REPORT SERIES 2

July 2001

Biodiversity Conservation of the World's Lakes: A Preliminary Framework for Identifying Priorities

Laurie Duker and Lisa Borre

LAKENET

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July 2001

This report is the second in a series published by the LakeNet Secretariat. Those in print are listed below.

1. The state of the world's lakes: A literature review. January 2001.
2. Biodiversity conservation of the world's lakes: A preliminary framework for identifying priorities. July 2001.

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LakeNet is a global network of people and organizations promoting the conservation and sustainable management of lakes. Monitor International, a U.S.-based nonprofit organization, is dedicated to conserving marine and freshwater ecosystems throughout the world and serves as Secretariat for LakeNet.

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Please cite this report as: Duker, L. and L. Borre 2001. Biodiversity conservation of the world's lakes: A preliminary framework for identifying priorities. LakeNet Report Series, Number 2. Monitor International, Annapolis, Maryland USA.

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Biodiversity Conservation of the World's Lakes: A Preliminary Framework for Identifying Priorities

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Executive Summary

Lakes hold almost 90% of the liquid surface freshwater on earth, and are major regulators in global carbon, nitrogen and phosphorus cycles. Lakes are important reservoirs for freshwater, purifiers of terrestrial wastes, and zones for aquifer recharge, and provide critical floral and faunal habitat. Despite their importance, lakes continue to be fairly invisible on the global conservation screen. Lakes and their watersheds are dramatically underrepresented both in protected areas and in conservation funding.

This report suggests a preliminary methodology for identifying lakes, out of approximately five million that exist worldwide, with the most significant biodiversity in order to maximize the value of lake conservation work and funding. Two hundred and fifty lakes in 73 countries are identified as initial priorities for biodiversity conservation based on the available but very limited data on fish, mollusc, crab, shrimp, and bird biodiversity supported by each lake, and the rarity of certain representative types of lakes. Identified lakes are both fresh and saline, permanent and seasonal, natural and human-made.

This initial list of lakes is skewed toward Europe (where more key lakes have been added to Ramsar) and fails to include a number of highly biodiverse lakes in developing countries due to insufficient biodiversity data. As more data are collected and analyzed, lakes will inevitably be added and dropped from the priority list.

This attempt at prioritizing global lakes broadens the types of species considered in assessing biodiversity by combining data from past studies and data collected by the Ramsar Wetlands Bureau on lakes designated as being of international importance. It also promotes the use of risk factors such as water scarcity and human institution measures for assessing priorities and developing strategic approaches for conserving lakes.

Priority lakes are identified with the hope of soliciting feedback and engaging in dialogue with other organizations interested in conserving biodiversity of the world's lakes. Proposed next steps include: (1) convening a workshop of interested organizations to lay the groundwork for a partnership or alliance that would develop and help implement the conservation strategy; (2) further data collection and analysis, (3) development of watershed maps and management plans, (4) establishment of a central repository of information on the internet, (5) dissemination of effective strategies and (6) coalition building and raising awareness.

Biodiversity is only one of many important criteria for prioritizing conservation work on lakes. Lakes serve many beneficial and critical functions for humans including the provision of food and water and are integrally connected to local sanitation systems and industry. These lake functions should also be further evaluated in order to prioritize and strategize regarding additional lake conservation work in these important watersheds.

Introduction

Lakes hold almost 90% of the liquid surface freshwater on earth, and are major regulators in global carbon, nitrogen and phosphorus cycles (Shiklomanov 1993). Lakes are important reservoirs for freshwater, purifiers of terrestrial wastes, and zones for aquifer recharge. Lakes provide critical habitat for fish, crustaceans, molluscs, turtles, amphibians, birds, mammals, insects and aquatic plants, and support biodiversity on surrounding land. Due to the isolation between most lakes, many lakes harbor high numbers of endemic species, existing nowhere else on earth.

The maintenance of lake health and biodiversity is central to the lives of human communities that surround lakes. Lake Manzala, the largest of the Nile Delta Lakes, produces 30% of Egypt's fish yield and supports 120,000 fishermen (Ayres et al.1996). Lake Malawi fisheries supply 50% of the animal protein in Malawi. In many countries, lakes supply a large proportion of the drinking water. Lake Chapala, which has been shrinking dramatically due to water diversion for irrigation, is the main water source for Guadalajara, Mexico, whose population exceeds 4.5 million (International Lake Environment Committee 1998).

World lakes are in crisis. Diversion of lake water for use in irrigation and industry, invasions of plant and animal exotic species, and contamination by toxics and nutrients from industry, farms, sewage, and urban runoff are common on a scale today that significantly threatens lake ecosystems on every continent but Antarctica (Abramovitz 1996, Ayres et al. 1996, Jorgensen & Matsui 1997, Groombridge & Jenkins 1998, Postel 1999, Duda & El-Ashry 2000, Hall & Mills 2000, Khan & Siddique 2000, Lemly et al. 2000, Revenga et al. 2000). Fragmented and resource-poor lake management prevents, delays or distorts the efficient planning, implementing and enforcement of comprehensive, participatory watershed-wide lake management plans in both developed and developing countries (Harrington 1988, Crivelli & Maitland 1995, Carpenter 1998, Wilson 1999, Abderrahman 2000, Khan & Siddique 2000). In most parts of the world anthropogenic impacts on lakes are spreading geographically and becoming more intense in quantity and quality due to human population increases and the globalization of trade, which has increased deforestation and the use of pesticides and fertilizers, and has spurred the spread of invasive species (Ayres et al. 1996, French 2000).

Despite its importance, freshwater biodiversity continues to be fairly invisible in global conservation initiatives (Shumway 1999). Programs to protect freshwater biodiversity have lagged far behind programs directed toward terrestrial or marine habitats. Although freshwater issues in general have garnered increasing interest in the last five years, there continues to be little focus specifically on lake conservation, despite lakes' critical role in the freshwater cycle. Lakes and their watersheds are dramatically underrepresented both in protected areas and in conservation funding.

Trying to tackle interventions to conserve lakes, especially large ones, at the scale of entire watersheds can be a challenging, costly and lengthy undertaking, yet this is precisely the type of projects that are needed to effectively address threats to lakes. In some lake regions, agencies are shifting to planning on a lake watershed basis instead of on the basis of political boundaries, and are working to reach consensus among diverse constituencies about priorities and goals for

managing lakes. Many are moving in the direction of applying an integrated approach to water resources management and working to achieve sustainable industrial and agricultural planning as well as changes in institutional arrangements to promote planning at the lake watershed level.

Rationale for prioritizing world lakes for biodiversity conservation

Prioritizing conservation work on the five million lakes around the world can help maximize protection of aquatic biodiversity and husband scarce conservation resources. It can galvanize lake protection efforts by helping to educate decision-makers, the media and the public about the importance of lakes by telling the story of specific lakes with amazing diversity, facing serious threats. A priority list of lakes needing conservation and/or restoration will help international conservation donors and national and local government agencies make wise use of their conservation dollars. Increases in funding for lake conservation are urgently needed.

Identifying priority lakes can also provide a focus for data collection efforts to more effectively monitor the state of lake diversity and the effectiveness of efforts to protect it. A list of priority lakes can provide needed information and leverage for people working at the watershed level to save their lakes.

Previous efforts to identify lake biodiversity hotspots and key representative lakes

In 1998 the United Nations Environment Programme (UNEP), working with the World Conservation Monitoring Centre (WCMC), developed a preliminary global assessment of freshwater biodiversity. The UNEP report filled an important gap, since previous efforts by nonprofit groups and international agencies to identify biodiversity hotspots had focused solely on terrestrial and marine habitats.

UNEP identified 136 rivers, lakes, basins and entire countries "of special importance for diversity (species richness and/or endemism)" in fishes, molluscs, crabs, crayfish, and fairy shrimps (Groombridge & Jenkins 1998). UNEP identified 41 specific lakes or clusters of lakes as well as the lakes of the British Isles as being of "special importance for fresh water diversity". Of the 41 lakes or lake clusters, 13 lakes were identified as of particular importance for more than one of the faunal groups analyzed.

The same year that UNEP published its list of key lakes of "special importance for diversity" World Wildlife Fund (WWF) also attempted to prioritize global water hotspots. WWF described their effort as " a representation approach to conserving the earth's distinctive ecoregions" (Olson & Dinerstein 1998). WWF identified Global 200 ecoregions based on analyses of species richness, species endemism, unique higher taxa, unusual ecological or evolutionary phenomena, and added global rarity of major habitat types.

Included in WWF's Global 200 ecoregions are 15 individual lakes and 7 key lake regions, such as the Central Anatolian Lakes in Turkey and the Mexican Highland Lakes. Including the major

lakes in each lake region, World Wildlife Fund identifies approximately 53 lakes as key for conservation. The UNEP and WWF lists overlap considerably.

Neither the UNEP/WCMC nor the WWF lists of globally important lakes systematically include lakes with substantial bird biodiversity. Neither study provides a mechanism for subdividing priority lakes by risk factors such as expected water shortages to fine-tune conservation strategies for specific types of lakes.

A new framework: 250 lakes with significant biodiversity

Two hundred and fifty lakes in 73 countries are preliminarily identified as high priorities for biodiversity conservation. Globally important lakes for biodiversity conservation are identified as lakes that are:

- Identified in the UNEP/WCMC Preliminary Assessment as having high fish, crab or mollusc biodiversity; or are
- Identified as part of the WWF Global 200 process; or are
- A permanent, intermittent, fresh, saline or soda lake listed as a Ramsar site "of international importance" that hosts at least 1% of a global bird species population or is host to more than 20,000 waterbirds (i.e. is listed under Criteria 5 and/or Criteria 6); or are
- One of the approximately 15 ancient lakes in the world; or are
- Otherwise well documented to have high species diversity, endemism or be a globally important rare habitat type or critical habitat for large-scale ecological phenomena such as migrations.

Each of these criteria contains some degree of subjective assessment and is greatly complicated by the incompleteness of biodiversity data for many lakes. As more data is collected and analyzed, lakes will inevitably be added and dropped from the priority list.

The 250 lakes are identified with the hope of beginning discussions among diverse organizations such as UNEP, WCMC, WWF, BirdLife International, Wetlands International, Ramsar, International Lake Environment Committee (ILEC), World Resources Institute and others concerning which lakes should be targeted for conservation due to their biodiversity; how data collection on biodiversity, limnological and risk factors on key lakes might be accelerated; and how progress toward watershed-wide, participatory management plans in these lake watersheds might best be facilitated. More discussion is also needed on how data on water scarcity and human institutions could be better incorporated into strategic decisions regarding which lakes should be prioritized for conservation assistance.

Appendix I explains and provides sources for all data elements. Appendix II - VII list the 250 priority lakes by region and surrounding countries, and describe the biodiversity criteria met by the lake and risk factors such as water scarcity, climate change and human institutional measures. Information on risk factors is by country; ideally this should be replaced with data on individual

lake watersheds. Where available, background information on lake volume, catchment area, and type of lake is also provided. Appendix VIII lists the 250 priority lakes by country.

Needed additions to existing frameworks for prioritizing conservation of lakes

If conservation biologists fail to make saving lakes and their surrounding watersheds with rich bird, amphibian, insect and aquatic plant diversity a priority, many rich communities and endemic species will be lost. Also lost will be ecosystem functions that these species had a role in. The major obstacle to incorporating these types of diversity into a priority framework continues to be a lack of comprehensive assessments of biological diversity at the lake watershed level.

Globally important lakes for bird migrations and/or bird populations

Lakes and the wetlands that often fringe them provide critical wintering, feeding, resting and breeding habitat for many species of migrating birds, yet one of the largest gaps in freshwater biodiversity assessments to date has been bird diversity. Although World Wildlife Fund did seek to include this category in their analysis, their list is too brief and too heavily biased toward the U.S. to be sufficient. It includes only 10 lakes, 5 of which are in the U.S. Other sources of data provide useful information on a lake biodiversity criteria related to migratory birds and key bird populations.

Birdlife International data

BirdLife International has identified approximately 200 "Endemic Bird Areas" (EBA's) around the globe. Overlaying these with lake watersheds would provide extremely valuable new information about which lake watersheds contain a high number of endemic bird species. WRI and Worldwatch paired EBA's and lake watersheds for thirteen large lakes (Revenga et al. 1998), however identifying overlap between EBA's and most lake watersheds is likely to be very difficult, given the lack of watershed maps for many of the lakes listed. Assuming watershed maps can be created, Birdlife International should be consulted to help assess the viability of this approach.

Ramsar Convention data

The Convention on Wetlands, also known as The Ramsar Convention, is an intergovernmental treaty adopted in 1971 which relates to "all areas where water is the primary factor controlling the environment and associated plant and animal life", thus including lakes. Wetlands are listed as "internationally important" based on their significance in terms of ecology, botany, zoology, limnology, or hydrology. Two of the eight specific criteria which parties to the treaty may apply relate to waterbirds.

Criterion 5 states that "A wetland should be considered internationally important if it regularly supports 20,000 or more water birds" (Ramsar 2000). Criterion 6 states that "A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of water bird" (Ramsar 2000). This study identifies 161

Ramsar sites with lake habitat that were listed under either of Ramsar's two waterbird criteria. The diverse lake habitats identified include natural and man-made, permanent and seasonal, fresh, saline and soda lakes.

Are lakes which have been listed under the Ramsar Treaty precisely the wrong targets for conservation? It could be argued that these lakes already receive some level of conservation attention through their participation in Ramsar that makes international conservation attention less urgent than for lakes that lack the Ramsar designation. Alternatively it might be argued that Ramsar lake sites are ideal lakes on which to focus conservation efforts since their governments have shown at least minimal interest in their conservation by applying for internationally recognized wetlands status.

Although human uses of some Ramsar lakes are strictly limited, many Ramsar lakes are threatened by ongoing irrigation diversion, agriculture, cattle grazing, or mining. Many Ramsar lakes are "not the key conservation strongholds they were in the past" (Lemly et al. 2000). Ramsar has no power to enforce the implementation of significant changes in environmental management policy.

Although Ramsar Criteria 5 and 6 are not measures of bird species endemism or rarity, the Ramsar bird criteria are a useful means of identifying at least some portion of lakes with large migrating bird populations that may not have been identified in lake biodiversity assessments to date. Obviously, there are many additional lakes that also provide critical ecosystem functions for water birds and are home to endemic species, but are not listed under the Ramsar Treaty. The standard of 20,000 waterbirds may be too low for a global priority model.

Additional floral and faunal taxa

Additional floral and faunal taxa that should be added to the new prioritization framework include amphibians, insects, mammals and aquatic plants. Very little attention is given to amphibians in lake literature. Conversely very little attention is given to lake habitats in amphibian literature or by organizations working to protect amphibian habitat. An international list of lakes with high species richness or endemism for amphibians, insects, mammals or plants does not currently exist. Scientists and organizers within key lake watersheds often do have this type of information, and although collection of it will be time consuming, it should be one of the next steps for refining a list of priority lakes and developing a biodiversity conservation strategy.

Risk factors and impairment index

Current and future anthropogenic impacts are often incorporated into biodiversity assessments to evaluate whether a given ecosystem is relatively intact, relatively stable, vulnerable, endangered or in critical condition. Factors assessed can include percentage of habitat lost, degree of fragmentation, water quality, alterations of natural flow, and alterations of catchment basins (Olson et al. 1999). Impairment of lake ecosystems needs to be factored in when prioritizing lakes for conservation to ensure that efforts are directed at lake watersheds that are not so degraded that conservation efforts are likely to be ineffective or inefficient.

Impairment data do not exist for the majority of lake watersheds. Some information is available on a river basin basis, but can be difficult to translate to the lake watershed level. In addition to the factors noted above, valuable information on priority watersheds includes: the population density, urbanization rate, deforestation rate, percentage of original forest lost, percentage of watershed area that is irrigated farmland, large dams existing in the watershed, planned dams in the watershed, and some measure of current sewage and toxic output and treatment processes. This information is available on an *ad hoc* basis only, and only rarely at the lake watershed level.

Water shortages

One factor not regularly included in assessments of lakes is the present and future degree of water scarcity in the watershed. Water scarcity can be expected to negatively impact lakes due to human reliance on increasing proportions of their water for drinking water, irrigation and industrial needs. Expected population increases by country are reflected in most water scarcity measures; this incorporates another host of pressures on lakes in terms of alterations in land use in the watershed. A water scarcity measurement would be a useful addition to lake impairment indices. To date, the only available measures are at a country level, as opposed to lake watershed level. Obviously watershed data would be a far more accurate measure of threat.

Lakes that are key in terms of biodiversity and that are in countries forecast to face medium to high water stress by 2025 may be appropriate initial targets for intensive efforts at watershed-wide management plans that address biodiversity conservation through sustainable development and integrated water resource management approaches. It should be noted that although Mexico and China do not appear as water stressed countries in the ranking used in this report, lakes in these countries have been beset with problems related to water diversion. Their water stress ranking may need to be altered to more accurately reflect reality.

Global climate change

Forecasts of future climate change are becoming more accurate. Some attempts have been made to project the ability of different countries to cope with the amount of climate change expected in their region. While these numbers are included as a possible guide to countries that may face additional stresses to their ecosystems, including lakes, both the amount and type of climate change, and the impact of these changes on lakes are too uncertain to incorporate a measure of climate change in a practical assessment of threats to individual lakes at this time.

Assessment of human institutions

Political and bureaucratic issues directly impact stakeholders' ability to organize and to move toward a watershed-wide management plan for their lake. Voice and accountability, government effectiveness, regulatory frameworks, and corruption control are all critical factors. Some measure of these factors seems important to include when determining how to promote lake conservation in biodiverse areas. Often ignored, issues of government fragmentation, lack of accountability and widespread corruption need to be addressed head on in conservation programs. Currently most measures of government effectiveness are available only at the national level and are very rough.

Ancient lakes

Approximately 15 ancient lakes were created two million or more years ago, mainly by tectonic subsidence (Table 1). Those ancient lakes that experienced relatively stable abiotic parameters tend to have dramatically enhanced biodiversity, and their own highly endemic fauna, particularly in the littoral and benthos zones (Gorthner, 1994; Kawanabe et al. 1999). Three ancient lakes are not otherwise included in this analysis by virtue of diversity or representation, and are added due to their status as ancient lakes, and/or the likelihood that they are home to rich diversity and/or endemism that may not have yet been adequately documented. Lakes Issykul (Kyrgyzstan), Maracaibo (Venezuela) and Tahoe (United States) have been added to the framework on this basis.

Additional lakes having outstanding biodiversity

As additional data is gathered from the organizations working on assessing freshwater biodiversity, many other lakes may well be candidates for a refined list of biodiversity conservation priorities. One obvious omission has been added to the framework in this initial round. The Laurentian Great Lakes in the U.S. and Canada have been added to the preliminary list of priorities due to the significant biodiversity housed within their huge volumes and watersheds. Although they are neither Ramsar sites nor included in either the UNEP or WWF assessments, information from The Nature Conservancy indicates that the Great Lakes region "supports over 130 globally rare plants, animals and natural communities. Nearly half of these are found only in the Great Lakes region or have the best examples there" (Nature Conservancy 2001).

Table 1. Ancient lakes of the world

Lake	**Surrounding Countries**	**Age** (million years)
Eyre	Australia	20-50
Maracaibo	Venezuela	>36
Issyk-Kul	Kyrgyzstan	25
Baikal	Russia	20
Tanganyika	Tanzania, Burundi, Zaire, Zambia	20
Caspian	Iran, Kazakhstan	>5
Aral Sea	Kazakhstan, Uzbekistan	>5
Ohrid	Albania, Macedonia	>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

Drawn from data in Lerman, Imobden & Gat 1995 and Groombridge & Jenkins 1998.

Initial analysis of priority world lakes

Of the lakes identified as priorities, 89% are permanent, and 11% vary widely in volume throughout the year, many disappearing altogether either for months or years at a time as part of a natural cycle (Figure 1). Approximately 82% of the lakes identified are freshwater lakes; 18% (45 lakes) are saline or soda (Figure 2). Approximately 212 of the 250 priority lakes are natural, with 32 other lakes being human-made reservoirs that harbor substantial biodiversity (Figure 3). Data on the classification of some lakes identified as a priority were not available in the information used for this preliminary analysis. Table 2 shows the 250 lakes identified by region and notes how many cross international borders.

Interestingly, there appears to be almost no overlap between lakes that have been designated Ramsar sites due to bird diversity and lakes high in fish, mollusc and crab biodiversity, as identified by UNEP.

Figure 1. Permanent lakes vs. intermittent lakes

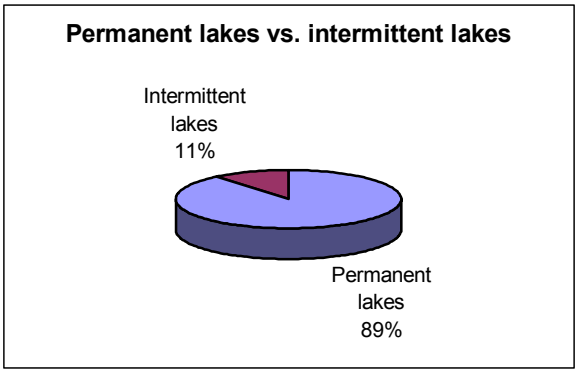

Figure 2. Freshwater lakes vs. saline and soda lakes

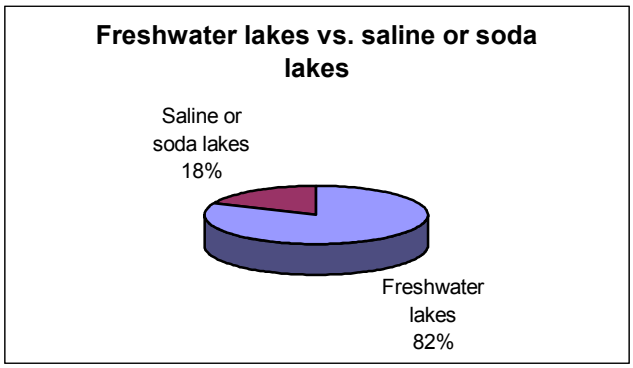

Figure 3. Natural lakes vs. human-made reservoirs

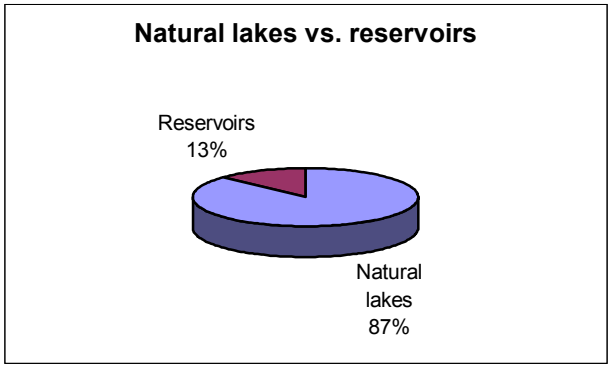

Table 2. Priority lakes by region, number of countries and number of international lakes

Region	Number of lakes	Number of countries	Number of international lakes
Asia	82	16	4
Europe	82	24	3
Africa	32	20	8
North America	25	3	6
Latin America	17	8	1
Australia	11	1	0
Caribbean	1	1	0
TOTAL	**250**	**73**	**22**

Biases in the list of priority lakes

European lakes are clearly over-represented in the new framework, due to their higher rate of participation in the Ramsar process. One would also expect developing countries to be under-represented on the list of lakes officially listed under Criteria 5 and 6, given the bureaucratic structure necessary to successfully apply for such designation. In addition, biodiversity tends to be less well monitored or researched in developing countries, although this is changing rapidly.

Asia

None of the priority Asian lakes are in countries projected to become water scarce. Asia has fewer international lakes proportionally than Africa. A high number of Asian priority lakes border on countries with weak governance and accountability mechanisms. Forty-three new lakes in Asia were identified using Ramsar's water bird criteria.

Lake Chilka, in India, is an example of a lake identified using Ramsar criteria that had not been identified by previous prioritization studies. Lake Chilka is a brackish coastal lake separated only by sand flats from the Bay of Bengal, and is home to many important migratory bird, gastropod, bivalve, reptile and mammal populations (Figure 4).

Africa

Thirty-two lakes in Africa are identified as harboring globally important biodiversity. Water scarcity data add a great deal to our understanding of the risks facing Africa's most biodiverse lakes. A full 62% of the priority lakes in Africa are bordered by at least one country that is expected to have high water scarcity by 2025. More than half of African priority lakes are bordered by at least one country with governance ratings in the most negative category, which could be expected to make conservation work there particularly difficult. Lake Barombi-Mbo in Cameroon is an example of a high priority lake situated in a country with extremely poor corruption control (Kaufmann et al. 1999) (Figure 5). Thirteen additional African lakes were identified as priorities using Ramsar's water bird criteria.

A tiered system of priorities and strategies

Both biodiversity and impairment information are needed in order to assess where conservation money can make the most difference. Scarce conservation funds should not be spent on places so decimated that they may not be restorable. A World Wildlife Fund/Wetlands International model gives priority to freshwater sites that are globally outstanding in their biological distinctiveness and are deemed endangered or vulnerable, but not critical. Ecoregions deemed either critical, relatively intact, or stable are given a lower priority for conservation (Olson et al. 1999).

A method for evaluating and balancing the diverse data collected on priority lakes is needed including the refinement of criteria and how different factors should be weighed. More work needs to be done to assess which lakes may be so damaged by watershed fragmentation and habitat loss, contamination, the introduction of invasive species, or weak institutions, that they

should assume a reduced priority. How much projected water scarcity in a country makes a lake a poor conservation prospect not worthy of risking funds on? Is a highly corrupt government a valid reason to not attempt lake conservation in certain countries? Many countries with the most diverse lake ecosystems rank extremely low on government effectiveness (see Kaufman et al. 1999). Although conditions are difficult in these watersheds, they cannot simply be dropped from the list, as they represent the heart of lake biodiversity. Rather, more effective strategies are needed to address problems such as corruption.

The large number of priority watersheds allows organizations with different interests or expertise to select their own subset of lakes on which to work. For instance, those particularly interested in water conservation, water reuse, efficient irrigation and/or dams might choose to focus on priority lake watersheds expected to face medium or high water scarcity in 2025 (see Appendix X.). Organizations or individuals with particular interest in protecting fish may focus on lakes identified as particularly rich in endemic fish species. Organizations that focus on particular regions may be interested in supporting the development of national or regional lake conservation initiatives.

Figure 4. Chilka Lake, India

Type of lake: Brackish coastal permanent lake. Chilka lake is dotted with islands. Only sand flats separate the lake from the Bay of Bengal.

Biological importance: Migratory bird species travel from as far as Persia and Siberia. Species include avocets, ruffs, pelicans, ospreys, flamingoes and rare cranes. Approximately 160 species of fish and prawns have been recorded. An island in Chilka Lake is home to the rare Limbless skink (Barakudia insularis) reptile. There are also dolphins in the lake. 28 species of gastropods have been identified (11 endemic). 43 species of bivalves (25 endemic) have also been identified.

Figure 5. Lake Barombi-Mbo, Cameroon Crater Lake

Male *Burjurquina vittata* pick up and mouth-brood their young for the first five days, after which he shares mouthbrooding duties with the female.

Type of lake: Natural freshwater, permanent crater lake. Baromi-Mbu is approximately one million years old, and is volcanic.

Biological importance: This small crater lake has at least 15 fish species, 11 of them endemic. Four of the five cichlid genera are endemic. Cameroon's crater lakes (50) are the smallest areas in with speciation (the process of evolutionary adaption) has been proven to take place.

Greatest threats: "This very important site is at risk from over-fishing, the effects of introduced crustaceans and fishes, siltation from local deforestation and water pollution." (WCMC) Fish farming is being advocated by several development agencies. The lake is also threatened by agriculture at the crater rim. The town of Kumba relies exclusively on water from Barombi Mbo Lake.

Recognition of the lake's importance: Barombi-Mbo has been nominated as Cameroon's second Ramsar site.

Next steps: A conservation strategy for the world's lakes

Workshop

A framework for prioritizing the biodiversity significance of lakes is an important step toward developing a conservation strategy for the world's lakes. Among the obvious next steps is the need to convene interested organizations and lay the groundwork for a partnership or alliance that would develop and help implement the strategy. An alliance of organizations is needed to: further refine the framework for evaluating priorities, reach consensus on the criteria for determining biodiversity significance; provide additional data and analysis; and ultimately develop and implement the strategy. Specific tasks related to the development of a conservation strategy are described below.

Data collection

Available data are a serious limiting factor in setting priorities and achieving lake conservation objectives. In addition to water quality, alterations of natural flow and alterations of catchment basins, it would be extremely useful to know for each priority watershed the population density, urbanization rate, deforestation rate, percentage of original forest lost, a watershed water stress index for 2025, large dams existing and planned in the watershed, and some measure of sewage and toxic output and current treatment processes. This information is available on an *ad hoc* basis only, and only rarely at the lake watershed level.

Experts in priority lake watersheds or countries are likely to have extremely valuable information that will be key to ongoing data collection, prioritization and strategic planning efforts. An ongoing process is needed to integrate locally available data and feedback on lake biodiversity, impairment, and risk factors into priority setting.

Assessment of ongoing lake conservation work and key contacts

Only a handful of lakes on the priority list have organizations working toward lake management plans at the watershed level, and/or significant national or international funding for their work. A brief assessment tool could be developed for use in each priority watershed to collect basic limnologic data, identify scientists and other stakeholders, and collect watershed maps where they exist. Results could be fed into an online, searchable database.

Watershed maps

An easily readable and widely reproducible watershed map that includes political boundaries should be collected or developed for each priority lake. Only a handful of lakes identified as priorities will already have this important foundation in place. LakeNet is exploring the feasibility of producing maps in conjunction with local partners. Collected data and maps could be made available on the Internet through an online database, for use by local stakeholders and international conservation organizations.

Comprehensive, participatory watershed management plans

The development of a comprehensive, participatory, watershed-wide management plan that integrates biodiversity conservation with other stakeholder priorities and is based on sound science should be the long-term goal in each of the priority lake watersheds. Development of such plans is extremely difficult and requires extensive inputs of time, technical assistance and financial resources. Political boundaries, weak government institutions, fragmented approaches, corruption, and a lack of effective enforcement often thwart the development and effective implementation of lake ecosystem management plans. Each of these potential obstacles needs to be explicitly addressed as part of lake conservation strategies. Building the capacity of local organizations to develop and implement watershed-wide management plans should be a high priority.

Sustainable development and integrated water resource management must be far more closely integrated into work to preserve biodiversity, as they are integrally connected; none of the three can succeed without the other two. Development data needs to be collected as well for these watersheds, and integrated more closely into biodiversity conservation planning.

A central repository for lake information on the Web

A database is needed that pulls together in one place data from a wide range of sources for each priority lake watershed including information on: biodiversity, conservation status, impairment levels, socio-economic data, risk factors, strategies and projects in process, lessons learned, and contact information for groups working in the watershed.

Dissemination of effective strategies and lessons learned

Proven and promising practices, strategies and technologies need to be more widely documented and disseminated. Case studies and documentation of lessons learned are desperately needed regarding comprehensive lake management approaches, including effective institutional arrangements and enforcement. Formal evaluations of lake conservation projects often fail to include institutional arrangement or enforcement components in their assessments.

Coalition building and raising awareness

Lake conservationists need to work far more closely with: irrigation programs, farming communities, industry groups which rely heavily on water in their processes (such as pulp and paper mills and mining), and population control programs at the lake as well as international level. Pilot projects in priority watersheds that link local nonprofit and government groups working to protect their lake and these constituencies would be valuable demonstrations. Lake conservationists also need to reach out to a much broader community of those involved in wetlands, bird, amphibian, insect, mammal and plant conservation to combine data and build knowledge of lake ecosystems. Coalition building and raising awareness about the need to conserve lake biodiversity is needed at both the local and global levels.

Conclusion

This report suggests a preliminary methodology for identifying, out of the five million lakes that exist worldwide, those lakes with the most extensive biodiversity in order to maximize the value of lake conservation work and funding. Much can be done to halt water diversion, invasive species, accelerated eutrophication, toxic contamination, sediment inundation, over-utilization of natural resources, global climate change and fragmented lake management, but the work is difficult and expensive, and needs to be prioritized to achieve meaningful progress.

This preliminary identification of a group of lakes that are possible priorities for biodiversity conservation should be useful to others working in the field of freshwater conservation and may help to raise important issues regarding the need for conservation programs at the lake watershed level. Working with local and global stakeholders over the long haul, toward effective watershed management plans will be key to conserving thriving lake ecosystems.

A framework for prioritizing the biodiversity significance of lakes is an important step toward developing a conservation strategy for the world's lakes. Next steps include: (1) convening a workshop of interested organizations to lay the groundwork for a partnership or alliance that would develop and help implement the conservation strategy; (2) further data collection and analysis, (3) development of watershed maps and management plans, (4) establishment of a central repository of information on the internet, (5) dissemination of effective strategies and (6) coalition building and raising awareness.

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