristics Data base and IGBP DISCover from 1-km AVHRR data." *International Journal of Remote Sensing* 21 (6-7): 1303-1330. Data available on-line at: http://edcdaac.usgs.gov/glcc/glcc.html.

Gleick, P.H. 1993. Part II: freshwater data. In Gleick, P.H. ed. *Water in crisis: a guide to the world's fresh water resources*. New York, NY: Oxford University Press.

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

Gopal, B. 1987. *Water Hyacinth. Aquatic Plant Studies 1*. Amsterdam and New York: Elsevier Science Publishers.

Gopal, B., W.J. Junk, and J.A. Davis (Eds.). 2000. *Biodiversity in wetlands: assessment, function, and conservation, volume 1*. Leiden, The Netherlands: Backhuys Publishers.

Gréboval, D., M. Bellemans, and M. Fryd. 1994. *Fisheries characteristics of the shared lakes of the East African Rift.* CIFA Technical Paper No.24. Rome, Italy: FAO.

Groombridge, B. 1992. *Global biodiversity: status of the earth's living resources.* London, U.K.: Chapman and Hall.

Groombridge, B. and M. Jenkins. 1998. *Freshwater Biodiversity: a preliminary global assessment*. Cambridge, UK: WCMC-World Conservation Press.

Groombridge, B. and M.D. Jenkins. 2000. *Global biodiversity: Earth's living resources in the 21st century.* Cambridge, UK: WCMC-World Conservation Press.

Hallingbäck, T. and N. Hodgetts. 2000. *Mosses, Liverworts, and Hornworts: Status Survey and Conservation Action Plan for Bryophytes*. IUCN/SSC Bryophyte Specialist Group. Gland Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

Hansen, M. 1998. *World Catalogue of Insects: Volume 1 Hydraenidae (Coleoptera)*. Stenstrup, Denmark: Apollo Books.

Hansen, M. 1999. *World Catalogue of Insects*: *Volume 2 Hydrophiloidea (Coleoptera)*. Stenstrup, Denmark: Apollo Books.

Harley, K., M.H. Julien, and A.D. Wright. 1997. "Water Hyacinth: a Tropical Worldwide Problem and Methods for its Control," in E.S. Delfosse and N.R. Spencer, eds., *Proceedings of the International Water Hyacinth Consortium.* Washington, DC: World Bank. Available on-line at: http://www.sidney.ars.usda.gov/scientists/nspencer/water_h/appendix7.htm

Harrison, I. J. and M. J. Stiassny. 1999. "The Quiet Crisis: A Preliminary Listing of the Freshwater Fishes of the World that Are Extinct or 'Missing in Action'." Pages 271-331 in R.D.E. MacPhee, ed. *Extinctions in Near Time*. New York, New York, U.S.A.: Kluwer Academic/Plenum Publishers.

Harrison, S. 2001. Global Lake Status Database project description available on-line at http://www.bgc.jena.mpg.de/bgc_prentice/projects/projects.html. Max-Planck-Institute for Biogeochemistry, Jena, Germany.

Heath, M.F. and M.I. Evans. Eds. 2000. *Important Bird Areas in Europe: Priority Sites for Conservation.* 2 vols. Cambridge, U.K.: BirdLife International.

Hebert, P.D.N. ed. 2002. Canada's aquatic environments. CyberNatural Software. Ontario, Canada: University of Guelph. On-line at: http://www.aquatic.uoguelph.ca/index.htm.

Hill, G., J. Waage, and G. Phiri. 1997. "The Water Hyacinth Problem in Tropical Africa," in E.S. Delfosse and N.R. Spencer, eds., *Proceedings of the International Water Hyacinth Consortium.* Washington, DC: World Bank. Available on-line at: http://www.sidney.ars.usda.gov/scientists/nspencer/water_h/appendix5.htm

Hilton-Taylor, C. 2000. *2000 IUCN Red List of Threatened Species.* Gland, Switzerland and Cambridge, UK: IUCN-The World Conservation Union.

Hinrichsen, D., B. Robey, and U.D. Upadhyay. 1998. "Solutions for a Water-Short World." *Population Reports*, Series M, No. 14. Baltimore, Maryland, U.S.A.: Johns Hopkins University School of Public Health, Population Information Program.

Holsinger, John R. Professor of Biological Sciences, Old Dominion University, Norfolk, VA. Personal communication of April 23, 2002.

Holsinger, J.R. ed. 2000. The Subterranean Amphipod Database. Norfolk, VA: Old Dominion University. On-line at: http://web.odu.edu/sci/biology/amphipod/index.html

Holzenthal, R.W. and R.J. Blahnik. 1997. Trichoptera page in D.R. Maddison, ed. The Tree of Life Web Project. On-line at: http://tolweb.org/tree?group=Trichoptera&contgroup =Endopterygota.

Houlahan, J. E., C. S. Findlay, B. R. Schmidt, A. H. Meyer, and S. L. Kuzmin. 2000. "Quantitative Evidence for Global Amphibian Population Declines." *Nature* 404 (6779): 752-755.

ICOLD (International Commission on Large Dams). 1998. *World Register of Dams 1998.* Paris, France: ICOLD.

IJHD (International Journal of Hydropower and Dams). 1998. "1998 World Atlas and Industry Guide." Surrey, U. K.: Aqua-Media International.

ILEC (International Lake Environment Committee) Web site available on-line at: http://www.ilec.or.jp/database/database.html.

Illies J. 1978. *Limnofauna Europaea.* Stuttgart, New York, U.S.A.: Fisher Verlag.

International Odonata Research Institute. 2002. Odonata Information Network home page, list of species from around the world. Gainesville, Florida: International Odonata Research Institute. On-line at: http://www.afn.org/~iori/oinlist.html.

IPCC (Intergovernmnetal Panel on Climate Change) 1996. *Climate Change 1995 — Impacts, Adaptations and Mitigation of*

Climate Change: Scientific technical analysis. Contribution to Working Group II to the Second Assessment Report. Cambridge, U.K.: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change) 1998. *Regional Impacts of Climate Change: An Assessment of Vulnerability.* Summary for Policy Makers. Watson, R.T., Zinyowera, M.C. and Moss, R.H (eds). Cambridge, U.K.: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change) 2001a. Summary for Policy Makers. In: *Climate Change 2001, the Science of Climate Change.* Contribution of Working Group I to the Third Assessment Report of the International Panel on Climate Change, Houghton, J. T., et al. Cambridge, U.K.: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2001b. Summary for the Policy Makers. In: *Climate Change 2001: Impacts, Adaptations, and Vulnerability*. Contribution of Working Group II to the Thirds Assessment Report of the International Panel on Climate Change. McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (eds), pp1-17. Cambridge, U.K.: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2001c. *Climate Change 2001: Synthesis Report.* A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change,Watson, R.T. and the Core Writing Team (eds.). 398 pp. Cambridge, U.K. and New York, NY, U.S.A.: Cambridge University Press.

IUCN/SSC Cat Specialist Group Web site. Available on-line at: http://lynx.uio.no/catfolk/. Accessed May 2003.

IUCN/SSC Crocodile Specialist Group Web site 2002. Available on-line at: http://www.flmnh.ufl.edu/natsci/HERPETOLOGY/Crocs.htm. Accessed June 2002.

IUCN/SSC Hippo Specialist Subgroup Web site 2003. Available on-line at: http://moray.ml.duke.edu/projects/hippos/. Accessed May 2003.

IUCN/SSC Pigs and Peccaries Specialist Group, and the IUCN/SSC Hippo Specialist Group. 1993. *Pigs, Peccaries and Hippos: Status Survey and Conservation Action Plan*. Edited by William L.R. Oliver. 202pp. Gland, Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. 1991. *Tortoises and Freshwater Turtles: An Action Plan for their Conservation.* IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Gland, Switzerland and Cambridge U.K.: IUCN-The World Conservation Union.

Iverson, J.B. 1992. "A Revised Checklist with Distribution Maps of the Turtles of the World." Published by the author.

IWC (International Whaling Commision). 2000. Report of the Standing Sub-Committee on Small Cetaceans. IWC/52/4. 52nd Meeting of the International Whaling Commission. Adelaide, Australia: IWC.

Japanese Council of Ministers for Global Environmental Conservation. 1995. National strategy of Japan on biological diversity. Tokyo, Japan: Environment Agency of Japan. On-line at: http://www.env.go.jp/en/pol/nsj/

Jenkins, M. D. 1995. *Tortoises and freshwater turtles: the trade in Southeast Asia.* Cambridge, U.K.: TRAFFIC International, iv + 48 pp.

Jorgensen, S.E., R. de Bernardi, T. Ballatore, and V. Muhandiki. 2001. *Lake Watch 25: changes in the world's lakes*. Draft report. Kusatsu, Japan: International Lake Environment Committee.

Kapetsky, J. Inland Water Resources and Aquaculture Service, FAO Fisheries

Department. Personal Communication. August 1999.

Kapetsky, J.M. 2001. Freshwater fisheries from a global perspective: 2001. Unpublished paper provided to WRI. Wilmington, NC: C-FAST, Inc.

Kaufman, L. 1992. "Catastrophic Change in Species-Rich Freshwater Ecosystems: The Lessons from Lake Victoria." *Bioscience* 42 (11): 846-858.

Kay, E. A. (Ed.). 1995. "The conservation biology of molluscs : proceedings of a symposium held at the 9th International Malacological Congress, Edinburgh, Scotland, 1986 including a status report on molluscan diversity." Gland, Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

Keast, A. 1996. "Pacific Biogeography: patterns and processes." In: *The origin and evolution of Pacific Island biotas, New Guinea to Eastern Polynesia: patterns and processes*, 477-512 pp.

Kingdon, J. 1997. *The Kingdon Field Guide to African Mammals*. London, UK: Academic Press.

Kira, T. 1997. "Survey of the state of world lakes." Chapter 7 in Jørgensen, S.E. and S. Matsui, eds. *Guidelines of lake management, volume 8: the world's lakes in crisis*. Kusatsu, Japan: International Lake Environment Committee and United Nations Environment Programme.

Koenemann, Stefan. Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, The Netherlands. Personal communication of April 22, 2002.

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

Kreb, D. 2000. "Abundance and distribution of the pesut, Orcaella brevirostris in the Mahakam River, lakes, and coast of East Kalimantan, Indonesia." Paper submitted to the International Whaling Commission. SC/52/SM32.

Kurata, Akira. 1994. *Data book of world lake environments: a survey of the state of world lakes*. 5 volumes. Kusatsu, Japan: International Lake Environment Committee, and Nairobi, Kenya: United Nations Environment Programme (UNEP). Kingdon, J. 1997.

LakeNet Website 2003. Ancient Lakes of the World. Available on-line at: http://www.worldlakes.org/. Accessed June 2003.

Lévêque, C. 1997. *Biodiversity dynamics and conservation: the freshwater fish of tropical Africa.* Cambridge, UK: Cambridge University Press.

Lekagul, B. and J. A. McNeely. 1988. *Mammals of Thailand*. 2nd Edition. Banrak, Bankik, Thailand: Saha Karn Bhaet Co.

Lehner, B. and P. Döll. 2001. A global wetlands, lakes and reservoirs data set. Unpublished manuscript. Kassel, Germany: University of Kassel.

Lewison, R. Chair, IUCN/SSC Hippo Specialist Sub-Group. Personal Communication May 2002.

Lundberg, J.G., M. Kottelat, G.R. Smith, M.L.J. Stiassny, and A. C. Gill. 2000. "So many fishes, so little time: an overview of recent ichthyological discovery in continental waters." *Annals of the Missouri Botanical Garden* 87: 26-62.

Mandaville, S.M. 1999. Bioassessment of freshwaters using benthic macroinvertebrates—a primer. First ed. Feb. 1999. Halifax, Canada: *Soil & Water Conservation Society of Metro Halifax.* On-line at: http://www.chebucto.ns.ca/Science/SWCS/ZOOBENTH/BENTHOS/benthos.html.

Marquet, G. 1993. "Etude biogéographique de la faune d'eau douce de Polynésie Française." *Biogeographica* 69 (4): 157-170.

Marquet, G., L. Taiki Nimoho, L. Chadderton, and P. Gerbeaux. Biodiversity and biogeography of freshwater crustaceans (Decapoda: Natanta) from Vanuatu, a comparison with Fiji and New Caledonia. Bull. Fr. Peche Picic. 364: 217-232.

Mason, W.T. Jr., C.R. Fremling, and A.V. Nebeker. "Aquatic Insects as Indicators of Environmental Quality." Pages 182-184 in LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. 1995. *Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems.* Washington, DC, U.S.A.: U.S. Department of the Interior, National Biological Service. Available on-line at: http://biology.usgs.gov/s+t/index.htm.

Matthews, E. and I. Fung. 1987. Methane emissions from natural wetlands: global distribution, area, and environmental characteristics of sources. *Global Biogeochemical Cycles* 1(1): 61-86.

Mattison, Chris. 1986. *Snakes of the World.* New York, U.S.A.: Facts On Life Publications, 190 pp.

McAllister, D.E., A.L. Hamilton, and B. Harvey. 1997. "Global freshwater biodiversity: striving for the integrity of freshwater ecosystems." *Sea Wind—Bulletin of Ocean Voice International* 11(3): 1-140.

McAllister, D.E., J.F. Craig, N. Davidson, S. Delany, and M. Seddon. 2000. "Biodiversity impacts of large dams." A contributing paper to the World Commission on Dams. On-line at: http://www.damsreport.org/docs/kbase/contrib/env245.pdf

McDowall, R.M. 2000. *The Field Guide to New Zealand Freshwater Fishes*. Auckland, New Zealand: Reed Publishers.

Meine, C. D. and G. W. Archibald (Eds). 1996. *The Cranes: - Status Survey and Conservation Action Plan*. Gland, Switzerland, and Cambridge, U.K.: IUCN-The World Conservation Union, 294 pp. Available on-line at Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/distr/birds/cranes/cranes.htm (Version 02MAR98).

Meylan P. A. and E. Ganko. 1997. "Polycryptodira: Living turtles other than side-necked turtles." The Tree of Life Web Project at: http://www.eckerd.edu/turtles/polycryptodira/ polycryptodira.html.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. "Extinctions of North American Fishes During the Past Century." Fisheries 14 (6): 22-38.

Miller, S., Acting Chair, Department of Systematic Biology, Smithsonian Institution, National Museum of Natural History. Personal communication, April 2002.

Milner, A.M., J.E. Brittain, E. Castella, and G.E. Petts. 2001. "Trends of macroinvertebrate community structure in glacier-fed rivers in relation to environmental conditions: a synthesis." *Freshwater Biology* 46: 1833-1847.

Miserendino, M.L. 2001. "Macroinvertebrate assemblages in Andean Patagonian rivers and streams: environmental relationships." *Hydrobiologia* 444: 147-158.

Mitsch, W.J., ed. 1994. *Global wetlands: old world and new*. Amsterdam, The Netherlands: Elsevier Science Publishers.

Moore, N.W. 1997. *Dragonflies: status survey and conservation action plan*. IUCN/SSC Odonata Specialist Group. Gland, Switzerland and Cambridge, UK: IUCN-The World Conservation Union.

Moyle, P.B. and R.A. Leidy. 1992. "Loss of biodiversity in aquatic ecosystems: evidence from fish faunas." Pages 127-169 in P.L. Fiedler and S.K. Jain, eds. *Conservation biology: the theory and practice of nature conservation, preservation, and management.* New York, NY: Chapman and Hall.

MRC (Mekong River Commission). 1997. *Greater Mekong Sub-Region State of the Environment Report.* Bangkok, Thailand: Mekong River

Commission and United Nations Environment Programme.

Naylor, R. L., R. J. Goldburg, J. H. Primavera, N. Kautsky, M. C. M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, and M. Troell. 2000. "Effect of Aquaculture on World Fish Supplies." *Nature* 405 (6790): 1017-1024.

Nel, J.A.J. and Somers, M. 1998. "The Status of otters in Africa: An assessment. Proceedings of the VII International Otter Symposium, 13-19 March 1998." Trebon, Czech Republic.

Nilsson, A. 2001. *World catalogue of insects: volume 3 Dytiscidae (Coleoptera)*. Stenstrup, Denmark: Apollo Books.

Nilsson, A. 2002. *Catalogue of Palearctic Dytiscidae*. Umeå, Sweden: University of Umeå. On-line at: http://www.bmg.umu.se/biginst/andersn/Dyt_inae.htm. Updated on 15 February, 2002.

Nilsson, Anders. Senior lecturer in Zoology, Department of Biology and Environmental Science, University of Umeå, Sweden. Personal communication of May 15th, 2002.

Nilsson, C. and K. Berggren. 2000. "Alterations of riparian ecosystems caused by river regulation." *BioScience* 50(9): 783-792.

Nixon, C.P., D.B. Stoeckel, and M.R. Jeffords. 2001. "Stream quality indicators." Illinois, U.S.A.: Illinois Department of Natural Resources. On-line at: http://dnr.state.il.us/orep/inrin/ctap/bugs/.

Nowell, K. and Jackson, P. (compilers and editors) 1996. *Wild Cats. Status Survey and Conservation Action Plan*. IUCN/SSC Cat Specialist Group. Gland, Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

Nowak, R. M. 1991. *Walker's Mammals of the World 5th ed.* Volume I and II. Baltimore, Maryland, U.S.A.: The Johns Hopkins University Press, 1,629 pp.

O'Donnel, C. and Jon Fjeldsa (Compilers). 1997. *Grebes: Status Survey and Conservation Action Plan.* IUCN/SSC Grebe Specialist Group. Gland, Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

Ojeda, R. A. and S. M. Giannoni. 2000. *The marsupials of Argentina: an annotated checklist of their distribution and conservation.* Available on-line at: http://www.cricyt.edu.ar/INSTITUTOS/iadiza/ojeda/MARSUPIALES.htm.

Olson D.M. and E. Dinerstein. 1998. "The Global 200: A representation approach to conserving the Earth's most biologically valuable ecoregions." *Conservation Biology* 12: 502-515.

Olson, D.M., E. Dinerstein, P. Canevari, I. Davidson, G. Castro, V. Morisset, R. Abell, and E. Toledo, eds. 1998. *Freshwater biodiversity of Latin America and the Caribbean: a conservation assessment.* Washington DC: Biodiversity Support Program.

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

Paulson, Dennis. Director, Slater Museum of Natural History, University of Puget Sound, Tacoma, WA. Personal communication, April 22, 2002.

Pittock, B., Wratt, D. et al. 2001. "Chapter 12. Australia and New Zealand." In: *Climate Change 2001: Impacts, Adaptations, and Vulnerability.* Contribution of Working Group II to the Third Assessment Report of the International Panel on Climate Change. McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (eds). pp. 591-640. Cambridge, U.K.: Cambridge University Press.

Polhemus, D.A. 1993. "Conservation of aquatic insects: worldwide crisis or localized threats?" *American Zoologist* 33: 588-598.

Postel, S. 1999. *Pillars of Sand: Can the Irrigation Miracle Last?* Washington, DC: Worldwatch Institute.

Pringle, C.M., M.C. Freeman, and B. J. Freeman. 2000. "Regional effects of hydrologic alterations on riverine macrobiota in the New World: tropical-temperate comparisons." *BioScience* 50(9): 807-823.

Purvis, W. 2000. *Lichens.* Washington DC: Smithsonian Institution Press and London, UK: The Natural History Museum.

Rabuor, C.O. and J.J. Polovina. 1995. "An analysis of the multigear, multispecies fishey in the Kenyan waters of Lake Victoria." *NAGE,* the ICLARM Quarterly. April, 1995: 34-37.

Reeves, R. R. and Chaudhry. 1998. "Status of the Indus River dolphin Platanista minor." *Oryx* 32:35.

Reeves, R. R., B. D. Smith, and T. Kasuya (eds.) 2000. *Biology and Conservation of Freshwater Cetaceans in Asia.* IUCN Species Survival Commission Paper No. 23, viii + 152pp. Gland, Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

Reijnders, P., S. Brasseur, J. van der Toorn, P. van der Wolf, I. Boyd, J. Harwood, D. avigne, and L. Lowry (Compilers). 1993. Seals, Fur Seals, Sea Lions, and Walrus. Status Survey and Conservation Action Plan. IUCN/SSC Seal Specialist Group. 88pp. Gland, Switzerland and Cambridge, U.K.: IUCN-The World Conservation Union.

Revenga, C., S. Murray, J. Abramovitz, and A. Hammond. 1998. *Watersheds of the World: Ecological Value and Vulnerability*. Washington D.C., USA.: World Resources Institute and Worldwatch Institute.

Revenga, C., J. Brunner, N. Henninger, K. Kassem, and R. Payne. 2000. *Pilot Analysis of Global Ecosystems: Freshwater Systems.* Washington DC: World Resources Institute. On-line at: http://www.wri.org/wr2000/freshwater_page.html

Ricciardi, A. and J. B. Rasmussen. 1999. "Extinction Rates of North American Freshwater Fauna." *Conservation Biology* 13 (5): 1220-1222.

Riverine Rabbit Conservation Project Web Site. Joint project between WWF-South Africa, Cape Nature Conservation, Northern Cape Nature Conservation, and the Society for the Conservation of Species and Populations. Available on-line at http://www.riverinerabbit.co.za/.

Roberts, T.R. 1978. "An ichtyological study of the Fly River in Papua New Guinea with descriptions of new species." *Smithsonian Contributions to Zoology* 281.

Rose, P.M. and Scott, D.A. 1997. Waterfowl Population Estimates - Second Edition. Wetlands International Publication No. 44. Wageningen, The Netherlands: Wetlands International.

Roshier, D.A., P.H. Whetton, R.J. Allan, and A.I. Robertson, 2001: "Distribution and persistence of temporary wetland habitats in arid Australia in relation to climate". *Austral Ecology* 26, 371-384.

Ross, C. 1989. *Crocodiles and Alligators.* Facts on File Inc., New York, U.S.A.

Ross, S. T. 1991. "Mechanisms structuring stream fish assemblages: are there lessons from introduced species?" *Environmental Biology of Fishes* 30: 359-368.

Ross, J. P. (ed.) 1998. *Crocodiles : Status Survey and Conservation Action Plan: Revised Action Plan for Crocodiles 1998*. IUCN/SSC Crocodile Specialist Group. World Wide Web Edition Gland, Switzerland and Cambridge U.K.: IUCN-The World Conservation Union.

Ross, J. P. Executive Officer, Crocodile Specialist Group, Florida Museum of Natural History, University of Florida, Gainesville, Florida, USA. Personal Communication April 2002. Chinese alligator wild population estimates derived from surveys conducted by J. Thorbjarnarson from the Wildlife Conservation Society in 1999.

Ryan, P.A. 1980. "A checklist of the brackish and freshwater fish of Fiji." *South Pacific Journaal of Natural Sciences* 1: 58-73.

Ryan, P.A. 1991. "The success of the Gobiidae in the tropical Pacific insular streams." *New Zealand Journal of Zoology* 18: 25-30.

Sahlén, G. and K. Ekestubbe. 2001. "Identification of dragonflies (Odonata) as indicators of general species richness in boreal forest lakes." *Biodiversity and Conservation* 10: 673-690.

Schorr, M., M. Lindeboom, and D. Paulson. 2002a. *List of Odonata of the world: part 1, Zygoptera, and Anisozygoptera.* Tacoma, Washington, U.S.A.: University of Puget Sound.

Schorr, M., M. Lindeboom, and D. Paulson. 2002b. *List of Odonata of the world: part 2, Anisoptera*. Tacoma, Washington, U.S.A.: University of Puget Sound.

Schotte, M. World List of Marine, Freshwater and Terrestrial Isopod Crustaceans. http://www.nmnh.si.edu/iz/isopod/ Department of Invertebrate Zoology, Smithsonian National Museum of Natural History. Personal communication, April 15, 2002.

Scott, D.A. and Rose, P.M. 1996. Atlas of Anatidae populations in Africa and western Eurasia. Wetlands International Publication No. 41. Wageningen, The Netherlands: Wetlands International.

Seddon, M. 2000. "Molluscan Biodiversity and the Impact of Large Dams." A contributing paper to the World Commission on Dams. On-line at: http://www.damsreport.org/docs/kbase/contrib/env242.pdf

Séret, B. 1997. "Les poissons d'eau douce de Nouvelle Calédonie: implications biogéographiques de récentes découvertes." In: Natjt, J. & Matile, L. (eds.) *Zoologia Neocaledonica*, Volume 4. Paris, France: Mém. Mus. Natn. Hist. nat., 171: 369-378.

Sharma, D. S. K 1999. *Tortoise and Freshwater Turtle Trade and Utilisation in Peninsular Malaysia*. TRAFFIC Southeast Asia. 39pp + vi.

Shiklomanov, I.A. 1997. "Comprehensive assessment of the freshwater resources of the world: assessment of water resource and water availability in the world." Stockholm, Sweden: World Meteorological Organization and Stockholm Environment Institute.

Shine, R. 1991. *Australian Snakes, a Natural History*. Ithaca, New York, U.S.A.: Cornell University Press.

Short, J.W. and G. Marquet. 1998. "New records of freshwater Palaemonidae (crustacean, Decapoda) from New Caledonia." *Zoosystema* 20 (2) 401-410.

Sinha, R.K. et al. 2000. "Status and distribution of the Ganges Susu (Platanista gangetica) in the Ganges River System of India and Nepal" pp: 54-61. In Reeves, R. R., B. D. Smith, and T. Kasuya (eds.) 2000. *Biology and Conservation of Freshwater Cetaceans in Asia.* IUCN Species Survival Commission Paper No. 23, viii + 152pp. Gland, Switzerland and Cambridge, UK: IUCN-The World Conservation Union.

Skelton, P. 1994. "Diversity and distribution of freshwater fishes in East and Southern Africa." Pages 95-131 in Teugels, G. G., J. F. Geugan, and J. J. Albaret, editors. *Biolgical diversity of African fresh and brackish water fishes.* Annales Sciences Zoologiques 275. Tervuren, Belgium: Musee royal d'Afrique central.

Smith and Cook in Thorp, J.H., and Covich., A.P. (eds.) 1991. *Ecology and Classification of North American Freshwater Invertebrates.* U.S.A.: Academic Press.

Smithonian Institution Web site. Invertebrate Zoology Collections, Department of Systematic Biology, Smithsonian Institution, National Museum of Natural History. Online at: http://goode.si.edu/mcs/iz/Query.php

Snoeks, J. 2000. "How well known is the ichthyodiversity of the large East African lakes?" Pages 17-38 in A. Rossiter and H. Kawanabe, eds. "Ancient lakes: biodiversity, ecology and evolution." *Advances in Ecological Research.* Vol.31. U.S.A.: Academic Press.

Spiers, A.G. 1999. "Review of international/continental wetland resources." In Finlayson, C.M. and A.G. Spiers eds. *Global review of wetland resources and priorities for wetland inventory*. 2nd edition. Wageningen, The Netherlands: Wetlands International and Jabiru, Australia: Environmental Research Institute of the Supervising Scientists. On-line at: http://www.wetlands.org/inventory&/GRoWI/welcome.html

Stattersfield, A. J., M.J. Crosby, A.J. Long, and D.C. Wege. 1998. *Endemic Bird Areas of the world: priorities for biodiversity conservation*. Cambridge, UK: BirdLife International.

Stiassny, M.L.J. 1996. "An overview of freshwater biodiversity: with some lessons from African fishes." *Fisheries* 21: 7-13.

Stone, D. (compiler) 1995. *Eurasian Insectivores and Tree Shrews: Status, Survey and Conservation Action Plan.* IUCN/SSC Insectivore, Tree Shrew and Elephant Shrew Specialist Group. Gland, Switzerland and Cambridge U.K.: IUCN-The World Conservation Union.

Stroud, D.A., Davidson, N.C., West, R., Scott, D.A., Haanstra, L., Thorup, O., Ganter, B. & Delany, S. (compilers) on behalf of the International Wader Study Group 2003. "Status of migratory wader populations in Africa and Western Eurasia in the 1990s." *International Wader Studies* 15.

Taub, F.B. ed. 1984. *Ecosystems of the World 23: Lakes and reservoirs.* Amsterdam, The Netherlands: Elsevier Science Publishers.

Teugels, G. G., J. F. Geugan, and J. J. Albaret, editors. 1994. "Biolgical diversity of African fresh and brackish water fishes." *Annales Sciences Zoologiques* 275. Tervuren, Belgium: Musee royal d'Afrique central.

Thompson, F. C., ed. 2000. *Biosystematic Database of World Diptera*. Washington DC: United States Department of Agriculture and Smithsonian National Museum of Natural History. On-line at: http://www.sel.barc.usda.gov/diptera/NAMES/BDWDSER.HTM

Thorsell, J., R.F. Levy, and T. Sigaty. 1997. "A Global overview of wetland and marine protected areas on the World Heritage list." Gland, Switzerland: IUCN. On-line at: http://www.unep-wcmc.org/wh/reviews/wetlands/

TRAFFIC 2002. News article: "Half of Asia's Freshwater Turtles Endangered" available on the Web site at: http://www.traffic.org/news/turtles.html. Accessed May 2002.

Trichoptera Checklist Coordinating Committee. 2002. "The Trichoptera World Checklist." Clemson, SC: Clemson University. On-line at: http://entweb.clemson.edu/database/trichopt/index.htm

Tsuda, S. 1991. "A distributional list of world Odonata." Published by author, Osaka, Japan.

Uetz, P. and T. Etzold. 1996. The EMBL/EBI Reptile Database. *Herpetological Review* 27 (4): 174-175. Available on-line at: http://www.reptile-database.org. Accessed May 2002.

UNEP-WCMC (United Nations Environment Programme - World Conservation Monitoring Centre). 1998. Global Wetland Distribution. GIS data from the UNEP-WCMC Biodiversity Map Library. Cambridge, UK: UNEP-WCMC.

UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2000. *Water Related Vision for the Aral Sea Basin for the Year 2025*. Paris, France: UNESCO.

UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2003.

The World Heritage List as of July 2003. On-line at: http://whc.unesco.org/nwhc/pages/doc/mainf3.htm

University of Florida. 2001. Aquatic, Wetland and Invasive Plant Database. Gainesville, FL: Center for Aquatic and Invasive Plants, University of Florida. On-line at: http://aquat1.ifas.ufl.edu/database.html

USEPA (United States Environmental Protection Agency). 2001. Biological indicators of watershed health. On-line at: http://www.epa.gov/bioindicators/index.html

USFWS (United States Fish and Wildlife Service). 1996. National List of Plant Species that Occur in Wetlands: 1996 national summary. St. Petersburg, Florida, U.S.A.: USFWS Ecology Section. On-line at: http://www.nwi.fws.gov/bha/USFWS 2002 (United States Fish and Wildlife Service). Web site available on-line at: http://ecos.fws.gov. Accessed April 2002.

USGCRP 2000. Water: *The Potential Consequences of Climate Variability and Change for the Water Resources of the United States*. The Report of the Water Sector Assessment Team of the National Assessment of the Potential Consequences of Climate Variability and Change. Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, 151 pp.

USGS (United States Geological Survey). 2001. Nonindigenous Aquatic Species. On-line at: http://nas.er.usgs.gov/

van Dijk, P.P., B. L. Stuart, and A. G.J. Rhodin. 2000. *Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia* Chelonian Research Monographs, No. 2, Chelonian Research Foundation in association with WCS, TRAFFIC, WWF, Kadoorie Farm and Botanic Gardens and the US Fish and Wildlife Service. Chelonian Research Foundation Lunenburg, Massachusetts, USA. 164pp.

Varadi, L. 2001. Review of trends in the development of European inland aquaculture linkages with Fisheries. *Fisheries Management and Ecology*, 8.

VMAP 1997: US National Imagery and Mapping Agency (NIMA). 1997. Vector Map Level 0, the third edition. Bethesda, Maryland, U.S.A.: NIMA.

Vörösmarty, C.J., K.P. Sharma, B.M. Fekete, A.H. Copeland, J. Holden, J. Marble, and J.A. Lough. 1997a. "The Storage and Aging of Continental Runoff in Large Reservoir Systems of the World." *Ambio* 26(4): 210-219.

Vörösmarty, C. J., M. Meybeck, B. M. Fekete, and K. P. Sharma. 1997b. "The Potential Impact of Neo-Castorization on Sediment Transport by the Global Network of Rivers," pp. 261-272 in D. Walling and J. L. Probst, eds. *Human Impact on Erosion and Sedimentation*. Wallingford, U. K.: IAHS Press.

Walter, T. Chad. The Wilson Copepods Library. http://www.nmnh.si.edu/iz/copepod/ Department of Invertebrate Zoology, Smithsonian National Museum of Natural History. Personal communication, April 26, 2002.

Walter, K.S. and H.J. Gillette, eds. 1998. *1997 IUCN Red List of Threatened Plants.* Compiled by the World Conservation Monitoring Centre. Gland, Switzerland and Cambridge UK: IUCN-The World Conservation Union.

Walther, G.R., E. Post, P. Convey, A. Menzel, C. Parmesan, T.J.C. Beebeef, J.M. Fromentine, O. Hoegh-Guldberg, and F. Bairlein. 2002. "Ecological responses to recent climate change." *Nature* 416, 388-395.

Ward, J. V. and J. A. Stanford. 1989. "Riverine Ecosystems: The Influence of Man on Catchment Dynamics and Fish Ecology," pp. 56-64 in D. P. Dodge, ed. *Proceedings of the International Large River Symposium*,

Canadian Special Publication of Fisheries and Aquatic Sciences 106. Ottawa, Canada: Department of Fisheries and Oceans.

WCD (World Commission on Dams). 2000. Dams and Development: A new Framework for Decision-making. The Report of the World Commission on Dams. London, U.K.: Earthscan Publications Ltd.

WCMC/WWF. ("Species Under Threat." UNEP-World Conservation Monitoring Center/World Wide Fund for Nature) 1997. Available at: http://www.wcmc.org.uk/species/data/species_sheets/.

Welcomme, R.L. 1988. *International Introductions of Inland Aquatic Species*. Food and Agriculture Organization of the United Nations (FAO) Technical Series Paper 294. Rome, Italy: FAO.

Wemmer, C. (ed.). 1998. *Deer: Status Survey and Conservation Action Plan.* IUCN/SSC Deer Specialist Group, vi + 106pp. Gland, Switzerland and Cambridge U.K: IUCN-The World Conservation Union.

Wetlands International. 2002. *Waterbird Population Estimates — Third edition*. Wetlands International Global Series No. 12. Wageningen, The Netherlands.

Whitaker, J. O. Jr. *Audubon Society Field Guide to North American Mammals*, Seventh printing 1991.

White, A., Cannell, M.G.R and Friend, A.D. 1999. "Climate change impacts on ecosystems and the terestrial carbon sink: a new assessment." *Global Environmental Change* 9, S21-S30.

Wiegmann, B.M. and D. K. Yeates. 1996. Diptera page in D.R. Maddison, ed. The Tree of Life Web Project. On-line at: http://www2.ncsu.edu/unity/lockers/ftp/bwiegman/fly_html/diptera.html.

Williams, W.D. 2000. "Dryland lakes." *Lakes & Reservoirs: Research and Management* 5: 207-212.

Williams, J. D. and R. J. Neves. 1995. "Freshwater Mussels: A Neglected and Declining Aquatic Resource." In LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. *Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems.* National Biological Service, 530 pp. Washington, DC, U.S.A.: U.S. Department of the Interior. Available on-line at: http://biology.usgs.gov/s+t/noframe/f076.htm.

Witte, F., T. Goldschmidt, J. Wanink, M. van Oijen, K. Goudswaard, E. Witte-Mass, and N. Bouton. 1992. "The Destruction of an Endemic Species Flock: Quantitative Data on the Decline of the Haplochromine Cichlids of Lake Victoria." *Environmental Biology of Fishes* 34:1-28.

WMO (World Meteorological Organization). 1997. *Comprehensive Assessment of the Freshwater Resources of the World.* Stockholm, Sweden: WMO and Stockholm Environment Institute.

Wood, S., K. Sebastian, and S.J. Sherr. 2000. *Pilot analysis of global ecosystems: agroecosystems*. Washington DC: International Food Policy Research Institute and World Resources Institute. On-line at: http://www.wri.org/wr2000/agroecosystems_page.html.

WRI (World Resources Institute) in collaboration with United Nations Environment Programme and United Nations Development Programme. 1994. *World Resources 1994-95*: *People and the Environment*. New York, U.S.A.: Oxford University Press.

WRI (World Resources Institute). 1995. *Africa Data Sampler User's Guide; A Georeferenced Data base for all African Countries.* Washington, DC: WRI.

WRI (World Resources Institute) in collaboration with United Nations Development Programme, United Nations Environment Programme, and the World Bank. 2000. *World Resources 2000-2001: People and*

Ecosystems: the Fraying Web of Life. Washington DC: World Resources Institute.
WWDR (United Nations World Water Development Report) 2003. *Water for People — Water for Life*. 576 pp. Paris, France: UNESCO and Berghahn Books.
WWF India 2002. Web site available on-line at http://www.wwfindia.org. Accessed April 2002.
Xie, Y., Z. Li, W.P. Gregg, and D. Li. 2001. "Invasive species in China—An Overview." *Biodiversity and Conservation* 10: 1317-1341.
Zabrano l., Scheffer M., Martinez-Ramos M. 2001. "Catastrophic response of lakes to benthivorous fish introduction." *Oikos* 94: 344-350.
Zedler, J.B. 2000. "Restoration of biodiversity to coastal and inland wetlands." Pages 311-330 in B. Gopal, W.J. Junk, and J.A. Davis eds. *Biodiversity in wetlands: assessment, function, and conservation*, Volume 1. Leiden: The Netherlands: Backhuys Publishers.

Annex I. REVIEW OF SOME ONGOING ASSESSMENTS AND INITIATIVES ON WATER RESOURCES AND INLAND WATER BIODIVERSITY

There are a number of freshwater assessments and initiatives going on around the world. The majority of these initiatives focus on broad freshwater resources issues, such as sustainable management of water resources; water for agriculture vs. nature; and the assessment of freshwater resources at the basin and global levels. Less numerous are those initiatives or assessments focusing on inland water species and conservation. This section provides a short summary of the different activities and the main institutions and organizations involved, starting with those more directly linked to biodiversity, and moving on to the broader water-related activities.

1. IUCN'S FRESHWATER BIODIVERSITY ASSESSMENT

IUCN launched the *Water and Nature Initiative (WANI)* in 2001. WANI is a collaborative effort of over 50 organizations worldwide to address the water crisis. The Initiative builds on the IUCN Water and Nature Vision and Framework for Action (March 2000), and responds to the call for action voiced at the 2nd World Water Forum in The Hague in March 2000, which identified the lack of freshwater biodiversity-related information as a key obstacle in the development of integrated water resource management.

The goal of the IUCN Water and Nature Initiative is the mainstreaming of an ecosystem approach into river basin policies, planning and management. This is needed to build a world in which the benefits of freshwater and related ecosystems to humankind are optimized, while the intrinsic values of these systems are respected and preserved.

As part of this initiative, IUCN's Species Survival Commission and the Ramsar Bureau have embarked on a project entitled *Benchmarking freshwater biodiversity for better design of sustainable water management strategies*. The aim of this project is to gather and synthesize data on the status of freshwater biodiversity and build the needed capacity to incorporate freshwater biodiversity in water resources planning and management. One of the expected outcomes will be to highlight priority conservation areas for freshwater species, which contrasts significantly with those richest in terrestrial biodiversity. The information generated will support the implementation of the Ramsar Convention on Wetlands and the CBD, especially at the national level (WANI Web site at: http://www.waterandnature.org).

In addition, the IUCN/SSC has a broader Freshwater Initiative, which will compile information on key freshwater taxonomic groups, which serve as indicators of freshwater biodiversity and ecosystem integrity; enhance the SSC's expertise networks on these species; assist in the identification of critical sites for freshwater biodiversity conservation; identify and address processes threatening freshwater biodiversity, and communicate the results to a broader audience.

Both efforts aim to address the gaps and lack of global coverage in current information on freshwater ecosystems, and calls for the generation of knowledge and the translation of existing information into formats that are accessible to water policy makers and water managers.

The first area of activity will be clarifying the degree of threat to freshwater biodiversity by carrying out a Red List assessment of freshwater fishes, amphibians, and key plant and invertebrate groups. The networks developed to assess the status of the indicator species' groups will also identify the critical geographic sites and the major threats to these species.

2. IUCN/SPECIES SURVIVAL COMMISSION SPECIES INFORMATION SERVICE

The IUCN/SSC has initiated a project to gather, compile, and map baseline species data: the Species Information Service (SIS). Data and information compiled will include: species distribution maps; population trends; species' ecological requirements (e.g., habitat preferences, altitudinal

ranges); degree and types of threat (conservation status according to IUCN Red List Categories and Criteria); conservation actions (taken and proposed); and key information on use of each particular species. In addition, the SIS hopes to provide species biodiversity analyses that draw on the baseline information. One of the first products that the SIS is working on is the mapping of all mammal species and the *Global Amphibian Assessment*, which is incorporating the information on all 5,000 species of amphibians into the SIS. All the ranges for African mammals have been mapped and their status assessed. The amphibian mapping work is expected to be completed by early 2004. Work on other groups such as reptiles, freshwater fish, marine fish, molluscs, plants, butterflies and other selected invertebrate groups will continue throughout 2003 (IUCN/SSC Web site at http://www.iucn.org/themes/ssc/). Finally, the key conservation-related information on all globally threatened birds has been mapped and summarized by BirdLife International, in collaboration with numerous experts, national Partners and the IUCN Species Survival Commission (BirdLife International 2000).

3. WWF-US FRESHWATER ECOREGIONAL ASSESSMENTS

Within its *Ecoregions of the World* project, which aims to assess and map the conservation status of terrestrial, freshwater and marine ecorgions, WWF-US has an ongoing freshwater ecoregion analysis. The terrestrial realms include North America, Indo-Pacific, Africa, Eurasia, Latin America and the Caribbean, and Oceania. The goal of the freshwater ecoregional analysis is to delineate freshwater conservation units based on zoogeography, and synthesize biodiversity information for all units. The goal of the project is to improve conservation initiatives at the international, regional, and landscape levels. WWF defines ecoregions as "relatively large units of land or water containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change."

The global work builds on several more detailed continental scale assessments. Assessments for Latin America and the Caribbean and North America have been published, and a volume for Africa is underway. These assessments include evaluations of both biodiversity and threats. Biodiversity visions describing what will be required to maintain biodiversity targets of ecoregions in the long term, are also being developed for WWF's priority ecoregions. Ecoregions with a freshwater focus include the southeast rivers and streams in the U.S., the Amazon River and flooded forests, the Congo River basin, lower Mekong River basin, and Niger River basin (WWF US Web site at: http://www.worldwildlife.org/ecoregions/related_projects. htm.).

4. WWF WATER AND WETLAND INDEX FOR EUROPE

WWF's Water and Wetland Index provides a "snapshot" of the condition of key freshwater ecosystems in Europe and can be used as a tool to set priorities for action. It also serves as a measure of the preparedness of governments to effectively manage their water resources, using the EU Water Framework Directive as a guide.

The index takes into consideration the main pressures on freshwater ecosystems (e.g. agriculture, aquaculture, industrial pollution, etc.), the ecological quality of its habitats, the status and loss of biodiversity, the status and use of water resources, and the quality of monitoring programmes.

The first phase of the Water and Wetland Index (WWI-1) ran from August 1999 to June 2001 and aimed at providing a 'snapshot' of the freshwater status in 16 European countries (Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Slovakia, Spain, Sweden, Switzerland, Turkey and the United Kingdom). The WWI-1 produced and

scored 49 indicators assessing: a) the "ecological status" of rivers, lakes, mires and wetlands; b) the condition of threatened freshwater species; c) pressures and impacts on freshwater; and d) the quality of the monitoring programmes. Data collection, scoring of indicators and index development was done in close collaboration with WWF offices and partner NGOs in the respective countries.

The results of the first phase, point to 3 key findings:

1. Fifty out of 69 river stretches in Europe were found to be of poor ecological quality due to the impacts of canalisation, dams, pollution and altered flow regimes;
2. Governments are in a weak position to protect biodiversity in freshwater ecosystems within Europe's "nature network";
3. Most European countries have inadequate environmental monitoring systems to properly safeguard their water resources.

The second Phase of the Water and Wetland Index is aimed at the evaluation of Government's water policy, especially in relation to the implementation of the EU Water Framework Directive, the application of Integrated River Basins Management (IRBM) principles and the quality of the programmes that are being implemented to solve the most urgent freshwater problems in each country. The second phase is currently under development (March 2002-October 2003) and includes 3 subsets of indicators:

1. Use of international legal instruments;
2. Application of IRBM principles;
3. Response to pressures and impacts

that will be scored both in EU and non-EU countries.

5. DECLINING AMPHIBIAN POPULATIONS TASK FORCE (DAPTF)

IUCN/SSC established the DAPTF in 1991 as a response to the alarming decline in amphibian populations around the world. The DAPTF operates through a network of 90 Regional Working Groups formed by experts and volunteers that collect geographical data on amphibian declines and their causes. DAPTF also provides funds to specific research projects related to amphibian declines. Currently DAPTF is focusing on producing a review of the amphibian population decline, developing and compiling information for the amphibian database that will provide researchers with all available data on the status of amphibian populations worldwide, and a compendium of reports from the regional working groups, which will bring information on the status of amphibian populations, particular threats to amphibians, and any recorded declines in their region into the public domain (DAPTF Web site at: http://www.open.ac.uk/daptf/index.htm.)

6. BIRDLIFE INTERNATIONAL'S IMPORTANT BIRD AREAS

BirdLife International has identified, and is in the process of identifying, priority areas for bird conservation: Important Bird Areas (IBAs). IBAs are sites of international significance for the conservation of birds at the global, regional or sub-regional level. They are identified using standardized, internationally agreed criteria and are intended to be a practical tool for conservation. The IBAs encompass a range of habitat types, including inland and coastal wetlands that support a variety of waterbirds. A regional inventory of IBAs in the Middle East was published in 1994, covering 391 sites within 14 countries/territories (Evans 1994). A revised pan-European IBA inventory was published in 2000, covering 3,619 sites in 51 countries/territories (Heath and Evans 2000). In 2001, the first pan-African inventory was published, covering 1,230 sites in 58 countries/territories (Fishpool and Evans 2001). Regional assessments are nearing completion in Asia and Antarctica, and are ongoing in the Americas and Pacific regions (BirdLife International 2001). It is anticipated that up to 12,000 IBAs will have been identified when global coverage is completed by 2005.

In addition to the regional IBA publications, at least 40 national IBA inventories have already been prepared and published in the national language by BirdLife Partner organizations. These include 11 from Africa, 3 from Asia, 2 from the Americas, 3 from the Middle East and 22 from Europe (BirdLife International 2001).

7. SPECIES 2000 PROGRAMME

Currently there is no comprehensive indexing system for the 1.75 million animals, plants, fungi and microorganisms named by science. A widely accessible index, will aid nations to fulfill their obligations under the Convention on Biological Diversity. The Species 2000 Programme, established by the International Union of Biological Sciences (IUBS), in co-operation with the Committee on Data for Science and Technology (CODATA) and the International Union of Microbiological Societies (IUMS) in September 1994, aims to fill in this gap. The goal of Species 2000 is to "enumerate all known species of plants, animals, fungi and microbes on Earth as the baseline dataset for studies of global biodiversity" (Species 2000 Web site at: http://www.sp2000.org/). Species 2000 will also provide a simple access point to other species databases. Users worldwide will be able to verify the scientific name, status and classification of any known species through species checklist data drawn from an array of participating databases. The Species 2000 Programme has been endorsed by the UNEP Biodiversity Work Programme (1996-1997), and is associated with the Clearing House Mechanism of the UN Convention on Biological Diversity. The Secretariat for the programme is based at the University of Reading in the U.K.

8. CONSERVATION INTERNATIONAL'S AQUARAP AND FRESHWATER BIODIVERSITY HOT-SPOTS

AquaRAP is a rapid assessment methodology used by CI "to assess the biological and conservation value of tropical freshwater ecosystems in Latin America." AquaRAP was created in 1996 as a joint initiative between Conservation International and The Chicago Field Museum (CI Web site at: http://www.conservation.org.) The methodology allows for a rapid, sample-based survey of fishes, plants, invertebrates, and water quality during 3-4 weeks expeditions. So far there are two published AquaRAP reports, one focusing on the Pantanal region in Brazil and one on the Upper Río Orthon Basin in Bolivia. There is also a preliminary report for the Caura River in Venezuela.

Recently, CI has also announced that they are in the planning process to identify the world's freshwater hotspots in collaboration with other non-governmental organizations. Efforts to map the distribution range of a number of aquatic taxa are underway in collaboration with IUCN/SSC.

9. THE NATURE CONSERVANCY'S FRESHWATER INITIATIVE

The Nature Conservancy's Freshwater Initiative was established in 1998 with the goal to "dramatically increase freshwater conservation in the United States, Latin America, and the Caribbean" (TNC Web site Freshwater Initiative at: http://www.freshwaters.org/). The Initiative works in over 40 selected sites across the Americas, where private and public partnerships are established to "reduce two of the most pervasive threats to freshwater ecosystems: altered natural water flows and farm run-off pollution." TNC's initiative has also developed a new tool for aquatic community classification, which allows users to map existing locations of freshwater animals and their habitats across broad regions and assess their relative conservation priority. Finally, the Initiative also compiles and communicates the "lessons learned" from their individual projects and makes these available to the wider public via meetings and conferences, training workshops, the Internet, literature, and video (TNC's Freshwater Initiative Web site at: http://www.freshwaters.org)

10. MILLENNIUM ECOSYSTEM ASSESSMENT (MA)

The MA is a four-year process initiated in April 2001, designed to improve the management of the world's natural and managed ecosystems by helping to meet the needs of decision-makers and the public for peer-reviewed, policy-relevant scientific information on the linkage between ecosystems and the goods and services they provide; the condition of ecosystems; the consequences of ecosystem change and the options for response. The MA will be undertaken at multiple spatial scales and will cover all ecosystems, including freshwater and wetlands. The design consists of a global assessment as well as sub-global assessments of conditions and change in ecosystems in individual communities, nations, and regions. The sub-global component of the MA includes numerous assessments at scales ranging from local villages to river basins designed to foster and build capacity for widespread adoption of integrated assessment approaches in other regions and nations. These sub-global assessments will develop methodologies to carry out cross-sectoral assessments and effectively integrate information across different scales. The MA process will also identify important areas of scientific uncertainty and data gaps that hinder decision-making and deserve greater research support (MA Web site at: http://www.millenniumassessment.org.)

The Convention on Biological Diversity, the Convention to Combat Desertification, and the Convention on Wetlands all have endorsed the establishment of the MA as a joint assessment process to meet some of the information needs of the conventions.

11. GLOBAL INTERNATIONAL WATER ASSESSMENT (GIWA)

GIWA is a UNEP lead initiative in collaboration with the Global Environmental Facility and the Kalamar Institute in Sweden. The assessment focuses on the ecological status and causes of environmental problems of 66 transboundary water areas, encompassing both marine and freshwater. The overall objective of GIWA is to "develop a comprehensive strategic assessment that may be used by GEF and its partners to identify priorities for remedial and mitigation actions in international waters, designed to achieve significant environmental benefits at national, regional and global levels. GIWA will analyze the current problems and their societal roots causes, and develop scenarios of the future condition of the world's water resources and policy options. Ultimately, the aim is to provide sound scientific advice to decision-makers and managers concerned with water resources and dealing with environmental problems and threats to transboundary water bodies.

12. UNITED NATIONS WORLD WATER ASSESSMENT PROGRAMME (WWAP)

This assessment is an initiative lead by the UN, with the Secretariat based at UNESCO. The primary output is a periodic publication entitled the World Water Development Report (WWDR). It is envisioned that this publication will provide an ongoing global assessment of the state of the world's freshwater resources and their use. The first WWDR will be launched at the 3rd World Water Forum in Japan, March 2003 and will focus on the following case studies: the Chao Phraya basin (Thailand), the Greater Tokyo region (Japan), Lake Titicaca basin (Bolivia, Peru), the Peipsi lake basin (Estonia, Russia), the Ruhunu basin (Sri Lanka), the Seine-Normandy basin (France), and the Senegal river basin (Guinea, Mali, Mauritania, Senegal). The Programme also serves as an "umbrella" for the coordination of existing UN initiatives related to freshwater such as, the data compilation done by the Global International Waters Assessment (GIWA) of UNEP, the Global Runoff Data Center (GRDC) of WMO, AQUASTAT of FAO, the International Groundwater Resources Assessment Centre (IGRAC) being established by WMO and UNESCO, the water supply and

sanitation databases of WHO and UNICEF and the databases of the World Bank system (WWAP Web site at: http://www.unesco.org/water/wwap).

The focus of the programme is both surface and groundwater, but will link with the coastal and marine environments as needed, for example to examine the issues of land-based pollution and sedimentation in coastal areas. The programme also hopes to identify water management strategies and policies which work well; compile and synthesize data, information and knowledge on all aspects of water resource assessment; build capacity on how to conduct water assessments; and provide advice to Member States on water-related policies and technical issues at local, national, regional and international levels.

13. WORLD WATER COUNCIL

The World Water Council is an international water policy think tank founded in 1996 following recommendations issued at the 1992 Rio Earth Summit. Its mission is to raise "awareness of critical water issues to facilitate efficient conservation, protection, development, planning, management and use of water in all its dimensions on an environmentally sustainable basis for the benefit of all life on the earth" (World Water Council Web site at: http://www.worldwatercouncil.org). The WWC delineated a *Water Vision* to build consensus among professionals and stakeholders to design management plans that avert further water crises. In order to prepare this comprehensive vision, the WWC held regional and sectoral consultations that resulted in different regional and sectoral visions, presented at the Second World Water Forum in The Hague in 2000, and which were incorporated into the final Vision document. The regional consultations took place in Africa, North and South America, Central America and the Caribbean, Central and Eastern Europe, Mediterranean region, South and Southeast Asia, Southern Africa, West Africa, Arab Countries, Australia, Russia, China, Nile Basin, Aral Sea Basin and the Rhine Basin. The sectoral consultations included three main themes: *water for people, water for food and water for nature.* These sectoral visions were developed by different organizations and specialists in their respective fields. For example, the *Vision for Water and Nature* was developed by IUCN-The World Conservation Union (available on-line at: http://www.iucn.org/webfiles/doc/archive/2001/IUCN769.pdf.) In addition several other sectoral visions were developed, including visions for water in rivers, sovereignty, inter-basin water transfer, water, education and training, tourism and recreation, rainwater harvesting, lakes, groundwater, and hydropower.

The WWC also created the World Water Forum. Its first meeting took place in Morocco in 1997; the third one will take place in Kyoto, Japan in 2003. The WWC produces publications on water-related issues, as well as publishes the journal *Water Policy*. The WWC also produces the World Water Actions Report, which compiles successful actions, which affect the way water is managed.

14. GLOBAL WATER PARTNERSHIP

The Global Water Partnership (GWP) was created by the World Bank, the United Nations Development Program (UNDP), and the Swedish International Development Agency in 1996. The GWP is a working worldwide network of partners including government agencies, public institutions, private companies, professional organizations, non-governmental organizations, multilateral development agencies and others working on water-related issues. Its mission is to "support countries in the sustainable management of their water resources" by promoting and implementing integrated water resources management. Its main role is to bring together "financial, technical, policy and human resources to address the critical issues of sustainable water management" from different regions and at different management levels (local, national, regional, international, and basin-level) (GWP Web Site at: http://www.gwpforum.org).

15. GLOBAL DIALOGUE ON WATER, FOOD AND ENVIRONMENT

The Dialogue is a strategic alliance comprising ten key stakeholders in the areas of water, agriculture and environment, housed within UN agencies, environmental organisations, farmers associations, water research institutions, irrigation engineers and water umbrella organisations. The goal of the dialogue, which came out of the Second World Water Forum, is to "improve water resources management for food security and environmental sustainability with a special focus on the reduction of poverty and hunger and the improvement of human health" by building bridges between the agricultural and environmental communities on water resource issues. The idea behind the dialogue is that by bringing together the irrigation, environment and rural development communities, a global consensus on the role that irrigated agriculture currently plays and should play in the future could be reached (Dialogue Web site at: http://www.cgiar.org/iwmi/dialogue/). The main areas of work undertaken under the dialogue framework are:

a) Establish cross-sectoral dialogues among key stakeholders, at national (10 countries) and river basin or local level (10-15 case studies) on options to achieve food and environmental security to reduce poverty and hunger and improve health;
b) Provide an enhanced knowledge base to feed the dialogue and establish credible and authoritative knowledge accepted by both agricultural and environmental constituencies. Activities include the development of common definitions for water, food, and environmental security; common indicators for poverty, hunger, health, and environmental quality; production of quality information and analyses on water availability, use and requirements for agriculture, environment and associated uses; the development of scenarios at global, national and basin levels concerning alternative options to develop and manage water resources for food and environmental security; and the assessment of impacts on food security, hunger, poverty, livelihoods, health, environmental quality and biodiversity of alternative scenarios.
c) Test and evaluate innovative approaches that enhance sustainable water security for agriculture and the environment via a network of local-and basin-level action-oriented projects, which would lead to the identification of "best practices."

The Dialogue Secretariat is based at the International Water Management Institute (IWMI), in Sri Lanka. In addition to IWMI, the Dialogue partners include the Food and Agriculture Organization, the Global Water Partnership, the International Commission on Irrigation and Drainage, the International Federation of Agricultural Producers, the World Conservation Union, the United Nations Environment Programme, the World Health Organization, the World Water Council and the WWF (Dialogue Web site at: http://www.cgiar.org/iwmi/dialogue/.)

16. CGIAR CHALLENGE PROGRAM ON WATER AND FOOD

The need for the Challenge Program (CP), envisaged as a major program of research, extension and capacity building over a period of perhaps 10-15 years, was identified through the extensive, participatory World Water Vision/World Water Forum process that ended in March 2000. The program's mission is "to increase the productivity of water for food production and livelihoods, in a manner that is environmentally sustainable and socially acceptable", and it is targeted at increasing food production without increasing global diversions of water to agriculture above the year 2000 level. In terms of geographic focus, the CP will be directed at "rural and peri-urban areas in river basins with low average incomes and high physical, economic or environmental water scarcity or water stress, with particular focus on low-income groups within these

areas" (i.e. developing areas). The five inter-related research themes (and the hierarchy of subsystems in the CP's Food-Water System with which they are coincident—as indicated in parentheses) for the CP directed towards the development of objectives for food security, poverty alleviation, improved health and environmental security are: (1) improving the efficiency of water use in agriculture via increased crop water productivity (Agro-ecosystems); (2) management of upland watersheds for multiple functions (Upper Catchments); (3) management of aquatic ecosystems, including biodiversity, ecosystem structure and function, with particular emphasis on capture fisheries and aquaculture (Aquatic Ecosystems); (4) policy and institutional aspects of water management (Global and National Policies and Institutions); and (5) interaction among the other four themes and synthesis of outputs (Integrated River Basin Management). Although all of these themes have direct bearing on the conservation and management of inland waters and their biodiversity, theme (3) is most central, having as its core objective the enhancement of food security and livelihoods by maintaining aquatic ecosystems and optimising fisheries (Dugan et al. 2002). The theme's research agenda aims to achieve this objective by directed research into four areas: (i) policies, institutions and governance; (ii) valuation of ecosystem goods and services, and the costs of degradation; (iii) environmental water requirements; and (iv) improvement of water productivity.

A series of benchmark basins, ranging from within-country to major international basins, will serve both to integrate the five major themes, as well as to link the initiative with the complementary Comprehensive Assessment of Water Management for Agriculture (SWIM2) and Dialogue on Water, Food and Environment.

It is proposed that the CP program, which has now reached the full proposal stage (IWMI Web site, 2002) be jointly owned and lead by a Consortium of partners, which would include Future Harvest Centres, major National Agricultural Research and Extension Systems in key countries, research institutes from OECD countries and several "NGO/private" partners.

17. COMPREHENSIVE ASSESSMENT OF WATER MANAGEMENT IN AGRICULTURE

The Comprehensive Assessment (CA) is an international research program, the primary goal of which is to create a new, improved knowledge base on all aspects of water management in agriculture, through investigating questions pertaining to water use (1950s to the present) and its impacts on the environment, poverty and food security. The knowledge base is aimed at the information needs of poor people investing in water/agriculture solutions, donors and policy makers. It specifically recognises the need to develop both a more precise understanding of the water-food-nature interactions in developing countries and knowledge-based analyses of the situation. It is expected that the program will generate several outputs, including: an as yet non-existent, comprehensive set of information on water use in agriculture; conceptual and analytic tools to assist water managers and policy makers advance their strategies for water, food and environmental security; identification and dissemination of innovative solutions to increase water productivity in agriculture, improve health situations and protect natural ecosystems impacted by agriculture; capacity building activities at multiple levels. The CA will also interact with the Dialogue on Water, Food and Environment, in addition to the CP and other initiatives.

The CA is organised through the CGIAR Systemwide Initiative on Water Management (SWIM2), and includes partners such as CG centres, FAO and others. It is a five year initiative, ending in line with the 4th World Water Forum, 2006.

As for all the other initiatives, the Global Dialogue on Water, Food and Environment, the CGIAR Challenge Program on Water and Food, and the Comprehensive Assessment of Water Management in Agriculture initiatives have direct

bearing on the CBD workplan for biological diversity of inland waters particularly in relation to the sections and subsections on basin-scale water resource management, assessment of the impacts of water users on aquatic biodiversity, and the impacts on and importance of aquatic biodiversity for dependent livelihoods. The International Water Management Institute in Sri Lanka coordinates the three initiatives.

18. LAKENET'S WORLD LAKES BIODIVERSITY CONSERVATION INITIATIVE

LakeNet is a global network of more than 800 people and organizations in 80+ countries, guided by an international steering committee that includes regional representatives from Africa, Asia, Europe, and North and South America. In its 2001 report, *Biodiversity conservation of the world's lakes: A preliminary framework for identifying priorities*, LakeNet identified 250 lakes in 73 countries as initial priorities for biodiversity conservation based on UNEP, WWF and Ramsar data. These lakes support globally significant fish, mollusk, crab, shrimp and bird biodiversity, or they are representative examples of ancient or rare types of lakes.

The world lakes biodiversity conservation initiative began in 2000. LakeNet hosts an online clearinghouse of lake information at; http://www.worldlakes.org/ is providing technical assistance and advisory services to lake basin management groups and has started to compile online GIS maps of lake watersheds. Through a joint project with Living Lakes, LakeNet is conducting biodiversity needs assessments with partner organizations on 20 lakes. In collaboration with the International Lake Environment Committee (ILEC), LakeNet is developing case studies and holding regional workshops to document lessons learned in lake basin management. And in collaboration with the Shiga Prefecture Government, ILEC and UNEP, LakeNet is preparing a World Lakes Vision to guide future work at the global level.

Also available

Issue 1: Assessment and Management of Alien Species that Threaten Ecosystems, Habitats and Species

Issue 2: Review of the Efficiency and Efficacy of Existing Legal Instruments Applicable to Invasive Alien Species

Issue 3: Assessment, Conservation and Sustainable Use of Forest Biodiversity

Issue 4: The Value of Forest Ecosystems

Issue 5: Impacts of Human-Caused Fires on Biodiversity and Ecosystem Functioning, and Their Causes in Tropical, Temperate and Boreal Forest Biomes

Issue 6: Sustainable Management of Non-Timber Forest Resources

Issue 7: Review of the Status and Trends of and Major Threats to Forest Biological Diversity

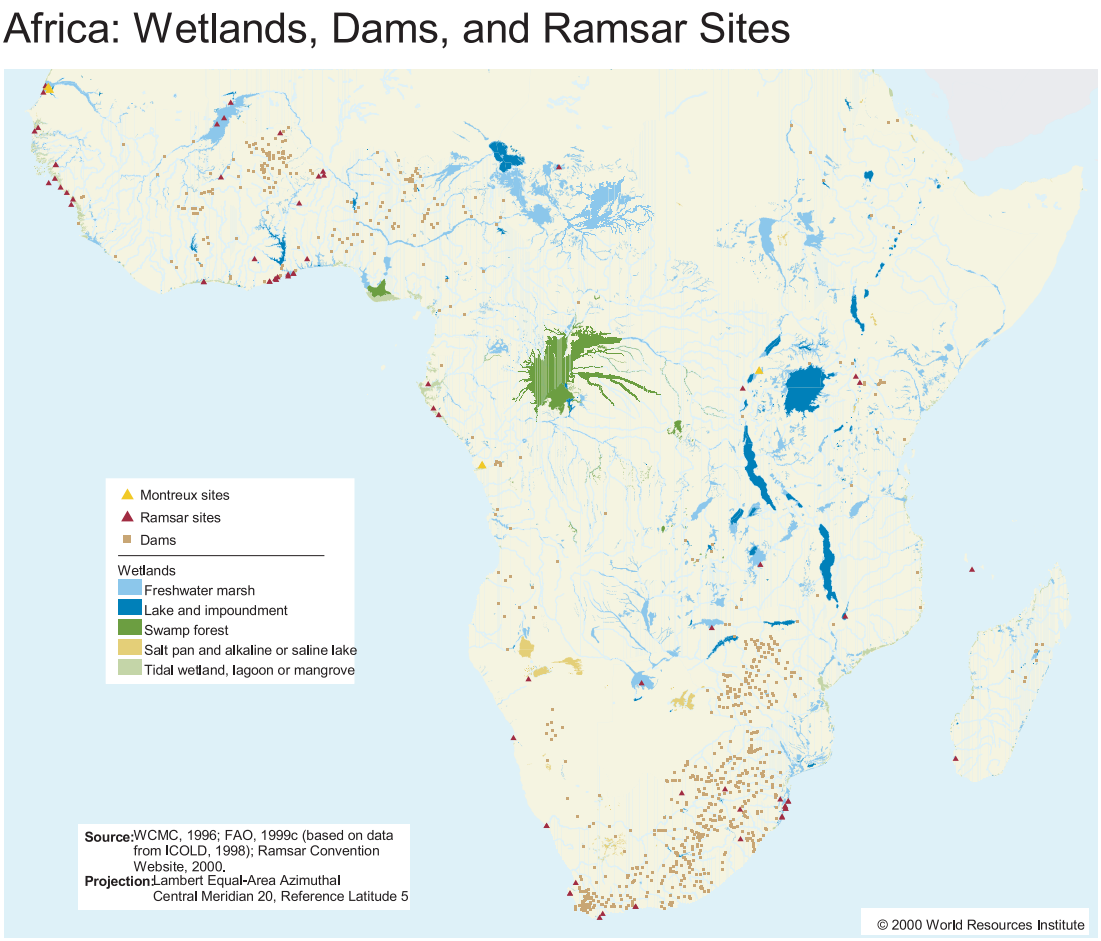
Issue 8: Status and Trends of and Threats to Mountain Biodiversity, Marine, Coastal and Inland Water Ecosystems: Abstracts of poster presentations at the eighth meeting of the Subsidiary Body of Scientific, Technical and Technological Advice of the Convention on Biological Diversity

Issue 9: Facilitating Conservation and Sustainable Use of Biodiversity: Abstracts of poster presentations on protected areas and technology transfer and cooperation at the ninth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice

Issue 10: Interlinkages Between Biological Diversity and Climate Change: Advice on the integration of biodiversity considerations into the implementation of the *United Nations Framework Convention on Climate Change* and its *Kyoto Protocol*

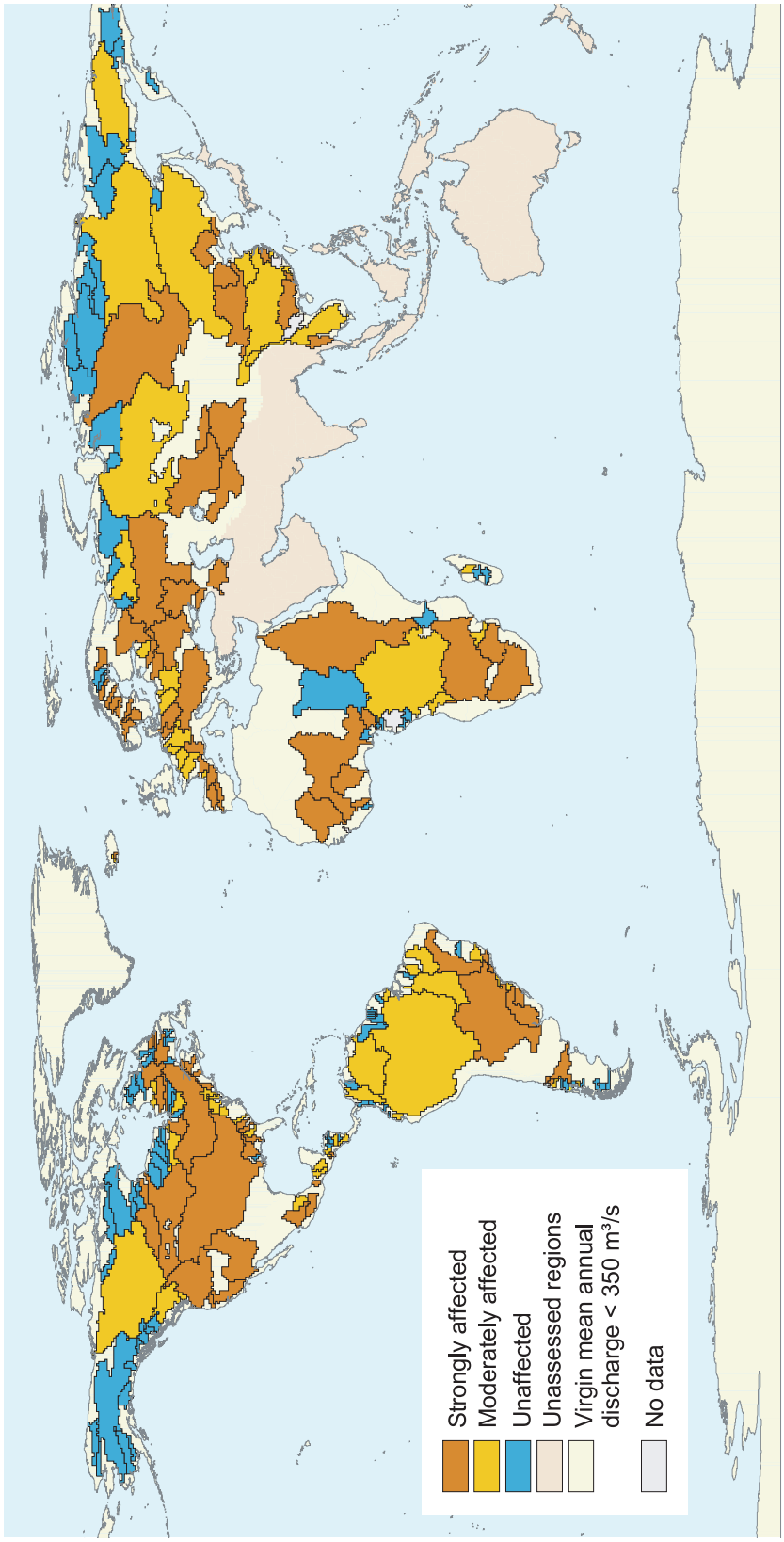
A. APPENDIX: MAPS

Map 1. Extent of wetlands in Africa



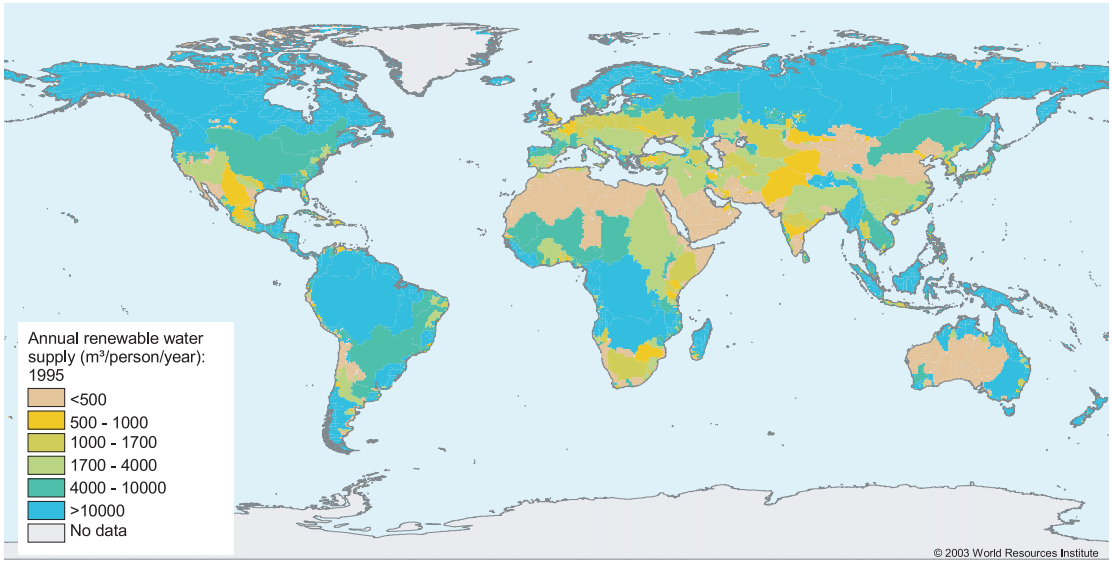
Source: Revenga et al. 2000.

Map 2. Fragmentation and Flow Regulation



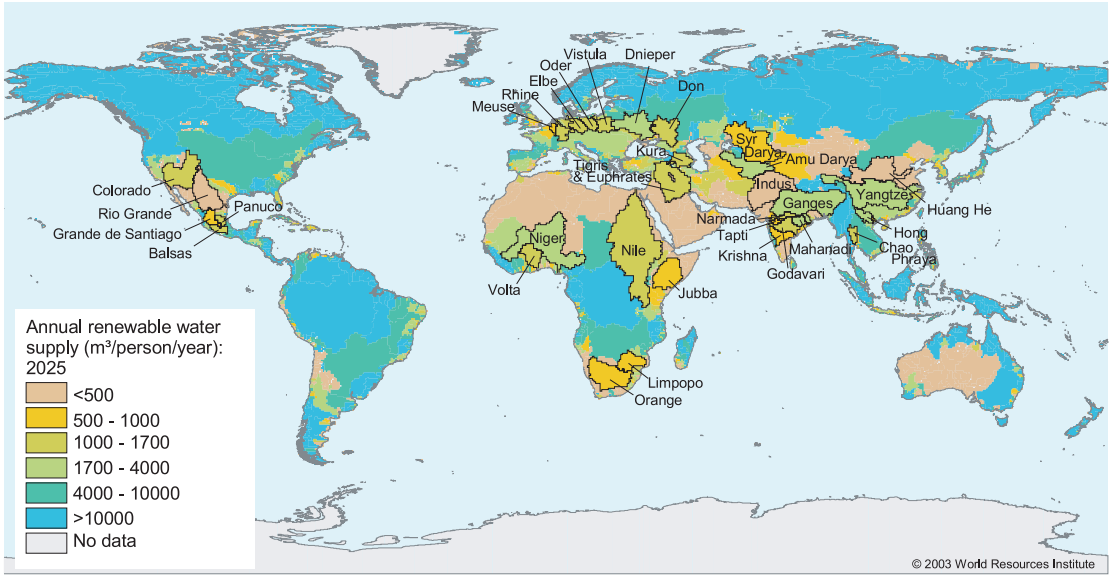
Source: Revenga et al. 2000.

Map 3a. Per Capita Water Supply by River Basin in 1995



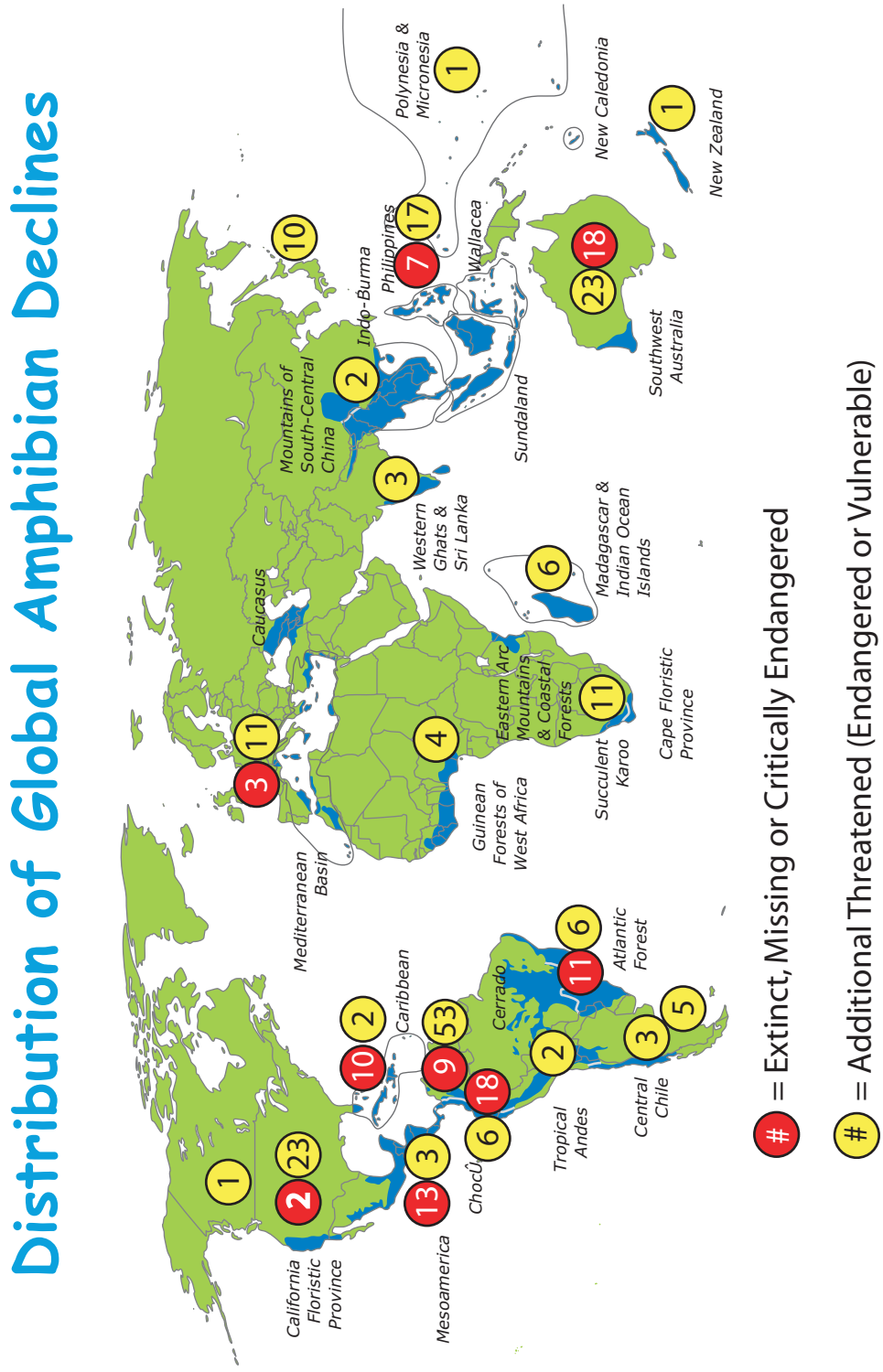
Source: Revenga et al. 2000.

Map 3b: Projections of per capita water supply for 2025.



Source: Revenga et al. 2000.

Map 4: Global decline in Amphibians



Source: Revenga et al. 2000.