Forgotten Waters: Freshwater and Marine Ecosystems in Africa

Strategies for Biodiversity Conservation and Sustainable Development

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The Biodiversity Support Program

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Forgotten Waters: Freshwater and Marine Ecosystems – Strategies for Biodiversity Conservation and Sustainable Development / Caroly A. Shumway

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Foreword

Over the last several years, the world's biodiversity crisis, and its implications for human development, has become clear. Solutions must be found for the problems created by humans for other life, for otherwise both humans and wildlife will continue to suffer. The situation is most critical for nations that rely on natural resources for economic development, such as those in Africa. As the World Bank notes, "sub-Saharan Africa depends more on its environmental resource base for its economic and social needs than any other region in the world" (Environment Matters, 1996). African nations simply cannot afford to lose their wildlife and the ecological services they provide, including the animals under water and those associated with water. It is for this reason that integrated approaches to conservation and development are necessary.

Although African governments, donors, and NGOs have recognized the importance of the continent's terrestrial biodiversity to human development, the rich biological heritage of Africa's aquatic systems -- its lakes, rivers and streams, wetlands, and coral reefs -- is being rapidly degraded. This is not unique to Africa. Aquatic biodiversity has been neglected worldwide.

In an attempt to help stem the loss of Africa's aquatic biodiversity, the U.S. Agency for International Development's (USAID) Africa Bureau commissioned this report. Essentially, this report provides a primer on African aquatic biodiversity, lessons learned from successful and failed conservation projects, and practical references for various aspects of conservation planning and management. The goal of this report is to provide practical advice for conservation planners and to increase funding and activities in this area. The report is based on an extensive literature review and synthesis, site visits to a number of African countries, dialogue with international and African colleagues, and the author's own conservation experience over the last eight years. The report provides an overview of the value of such systems, identifies the biologically and socio-economically most important sites, discusses threats, and recommends activities for urgent conservation action. The report addresses all of Africa's aquatic biodiversity, both freshwater and marine, because one of the key principles of aquatic conservation is the interdependence of such systems, and the interdependence between aquatic and terrestrial ecosystems as well. Hence the following aquatic habitats and their associated flora and fauna are addressed: lakes, rivers and streams, wetlands (including floodplains, freshwater swamps, also known as marais; mangroves; and coastal wetlands), and coral reefs. Associated wildlife include all terrestrial and aquatic organisms whose survival depends on wet habitats. Pelagic areas of the oceans are addressed briefly.

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Executive Summary

Why should we care about the biodiversity of African freshwater or marine systems? Governments, donors, and nongovernmental organizations (NGOs) should care because there are sound economic and developmental reasons for expanding effort in aquatic conservation and sustainable development. The people of sub-Saharan Africa critically depend on biological resources for food, shelter, and income, and will continue to do so for years to come (BSP, 1993). Sustainable use of fish and other aquatic fauna can yield increased income, broader participation in economic enterprises, better nutrition, and a greater integration of natural resource concerns into development programs. Africa's fisheries are in fact critical, both economically and nutritionally as they provide a large portion of the people's protein needs in a continent where malnourishment is common. From a purely utilitarian standpoint, governments and donors should care because protecting the aquatic world, which contains more phyla than that of land, protects much of the planet's genetic diversity. Such diversity is invaluable to mankind for its medicinal, chemical, nutritional and scientific utility.

Aquatic ecosystems provide innumerable economic and ecological benefits (reviews: Ewel, 1997; Postel and Carpenter, 1997; Peterson and Lubchenco, 1997; Kaufman and Dayton, 1997). For example, wetlands provide wastewater treatment, aid in flood control, act as feeding, breeding, and nursery grounds for fishes, purify water supplies, protect coastal areas, and are the source of a variety of products which can be harvested sustainably.

Governments, donors, and NGOs also should care because Africa has considerable aquatic treasures, containing a rich diversity of life. Although the continent has too many important sites to list here, some important areas include: the Zaire River basin (one of the most species-rich in the world); Africa's Great Lakes -- Tanganyika, Malawi, and Victoria -- each of which harbors an amazing diversity of cichlid and other fishes; the Sudd swamp, the largest swamp in the world (harboring the richest bird life of any of the African wetlands); the Okavango Delta; the mangroves of Guinea-Bissau, Gambia, and Tanzania; Madagascar's endemic freshwater fishes (more threatened than its terrestrial species); and East Africa's coral reefs.

Unfortunately, the productivity and diversity of Africa's aquatic ecosystems, so important to the livelihood, if not survival, of its peoples, are threatened by a plethora of short-sighted activities. These include both aquatic and land-use decisions, such as the introduction of exotic species; overfishing; deforestation; agricultural, municipal, and industrial pollution; conversion of sites for agriculture and aquaculture; changes in the water regime resulting from water diversion and large-scale irrigation; poor land-use planning; inappropriate policies; and global climate change. Many sites face multiple threats. As the Environmental Defense Fund (EDF, 1994) notes, "Add to this our very incomplete knowledge about the ecology of most aquatic species," not to mention limited taxononomic knowledge and incomplete information on species distributions, "and any hope for simple solutions vanishes."

However, steps can be taken now to reverse or halt some of the damage to African aquatic ecosystems. It is not too late.

The following proposed recommendations will contribute to the sustainable utilization and conservation of aquatic biodiversity in Africa. In deciding where to provide financial or technical assistance, however, one must carefully consider the conservation feasibility of a given site. In other words, is the national and local government interested and committed? Are local communities interested in conserving and better managing their resources? A description of some of the criteria to be considered is included on pages 67-87.

A. Summary of Recommendations

1. Improve institutional capacity.

- Support regional, or transboundary, collaboration.
- Within a country, enhance inter-agency coordination and management among those agencies impacting aquatic ecosystems and their wildlife. Strengthen wetland and coastal management institutions such that they have power over land-use decisions affecting their areas.
- Strengthen the institutional capacity of local NGOs involved in aquatic conservation.
- Improve the institutional capacity for water quality monitoring. Develop national aquatic monitoring standards for measuring nutrient and toxicity levels, sedimentation, turbidity, and habitat destruction. Appropriate monitoring methods and standards can be modified from existing efforts in Africa and elsewhere.
- Assist with training and education in aquatic conservation and fisheries science. Consider establishing scholarships, with the requirement that awardees apply what they learn by providing a certain number of years of service in that area in Africa following completion.
- Provide technical and economic assistance for biological control of exotic plants and animals.

- Provide financial and/or technical assistance to community-generated conservation and management initiatives, i.e., initiatives that start from the ground up.

- Build partnerships between the public and private sector, and between the government and local communities.

2. Encourage appropriate economic and sectoral policies.

- Encourage the development of a more integrated approach to water and land-use planning.
- Support integrated river basin planning and development. Consider the views of all stakeholders in the process. Actively involve NGOs in planning efforts. Lessons learned from integrated coastal zone management efforts are described on pages 72-75.
- Assist in the development of national economic and sectoral policies which encourage sound water use and conserve wetlands. Review water, forestry, agricultural, tax and other relevant policies to determine how they contribute to wetland loss and degradation of other freshwater habitats. Eliminate water subsidies. Develop realistic pricing of the ecological services aquatic systems provide; use the fees for conservation efforts. Consider market-based incentives, such as compensated water transfers, tradeable non-point pollution permits, etc.
- Help develop policies limiting and regulating the introduction of exotic species.
- For recommendations on fisheries policies, see pages 102-106.

3. Involve the community.

- Support well-designed integrated conservation and development projects, where appropriate. When successful, expand to broader landscape. Lessons learned are described on page 77.
- Consider community management or bioregional management, where appropriate.
- Encourage community involvement in monitoring. An overview of simple methods, along with information about sources for community monitoring is described on pages 85-86.
- For a given site, consider which human behaviors have the greatest impact on resources under threat, and what the motivating factors are. Design public awareness efforts to address the diversity of motivating factors.

4. Support needed research.

- Support studies on the ecological and developmental effects of varying the timing and volume of artificial flood releases at a variety of African dams. This knowledge will help in modeling various options for artificial releases.
- Develop models for wetland utilization which allow use while conserving ecological integrity.
- Improve decision-making methodologies for wetland and river basin planners. Help create a support system of scientists and environmental economists to assist with constructing alternative development options.
- Support research assessing the effect of size of marine reserves on adjacent fisheries productivity, and on maintaining biodiversity within the reserve.
- Support research on the development of sustainable aquaculture systems, using indigenous freshwater or marine resources.
- Support pilot aquatic restoration studies.
- Support studies examining the impact of sedimentation on various coral communities. This knowledge will facilitate predictions of impact in coastal zone planning.
- Support small-scale experiments in East Africa to assess the impact of removing sea urchins from overfished, unprotected areas.
- The following basic research is needed: regional marine surveys, and the development and/or expansion of national marine and freshwater databases.

5. Mimic natural disturbance regimes: maintain or restore natural hydrological cycles.

- Modify existing dams to allow artificial releases. Both the timing and volume of release should be modified to better mimic natural spatial and temporal variability, taking into account ecological and all stakeholder needs. Such an effort is a necessarily iterative one, as we learn about ecological requirements.
- If future dams are planned, support design efforts to allow sediment transport downstream.

6. Assist with the establishment of critical aquatic reserves, which can provide both conservation and fisheries benefits.

- Discussion of principles of aquatic reserve design is provided on pages 92-102.

7. Assist with the development of sustainable fisheries, i.e., fisheries compatible with biodiversity goals.

- Adopt a precautionary approach for fisheries and other coastal resources. Incorporate into national legislation the currently voluntary FAO code for responsible fisheries. See pages 102-103 for more detail.
- Incorporate aquatic reserves as part of a fisheries management strategy.
- Enhance collaboration and cooperation between fisheries departments and departments of wildlife and conservation.
- Encourage governments to work *with* fishers to design locally appropriate fisheries regulations. Fisheries regulations should be developed in conjunction with the relevant local communities. Work with governments and traditional authorities to determine the extent to which traditional conservation and resource practices could be re-established or strengthened and reinforced by laws. Boost the capacity of fisheries departments and/or communities to monitor and enforce fisheries regulations. Support community-based management or co-management, where feasible.
- Work to reduce dynamiting and poisoning in East African reef fisheries. Work with fishers for the aquarium trade to ensure they are collecting the fish sustainably.
- Help reduce bycatch, waste, and overexploitation by: encouraging the development of artisanal fisheries using selective gear; encouraging fishermen to diversify their choice of fish, and assisting with the marketing of diverse species; and improving methods of fish handling and preservation through training at technical workshops.
- Encourage integrated aquaculture. In addition, support traditional aquaculture methods, utilizing indigenous species, where possible.
- Where overfishing is a problem, support the development of alternative livelihoods for fishers, working together with those fishers directly affected.

The case study section on pages 107-124 shows how some of these recommendations might be applied to specific areas, including:

1. Lake Victoria
2. Lake Tanganyika
3. Lake Malawi
4. Madagascar's lakes, streams, and wetlands
5. Okavango River wetland (Namibia)
6. Uganda's wetlands
7. Rufiji Delta/Mafia Island (Tanzania)
8. Delta du Saloum mangroves (Gambia/Senegal)
9. Guinea-Bissau's mangroves
10. East Africa's coral reefs:
    A) Madagascar;
    B) Other East African reefs
11. Inner Niger Delta (Mali)
12. Lake Chad (Niger)
13. Diawling/Djoudj wetlands (Senegal/Mauritania)
14. Bazaruto Archipelago (Mozambique)

Chapter 1.
Introduction

"Everything is water, water is all."
Thales (ca. 624-546 B.C.)

While all life depends upon water, the life within water is often forgotten. Photo credit: Dennis Zemba.

Life on Earth depends upon water. Water comprises 99% of our own bodies and covers 71% of the earth's surface. Too often, however, the life *within* water is forgotten. The biological diversity of aquatic areas is neglected worldwide, even in coral reefs that rival tropical rain forests in their extraordinary diversity of life.

Freshwater fauna are particularly neglected. Yet in terms of vertebrate biodiversity, freshwater ecosystems also rival tropical rain forests. Twenty thousand species of fish make up more than half of all vertebrate biodiversity; 8,000 of these species live in freshwater (Bone and Marshall, 1982). In sum, nearly 25% of the earth's vertebrate biodiversity is found in less than .001% of the earth's water (Stiassny, 1999). Freshwater ecosystems now struggle to survive in the face of man's ever-increasing demand for water. Since 1940, the world's population has doubled but its water consumption has almost quadrupled, primarily for agricultural uses (Stiassny, 1999). Numerous freshwaters have been degraded as a result of pollution and sedimentation. *As a result of these and other threats, over 20% of freshwater fishes worldwide may be threatened or endangered,* a startling number in comparison with terrestrial and marine species (Andrews and Kaufman, 1994). This loss is occurring in developed and developing countries alike. The Species Survival Commission (1998) notes that wherever surveys are conducted, more threatened freshwater species are found. More than one-third of North American freshwater fish species, for example, are considered rare, threatened, endangered, or extinct, a far greater proportion than the continent's birds or mammals (Master, 1990, cited in EDF, 1994). The Aral Sea, once the world's fourth largest water body, has lost two-thirds of its volume due to water diversion, resulting in a nearly complete loss of its valuable ecosystems and fisheries (Postel, 1996). Fishes are not the only species at risk: freshwater molluscs, crustaceans, amphibians, and 57% of turtles, tortoises, and terrapins, most of which are freshwater species, are threatened as well (SSC, 1998). Twenty percent of threatened insects have aquatic larval stages (McAllister et al., 1997).

Africa has a wealth of freshwater species (Figure 1). Equally importantly, numerous African populations are dependent on freshwater resources for their survival. Thomas (1996) notes that "*conservation of wetlands, certainly in sub-Saharan Africa, is as much for the sake of the economic well-being of the people who depend upon them, as for the sake for their value for wildlife.*" For example, the floodplains of Mali's Inner Niger Delta are a highly productive ecosystem that has supported over 550,000 Malians (including pastoralists, farmers and fishermen), domestic animals, and wildlife for a thousand years (Webster, 1994; IUCN, 1990b). Floodplain grasses contain a relatively high protein content, making them especially good livestock fodder (Gaudet, 1992). Pastoral communities synchronize their livestock cycle to the annual river flood, moving their herds onto arid, rain-fed rangelands as the waters rise, and back onto the floodplain as the water recedes. The postflood plain pastures of the delta support the highest density of herds in Africa, including cattle, sheep and goats, as well as over 170,000 hectare (ha) of rice (Webster, 1994). During drought and before rice harvests, the people depend on the natural production of wild grains in the delta. During times of flood, 80,000 fishermen depend on the fish catch, which amounts to over 61,000 tons (IUCN, 1990b). In addition, most of the African lakes and rivers, and a number of African wetlands support tribes whose livelihood has historically depended upon fishing.

Unfortunately, Africa's freshwaters may also be among the most vulnerable to threats. Because it has more semi-arid and desert areas than any other continent and has such a rapidly increasing human population, the wealth of aquatic biodiversity concentrated in its limited freshwaters is particularly threatened by human activities (Stiassny, 1996).

Already, 30 out of 46 commercial fish species in the Nile River are either economically or biologically extinct. Lake Chad has lost 75% of its area in the last 30 years due to water diversion for agriculture and drought (Africa News Service, 1996a). Lake Victoria is the most well-known disaster. As many as half of the cichlid species in the lake may be extinct due to a multitude of human-induced stressors. This is the largest vertebrate extinction in the world.

Worldwide, coastal and marine systems are being damaged as a result of population growth, poverty and the lack of alternative livelihoods, undervaluation of coastal resources, large-scale commercial enterprises with interest in maximizing short-term profits, overfishing, and degradation of marine habitats (Clark, 1992). Although the coast occupies just 8% of the earth's surface, it provides 26% of all biological production (Holligan and de Boois, 1992, cited in Pernetta and Elder, 1993). It also is the preferred habitat for much of our species. Worldwide, an estimated 10% of coral reefs are dead, 50% of mangrove habitats are destroyed, and estuaries and bays are heavily polluted or their natural habitat lost, with the original life "all but gone" (McAllister, 1995, NRC, 1995). Nearly 70% of the world's marine resources are estimated to be "full to heavily exploited, over-exploited, depleted, or slowly recovering from overfishing" (FAO, 1994). IUCN added 100 marine fish species to its Red List in 1996, the majority threatened by overexploitation (SSC, 1998).

Africa's burgeoning coastal population is placing increasing pressure on mangroves, estuaries, coral reefs, and their associated flora and fauna (World Bank, 1996). The East African/Madagascar coral reef habitats are considered among the most globally threatened sites, at great risk of destruction over the next 10-20 years.

The purpose of this report is to explore options for conservation of Africa's freshwater and marine biodiversity. Throughout the report, lessons learned from past conservation and management -- both successes and failures -- are noted. I hope that this report will increase funding, technical assistance, and projects in this critically important area.

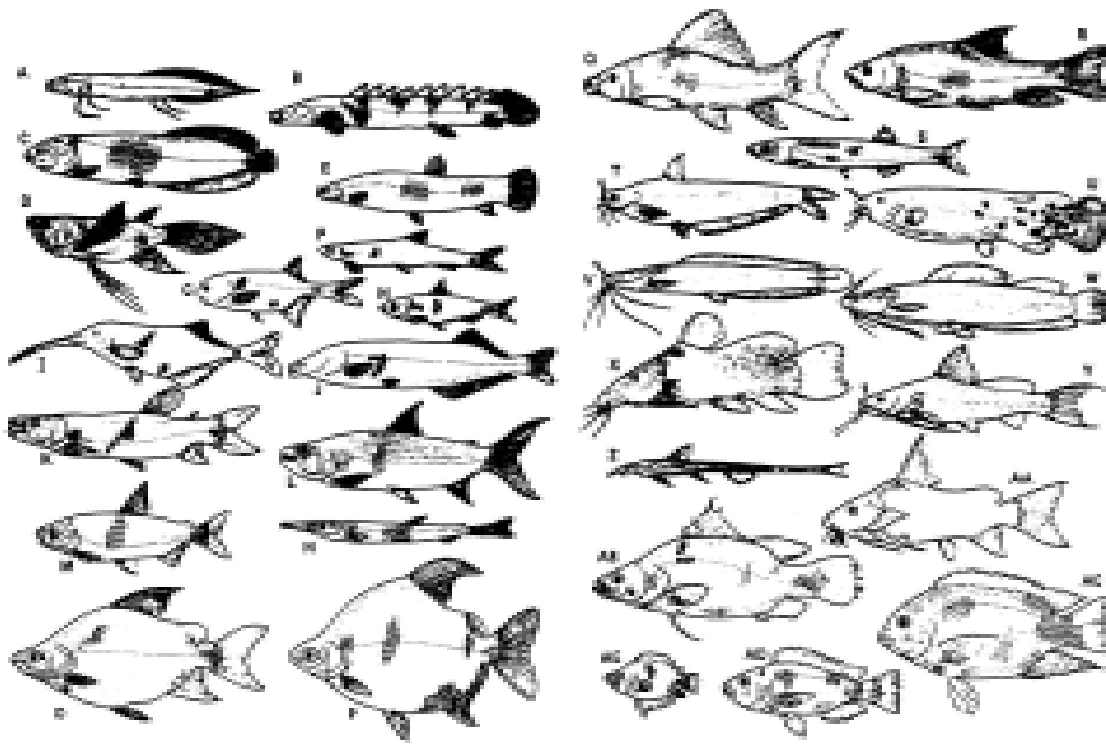

Figure 1. Representative African freshwater fishes. From R. Lowe-McConnell, 1987b. Reprinted with the permission of Cambridge University Press.

Chapter 2.
Why Has Aquatic Conservation Been Neglected?

"Africa is well known for the diversity of its mammals, reptiles, birds and insects, but (to date) its spectacularly diverse freshwater fauna has caught the imagination of relatively few..."

Fryer and Isles, 1972a

"Given the current state of knowledge, when future generations look back at the 20th century and try to make sense of the lack of commitment to preserving biodiversity, many reasons may be cited, but ignorance of the magnitude of the issue will not be a valid justification for inaction."

SSC Home Page, 1998

Part of the reason aquatic conservation has been neglected is that we can not readily see underwater. As a result, we are less aware of human impact. Photo credit: Dennis Zemba.

Part of the reason aquatic conservation has been neglected is that we cannot readily see what is happening underwater, so we forget about it. Yet our fascination with the world underwater is clearly demonstrated by the fact that the most popular part of the London Zoo is the aquarium, not the "charismatic megavertebrates" (Balmford, 1996). Although the situation is improving, aquatic conservation has also been largely neglected by the international NGOs, certainly in comparison with their emphasis on tropical terrestrial wildlife. The lack of attention to aquatic biodiversity is also indicated by the paucity of environmental groups devoted solely to aquatic wildlife, in sharp contrast to the large number of groups devoted to terrestrial conservation.

Most conservation efforts in Africa also focus on terrestrial wildlife. Only a few international NGOs address African aquatic issues at all. Those that do include the IUCN, the Wildlife Conservation Society (through the Coral Reef Conservation Project, Kenya), World Wildlife Fund (U.S. and U.K.), Wetlands International, and BirdLife International, among others. Similarly, the conservation biology journals offer only a few papers on aquatic conservation relative to terrestrial ones, although the situation is improving here as well.

Part of the problem is the lack of dialogue between fisheries researchers, who are familiar with the threats to aquatic fauna, and conservation biologists. For example, documentation of population declines are indicated in fisheries journals, not conservation biology journals. Only 1.75% of all marine vertebrates have been evaluated in the IUCN Red List of Threatened Species (NRC, 1995). Further, listing fishes as endangered or threatened is politically and economically sensitive, as demonstrated by the recent controversy over the IUCN Red Listing of 100 marine species (Stevens, 1996), and the reluctance to consider endangered fish species as wildlife, rather than food, such that they could be listed under CITES (Species, 1997; Vincent and Hall, 1996). In addition, the lack of marine and freshwater taxonomists means that indications of declining species, or of degradations of aquatic habitat are not readily noticed. Paul Dayton (1998) has noted that "in fact, each succeeding generation of biologists has markedly different expectations of what is natural, because they study increasingly altered systems that bear less and less resemblance to their former, pre-exploitation versions."

Finally, aquatic conservation is neglected due to four widely-held myths.

<u>Myth #1: Marine species have globally widespread larvae or globally widespread ranges, therefore extinction is less likely.</u> There are a number of points to consider. First, even species with wide-ranging larvae can become endangered or extinct. Three marine mammals, ten seabirds, and one marine invertebrate are known to have become extinct (Norse, 1993); at least five of these species had ranges covering at least two or more marine biogeographical provinces (Vermeij, 1993). Large ranges are also a characteristic of many currently endangered marine species. Marine species on the IUCN Red List of threatened and endangered animals include cetaceans, seabirds, crocodiles, sea turtles, and marine fish. The North Atlantic swordfish and haddock have recently been added to the IUCN Red List. Both species previously roamed widely and were highly fecund. Just like the American bison, both were hunted to the point of endangerment (Stevens, 1996).

Second, many species actually settle at short range, close to their origin. Settlement is not entirely a passive act, dependent only on the pattern of water circulation. Both behavioral and stochastic factors play a role, with the larval stage of fishes known to behaviorally complex. According to Leis (1991), larval distributions are affected by the following six factors, the first four of which are behavioral: 1) adult spawning location and timing; 2) vertical larval distribution; 3) horizontal swimming by larvae; 4) larval behavioral capabilities and flexibility; 5) hydrography; and 6) topography. Leis argues that "to treat fish larvae as a conservative property of sea water such as salinity is to mislead." Some fishes can extend their larval phase if they do not encounter a suitable habitat, and post-settlement habitat changes can occur as well (Kramer et al., 1997). The myth of globally widespread larvae was based on evidence from certain large marine species, such as certain fish, starfish, crustaceans, and molluscs. While some large species have globally widespread larvae, other large species do not. Furthermore, most coral reef (and other marine) species are small and have limited periods of larval development and restricted geographic ranges. Restricted dispersal windows occur for algae and many colonial animals (Fairweather, 1991). <u>Recruitment of coral larvae logarithmically decreases with distance from the source reef</u> (Sammarco and Andrews, 1988, cited in Roberts, 1994). Reaka (1980) has shown that the body size of shrimp is highly correlated with the size of their geographic ranges. A number of the smaller species brood their larvae (Reaka-Kudla, 1995). Paleontological research has shown that species with limited geographic ranges are more vulnerable to extinction[1] than those with larger ranges (Jablonski, 1991, cited in Reaka-Kudla, 1995).

Third, range of habitats is often more restricted than previously thought. Briggs (1974) and McAllister et al. (1994) list numerous coral reef fishes with small and moderate size

[1] This applies to normal rates of extinction, not mass extinctions.

ranges. Michael Smith of the Center for Marine Conservation examined the range of 500 species in the Caribbean and found that 20% occurred only within a particular area, often around only a single island (Stevens, 1996). Salm (1989) notes that unique subspecies of a mollusk have been found on reefs separated by less than ten kilometers.

Fourth, as we learn more about marine species we find that what was thought to be a single species or population is separatable into genetically distinct groups, implying a less than open genetic exchange. For example, a study of humpback whales separated by only 2,500 miles showed clear genetic differences; the mussel *Mytelus edulis* is now known to be three species; the marine worm *Capitella capitata* was thought to be widespread, but is now known to be 15 or more sibling species; and a number of corals and bryozoans are now known to be species complexes (NRC, 1995). As Ray and McCormick-Ray (1994) have stated, "All species are endemic at some scale, regional or local. All are also restricted in range and distribution by physical and/or biotic factors." Vermeij (1993) comments that while a species may appear to have a large range, as measured by distribution, in practice its breeding sites may be restricted.

Myth #2: The decline of aquatic species number due to human activities is reversible, and therefore, not critical. First, while economists believe that fishing of a particular species will not lead to biological extinction because of the prohibitive cost of exploitation at low densities, biologists now believe that this situation does not hold for high value fish. For example, live-food fish (e.g., large groupers) may be fished even at very low densities for the Asian restaurant trade (Vincent and Hall, 1996). Second, severe changes to the ecosystem or its food webs may *not* be reversible. Hughes (1994) showed a phase shift on Jamaican reefs from coral-dominated to algal-dominated communities following multiple impacts, starting with overfishing. Biomass flips -- in which a dominant species is replaced by another species -- have occurred in several of Africa's Large Marine Ecosystems as a result of pelagic overfishing, resulting in a costly drop in production, along with cascading effects on marine birds, mammals, and zooplankton (Okemwa, 1995). Paleontological research indicates that tropical marine species are particularly vulnerable to environmental changes, as there is a striking die-off of reef communities at each of the major mass extinctions (Jablonski, 1991). Any populations following metapopulation dynamics will be susceptible to extinction if habitats are severely fragmented. This is because a decline in abundance in one site can lead to extinction at others, due to difficulty in reproduction and colonization across sites (Nee and May, 1992).

Myth #3: We still have time. The coast is where humankind prefers to live, and the human population is rapidly increasing (Figure 2). As a result, the pressures on coastal marine life are intense. Habitat loss, pollution, and overexploitation all take their toll. More than 90% of fishermen's catch is caught in the coastal zone (Ray, 1988). One hundred of Africa's largest 150 cities are coastal (Intercoast Network, 1998). Populations in many coastal African nations will double by the year 2025, with some areas on both coasts doubling in less than 20 years (World Bank, 1996). The coastal area from Accra to the Niger Delta could be a continuous "chain of cities" by the year 2025. The World Bank (1996) predicts that if no action is taken in Africa to amelerioate these effects, there will be severe ecological, economic, and health consequences, including: the destruction of coastal productivity; the collapse of commercially important fish stocks; the loss of most of East Africa's coral reefs and 70% of Africa's mangroves; and the deterioration of water quality and sanitation in urban environments.

Figure 2. Populations in many coastal African nations will double by the year 2025, placing increasing pressure on aquatic species and habitats. World Bank, 1975. Photo credit: Edwin Huffman.

Myth #4: Humans impact the ocean less than they do on land. Humans have already greatly altered marine life and habitats worldwide. Kaufman and Dayton (1997) state that, "The unfortunate truth is that there is nowhere left to run and no place left to ruin." Large vertebrate grazers, such as whales, turtles, groupers, and manatees, have been decimated; invasive species are a problem worldwide; and wetland habitats have been greatly reduced, particularly in estuaries and bays (NRC, 1995). The effects of human pollution, for example, are found even in very remote areas. Polychlorinated biphenyls (PCB's), of concern due to their estrogen-mimicking effects, have been found in albatrosses living in the middle of the South Pacific (Rolland and Colborn, 1996). Finally, destructive fishing methods such as trawling have devastated soft bottom habitats worldwide. Studies have shown a close connection between trawling, habitat degradation, and decline in fishery landings (Auster et al., 1996; Peterson et al., 1987; Sainsbury, 1988).

Chapter 3.
Why Should African Aquatic Conservation Be Supported Now?

Sustainable use of fish and other aquatic species can provide increased income, broader participation in economic enterprises, better nutrition and a greater integration of natural resource concerns into a development program. New England Aquarium, 1998. Photo credit: Alexander Goldowsky.

A. It Makes Developmental Sense

There are sound economic and developmental reasons for specifically addressing freshwater and marine biodiversity in Africa, as outlined in the following section. First, there are sound development reasons for maintaining healthy freshwater environments, since many of the larger freshwater systems are critical to Africa's water supply. Second, sustainable use of fish, other aquatic fauna, and flora can yield increased income, broader participation in economic enterprises, better nutrition, and a greater integration of natural resource concerns into an overall development program.

Making Africa's fisheries sustainable is an important way to develop long-term increases in productivity through improved natural resource management and food security. In many African countries, fisheries are already among the most economically important renewable natural resources (Figure 3). Fish also represent an irreplaceable source of protein for a continent in which there is often a widespread and chronic shortage of animal products; lack of protein is a major cause of infant death and slowed mental development. Fish is often the least expensive source of animal protein, and is therefore the most consumed in almost every riparian African state. <u>Over 25% of Africa's protein needs are provided by fish.</u> Some countries derive over 50% of their animal protein from fish: these include Ghana, the Democratic Republic of the Congo (formerly Zaire), Senegal, Sierra Leone, Uganda, and Malawi (USAID/R&D/AGR draft fisheries strategy, 1987). Fish also contain an abundance of an essential amino acid, lysine, that is limited in cereal grains. Most of the African lakes and rivers and a number of African wetlands support tribes whose livelihood has historically depended upon fishing.

B. The Value of African Freshwater and Marine Ecosystems

1. Their socio-economic value

Rivers provide innumerable benefits to Africans, including drinking water, routes of transport and trade critical to inland villages, such as those along the 8,500 mile-long Zaire River (Caputo, 1991), hydropower, and harvestable plants and animals (Figure 4). They also afford some of the most spectacular scenery in Africa.

Africa's fisheries are economically important, both for the external market and the domestic market. In 1995, the total annual yield from the continent (both freshwater and marine) was estimated to be 5,013,000 metric tons, with an economic value of $313,583,000 (exports only) (FAOSTAT database, 1997). The total annual yield of fish from African inland waters <u>alone</u> was nearly 1.8 million tons, larger than that of North American waters. A number of marine invertebrates are also of commercial value, including a variety of molluscs, crustaceans, coral and echinoderms (Gawler and Agardy, 1994).

Figure 4. African rivers provide innumerable benefits including drinking water, routes of transport and trade critical to inland villages. This is the Nile River. New England Aquarium, 1998. Photo credit: Mark Chandler.

Many wild populations of freshwater fishes are valuable as <u>sources of genetic material</u> to improve domestic fish strains used in aquaculture. In particular, pure strains of tilapia (a type of cichlid) are critically important worldwide, as many parts of the developing world depend on this species for aquaculture. Unfortunately, pure strains of tilapia are disappearing due to habitat loss and the impact of exotic species. Freshwater fish can also provide potentially clinically beneficial substances. In the Korup rainforest of Cameroon, a species of Salminus has a folk reputation of curing leprosy; several species of fishes have toxic spines and viscera that may be useful blood anticoagulants (Reid, 1989).

Some species can be used for <u>biological control of disease and weeds,</u> eliminating the use of chemical insecticides or molluscicides. They can control insect and snail vectors of human and livestock disease in ponds and rice paddies. Some fish can also be used to control weeds in irrigation ditches, canals, and ponds without the use of chemical herbicides. Fish can also be used for <u>environmental monitoring of water quality</u>. They can be utilized to detect pesticide runoff, organic pollution, siltation, etc.

The spectacular behavior of fish can also be a <u>tourist attraction.</u> The beauty and diverse behaviors of Africa's

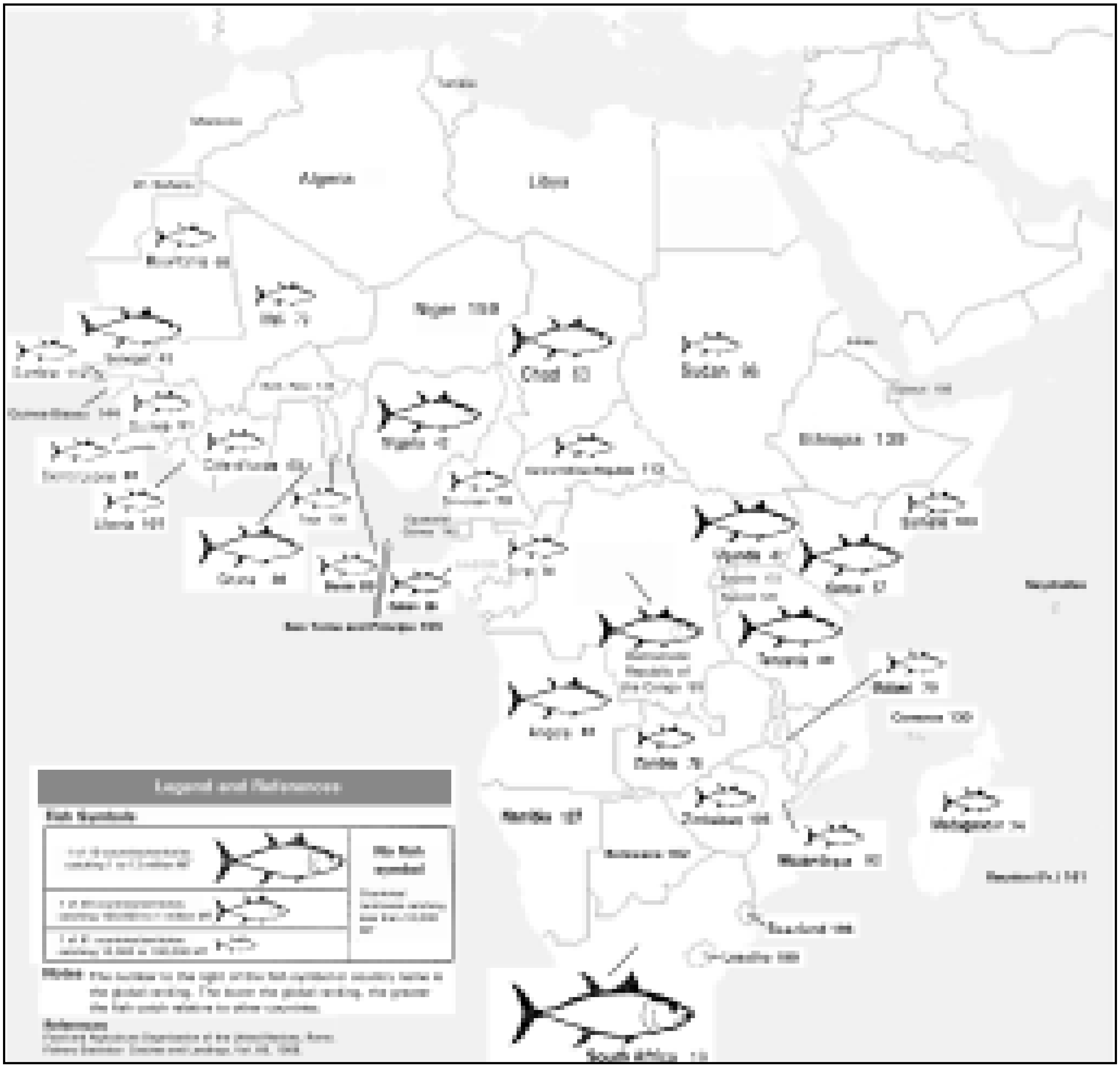

Figure 3. Fish catch by country. The size of the fish symbol indicates the importance of fisheries to that country (see inset). Modified from "African Fish Yields by Country", 1991 with permission from the Food and Agriculture Organization of the United Nations.

cichlid fishes in the Great Lakes offer tremendous opportunities in this regard. Recreational fishing, like tourism, spreads dollars around to a variety of enterprises. Part of the money is earned by the manufacturing sector building fishing tackle, boats, outboard motors, etc. Other jobs, especially in rural areas, include fishing guides, sellers of bait, motor fuel, etc., as well as the local hotel and restaurant trade.

Wetlands are of major human importance. Wetlands refer to a diverse range of ecosystems with vegetation that is permanently or temporarily covered by either fresh or salt water. Too often wetlands are lost, however, because development proceeds without any planning, or because the full economic and ecological value of wetlands is not taken into account in the planning process.

Throughout history, wetlands have been thought to be useless lands -- unproductive and riddled with disease-carrying insects. For this reason, it is often assumed that other uses of wetlands will be economically more productive than their original uses. Emerging evidence, however, points to the opposite conclusion. The ability of wetlands to sustain alternative development is generally found to be low (Burbridge et al., cited in IUCN, 1990b). "If efficiency is measured in terms of profit per unit of water, the data suggests there is little difference between traditional agricultural practices (utilizing and maintaining

Table 1. Products of Mangrove Ecosystem

A. Mangrove Forest Products	
Fuel	Firewood (cooking, heating) Charcoal Alcohol
Construction	Timber, scaffolds Heavy construction (e.g., bridges) Railroad ties Mining pit props Boat building Dock pilings Beams and poles for buildings Flooring, panelling Thatch or matting Fence posts, water pipes, chipboards, glues
Fishing	Poles for fish traps Fishing floats Wood for smoking fish Fish poison Tannins for net and line preservation Fish attracting shelters
Textiles, leather	Synthetic fibres (e.g., rayon) Dye for cloth Tannins for leather preservation
Food, drugs & beverages	Sugar Alcohol Cooking oil Vinegar Tea substitute Fermented drinks Dessert topping Condiments from bark Sweetmeats from propagules Vegetables from progagules, fruit or leaves Cigar substitute
Household items	Furniture Glue Hairdressing oil Tool handles Rice mortar Toys Matchsticks Incense
Agriculture	Fodder, green manure
Paper products	Paper of various kinds
Other products	**Packing boxes** Wood for smoking sheet rubber Wood for burning bricks Medicines from bark, leaves and fruits
B. Other Natural Products	
Fish	Birds
Crustaceans	Mammals
Shellfish	Reptiles and reptile skins
Honey	Other fauna (amphibians, insects)
Wax	

Mangroves provide a variety of economically useful products. From Saenger, Hegerl, and Davie, 1983. Reprinted with permission from Kluwer Academic Publishers.

natural wetlands) and intensive cultivation (i.e., irrigation)" (IUCN, 1990a). For example, Drijver and Marchand (1986, cited in IUCN, 1990b), estimate that the natural processes of the inner Niger Delta are worth $1.00/100 m^3/year, producing a much more diverse array of foodstuffs than a monoculture of rice.

Developed countries, which have already lost much of their wetlands, are belatedly realizing their value. The United States, for example, which has lost 54% of its wetlands (87 million hectares since colonial times), has finally begun to recognize the economic and ecological cost of the loss of its wetlands: it is no longer providing federal aid for drainage projects or crops subsidies for farmers who drain wetlands (Tiner, cited in IUCN, 1990b). The degradation of the United States' coastal wetlands has been estimated to cost its marine fisheries $86 million a year (IUCN, 1980, cited in Salm, 1989).

Natural wetlands yield critical economic benefits, including:

- Wastewater treatment -

  Wetland ecosystems, including seasonally waterlogged floodplains, freshwater marshes, peatlands, swamp forests, and estuaries, play a central role in water purification. They prevent eutrophication by absorbing nutrients and retain sediments and toxicants. If wetlands are destroyed, these functions must be achieved artificially, at a significant cost. The Ugandan National Sewerage and Water Corporation is supporting conservation of papyrus swamps and other wetlands around Kampala because of their importance in absorbing sewage and purifying the city's water supply (IUCN, 1990b).

- Fishery production -

  Wetlands serve as feeding, breeding and nursery grounds for numerous commercially important fin and shellfish species. For example, the wetlands in the Banc d'Arguin National Park in Mauritania play a critical role in Mauritania's offshore fishery, which contributed $34 million to the national economy in 1980 (IUCN, 1990a). More than 50% of Zambia's fish production comes from freshwater floodplains or wetland swamps (Harper and Mavuti, 1996).

- Wetland products -

  Wetlands yield a range of products which can be harvested sustainably, such as fish, fodder, timber, non-timber forest products (e.g., resins and medicines), agricultural crops, and wildlife resources (e.g., meat, skins, honey, and both bird and turtle eggs) (Table 1). Worldwide, millions of people use the products of **mangroves** and the mangrove environment for subsistence. In East Africa, tannin is collected from mangrove trees to preserve fishing nets, ropes, and sails.

- Energy generation -

  Some wetlands can be used as energy sources. Mangroves can provide fuelwood. Papyrus can be harvested and compressed into fuel briquettes, as is currently being done in Rwanda (IUCN, 1990b).

- Tourism -

  Wetlands offer great potential for African tourism because they are important to both terrestrial and aquatic life. In one spot, tourists can view both large mammals and an astonishing abundance of waterfowl (Harper and Mavuti, 1996). The floodplains of the Senegal, Niger, and Chad basins in West Africa support over a million waterfowl. The wetlands in Amboseli National Park in Kenya are one of the park's principal attractions (MENR, cited in IUCN, 1990b).

Human adaptation to and dependence upon wetlands is found throughout Africa. In fact, for some African peoples, wetlands are an integral and necessary part of their survival (Figure 5). Acreman and Hollis (1996) state

Figure 5. Numerous African peoples depend on wetlands for their livelihoods. © World Resources Institute.

that, "The importance of wetlands to human populations is arguably most clearly demonstrated within the African continent." For example, the people living around Lake Chad have relied for generations on a blue-green alga (*Spirulina platensis*) as a protein-rich food (Leonard and Compere, 1967). Over one million people and several million livestock depend on the Sudd swamp in the Sudan (one of the largest wetlands in the world) (Scudder, 1991). Some subtribes of the Dinka in the Sudd region are dependent upon swamp fish for survival, at least during the long dry season. "The fishermen live in the swamps for several months, often on floating papyrus islands, and spend much of their time in the water, fishing with spears and traps" (Beadle, 1984).

Coastal areas encompass productive and diverse ecosystems, and support much of the world's agriculture, industry, fisheries and tourism (Needham, 1991). In 1988, Kenya generated more money from coastal tourism than from tourism on wildlife safaris (Samoilys, 1988a).

Coral reefs, with their spectacular abundance and diversity of colorful fishes, as well as other species, can generate money from tourism, the aquarium trade (worldwide,

Table 2.

A. Major Coral Reef Export Products of Economic Importance

Resource	Role in Reef	Product Use
Stony coral	Primary Reef Frame Builder	Building material, fish tank decoration
Precious coral	Enhances habitat	Jewelry, decoration
Fish	Link in metabolism	Food, aquarium fish
Mollusks	Calcification, food chain	Shell collection
Tridacna clams	Calcification	Decoration, novelty
Top Shells, Trochus	Calcification, food chain	Mother-of-pearl
Oysters	Calcification, food chain	Pearls
Lobsters	Scavenger	Gourmet food
Sea cucumbers	Detritus feeder, sand	Food
Sponges	Borer	Toiletry
Sea turtles	Food chain	Shell, oil, meat, eggs
Sea snakes	Food chain	Skin, crafts
Misc. invertebrates	Varied	Antibiotics, drugs
Coral sand	Substrate, beaches	Concrete, building
Ecosystem	Conservation, genetic diversity	Tourism, aesthetic appeal, natural laboratory

B. Subsistence Food Products Commonly Used

Organism Group	Kind
Fish	Large variety
Bivalves	Clams, mussels, oysters
Gastropods	Most large ones
Cephalopods	Squid, cuttlefish, octopus
Crustaceans	Crab and shrimp
Echinoderms	Sea cucumbers and sea urchins
Coelenterates	Jellyfish and anemones
Sea Turtles	All except hawksbill, eggs
Algae	Many edible varieties

Coral reef resource products and uses. From White, 1987. Reprinted with permission of the International Center for Living Aquatic Resources Management (ICLARM).

estimated at $40 million in 1990, McClanahan and Obura, 1996), shellfish products, and even chemical products. Because marine organisms evolved over 500 million years ago, the long evolutionary separation among various phyla has culminated in great biochemical and genetic diversity (Reaka-Kudla, 1995). Sponges, for example, exhibit diverse antibiotic and feeding-deterrent properties (Rutzler and Feller, 1988). Unlike the well-publicized medicinal value of tropical rainforests, however, the chemical potential of marine organisms has not been as widely appreciated. From an economic standpoint, coral reef ecosystems are important both for the commercial products they yield as well as for the subsistence market (Table 2).

2. Their ecological value

In addition to the direct economic benefits mankind receives from aquatic resources, aquatic ecosystems provide numerous ecological services, benefiting both aquatic and terrestrial life. Where the economic value of these services has been calculated, the benefits are considerable (Daily, 1997). Conversely, the economic cost of artificially replacing such services is high.

Rivers and streams are generally thought to lack the biological richness of other ecosystems. Yet, as the American River Protection Imperative (1991) states, they "are frequently part of complex systems that are valuable in themselves, are the beginning of... food chains and, as moving, dynamic systems, are essential to the survival of other ecosystems." Furthermore, rivers and streams play an essential role in the water cycle and in the movement of nutrients and minerals from watersheds to lowland areas and eventually to the sea (Allan and Flecker, 1993). African **river basins** (together with their associated **wetlands**) are in fact highly productive ecosystems, with an estimated 40% of fish in Africa coming from riverine and floodplain fisheries (FAO, 1981).

In addition to their role in water purification discussed earlier, **wetlands** help to ensure a year-round water supply by their role in groundwater recharging (i.e., the movement of water from the wetlands into the underground aquifers) and discharging (i.e., when underground water moves upward into a wetland). Evidence has accumulated showing that where wetlands have been lost, the hydrological cycle is affected and the water supply during the dry season has been lost (IUCN, 1990b).

Wetlands also help to stabilize shores, prevent erosion, and help to protect many coastal areas from storms through their damping of wind and wave action and their retention of the bottom sediment by plant roots. Wetlands lining the sides of rivers help to prevent erosion of the banks, while those lining the shores of lakes play a critical role in the ecological balance of the lakes. Wetlands also control floods by absorbing floodwaters and releasing runoff evenly. The importance of wetlands in storm protection is indicated by the fact that in the U.S., the Federal Insurance Administration regulations now prohibit payment of flood insurance benefits to communities that cut down mangroves (IUCN, 1990b). Although mangroves can become damaged in heavy storms, they will grow back. The effects of humans, however, can so change the intertidal environment that re-establishment of the mangroves is prevented.

It is important to note that not all wetland types can perform the same ecological function. This depends on the interaction of the biological, chemical and physical characteristics of the site. For example, floodplains, marshes and lake wetlands are important for groundwater recharge, while mangroves are not. **Mangroves,** on the other hand, provide six ecological functions, falling under two categories: 1) they improve water quality, by reducing sedimentation and acting as a nutrient and pollution sink; and 2) they support coastal and estuarine ecosystems, by acting as a nursery, source of food, and by protecting coasts (Rutzler and Feller, 1988; Figure 6).

Mangroves produce considerable organic litter such as leaves, fruits, and dead wood. While some of this detritus stays in the mangroves, the rest ends up in estuaries. There, biological degradation by bacteria, fungi, and larger organisms results in detrital complexes that appear to be the most important source of energy for maintaining estuarine fisheries and supporting tropical marine coastal ecosystems. Over 60% of commercially important marine species are known to either live in mangroves or depend on mangrove

Figure 6. Mangroves provide important ecological services, including improvement of water quality and the support of coastal and estuarine ecosystems. Photo credit: Caroly Shumway.

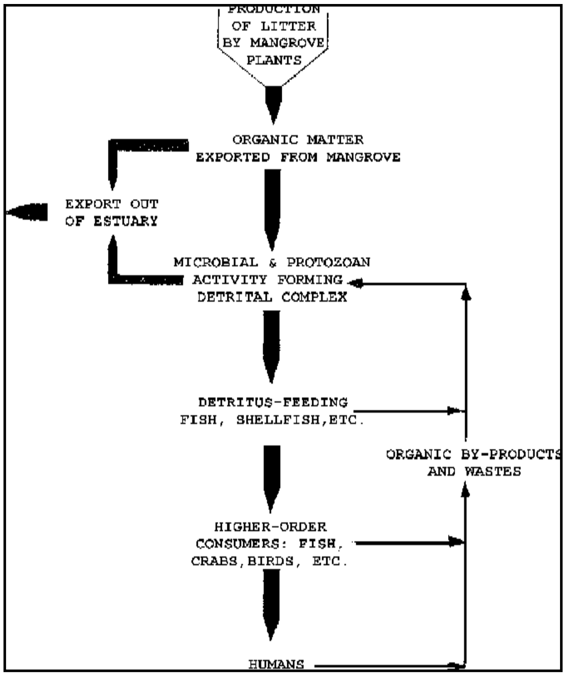

Figure 7. Important pathways of energy flow in tropical estuaries. From Saenger, Hegerl, and Davie, 1983. Reprinted with permission from Kluwer Academic Publishers.

food webs at some stage in their life cycle (Republic of Kiribati UNCED report, 1991).

Few ecosystems in the world exceed the high primary productivity of wetland areas. The nutrient-rich waters of wetlands provide critical feeding, breeding and nursery grounds for fish. Without significant contributions from their floodplains which trap a large amount of nutrient material (Gaudet, 1992), in fact, very few large rivers would support productive fisheries. **Estuaries**, which are semi-enclosed areas influenced by inflowing river water as well as ocean tides, are among the most fertile waters in the world. Although these areas have a relatively low species diversity, they are functionally complex (Figure 7), and a number of young fish use estuaries as a nursery. In sum, "most of the fish we eat... depend on wetlands at some stage in their life cycle" (IUCN, 1990b). Estimates of the total value of estuaries in the U.S., including water treatment, protection from storm damage, fish production, and recreation, range from $800 - $9000 per acre (Anderson and Rockel, 1991; Kirby, 1993; both cited in Peterson and Lubchenco, 1997).

The high levels of primary production in wetlands, coupled with their characteristic habitat complexity, provide the support base for some of the world's highest levels of biodiversity. Many wetlands support important populations of wildlife and plants, including endangered species, terrestrial mammals such as primates, and often a spectacular concentration of birds. Numerous mangrove areas form parts of international flyways for migratory birds. The importance of American wetlands to wildlife has now been recognized by the U.S. federal government which is currently suing the South Florida Water Management District over its failure to prevent degradation of wetland ecosystems in the Everglades National Park caused by agricultural runoff (IUCN, 1990b).

Figure 8. Coral reefs rival tropical rain forests in their richness of biodiversity. New England Aquarium, 1988. Photo credit: Paul Erickson.

Marine ecosystems are important in global geochemical cycling (including carbon sequestration), in dilution, detoxification, and retention of human-generated pollutants, and in providing fishes, shellfish, and other valuable wildlife products (Peterson and Lubchenco, 1997).

Coral reefs rival tropical rain forests in their richness of biological diversity (Figure 8). Like rain forests, coral reefs are physically complex environments containing high species diversity, elaborate species adaptations, and intricate associations between species (Reaka-Kudla, 1995). Coral reef communities contain three different types of organisms: 1) suprabenthic fishes; 2) sessile benthic organisms that provide the physical reef structure (e.g., hard and soft corals, coralline and fleshy algae); and 3) the cryptofauna,

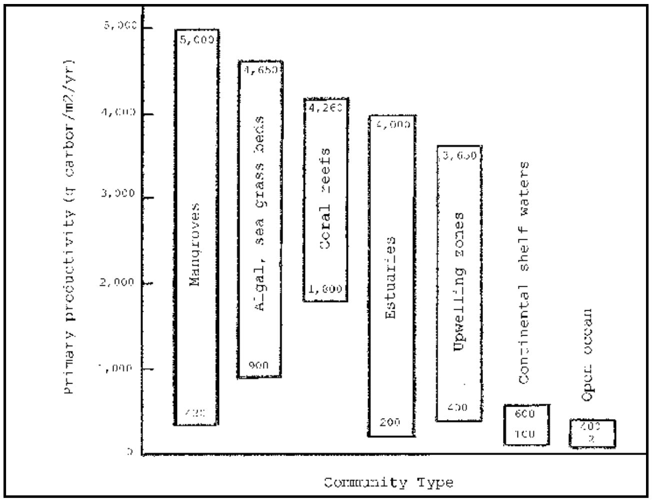

Figure 9. Ranges of primary productivity of some major marine communities. From White, 1987. Reprinted with permission of the International Center for Living Aquatic Resources Management (ICLARM).

including animals that bore (e.g., sponges, bivalves), and sessile organisms and motile organisms that live in holes and crevices (e.g., sessile: bryozoans, motile: echinoderms, crustaceans). Like insects in the rain forest, the greatest species diversity is found in the cryptofauna (Reaka-Kudla, 1995). A large proportion of reef species are believed to be still unknown to science. While only 93,000 coral reef species have been described worldwide, one respected scientist has estimated that the true number is 600,000-950,000 (Reaka-Kudla, 1995). Many fauna of tropical oceans, including coral-reef dwelling organisms, depend upon a number of separate but interlinking ecosystems, including upwelling regions, offshore oceanic areas, continental shelves with hard or soft bottom deposits, coral reefs and mangrove swamps. The high productivity of reef communities (Figure 9) may be directly dependent on the health of neighboring habitats, including seagrass beds, reef flats, soft-bottomed areas and mangroves. These adjacent habitats can provide coral reef communities with the essential nutrient nitrogen. Nitrogren is obtained from the algae on adjacent dead reef flats and from bacteria in the seagrass beds, mangroves and reef sediments (White, 1987). These surrounding habitats also contribute to the feeding, shelter, breeding and nursery grounds of fish and invertebrates at different stages of their life cycle. Numerous tropical fishes move from one ecosystem to another as they grow, as in the case of reef fishes having pelagic larval stages.

Like wetlands, coral reefs, seagrass/seaweed beds, and coastal supra-littoral flora protect coastal areas where much of the world's population resides. Living coral reefs, for example, play a major role in providing sand for beaches as they are biologically broken down over time. Coral reefs also protect the mainland and the beaches by acting as buffers against storm and wave action. Salt-tolerant coastal, strand, and supra-littoral ecosystems (e.g., mangroves, strand and supra-littoral scrub and forest) play an important role in protecting inland ecosystems from salt spray.

C. The Link Between Aquatic and Terrestrial Ecosystems

In thinking about aquatic systems, we are forced to appreciate the linkages across ecosystems, as aquatic systems influence and are influenced by terrestrial ones. In addition to the importance of drinking water for terrestrial wildlife (Figure 10), nutrient flow, food webs and species distribution all show linkages across aquatic and terrestrial ecosystems. This is why aquatic conservation can be so difficult, as both land and aquatic human activity must be addressed. Although all aquatic ecosystems show a linkage, transitional ecosystems (called ecotones) such as floodplains, intertidal wetlands, and other wetlands are the most heavily influenced by terrestrial ones. These ecotones attract species from both systems and are often very productive regions with high species richness (Harper and Mavuti, 1996).

Figure 10. Aquatic and terrestrial ecosystems are linked: terrestrial with freshwater; freshwater with marine. At a minimal level, freshwater systems provide drinking water for terrestrial wildlife, such as these baboons. Photo credit: Dennis Zemba.

Nutrient flow: Rivers and streams move nutrients and minerals from watershed and lowland areas to the sea, and all of the points in between (Allan and Flecker, 1993). For example, floodplains are extraordinarily productive agricultural areas as rivers transport organic material and sediments over the floodplain soil. The flooding also releases terrestrial nutrients into the aquatic system, generating increased aquatic plant production and food for spawning fish and their young (Scudder, 1991). According to Adams (1996), African wetlands also play a role in sustaining dryland grazing systems.

Species distribution: The distribution of both terrestrial and aquatic species can depend on one another. Quite a few African amphibian, reptilian, bird and mammal species are found near riverine or floodplain habitats, such as buffaloes, certain antelopes, snakes, and cane rats (Cooper, 1996). A number of African wildlife populations base their migration patterns around the production of floodplain grasses (Harper and Mavuti, 1996). For example, the Tiang (*Damaliscus lunatus*), a large antelope, migrates to the Sudd floodplain as water levels recede, and fresh grass is exposed (Thompson, 1996). Similarly, terrestrial wildlife depend on ephemeral rivers in arid areas, for both water and the associated plantlife (see Box below). The distribution of some floodplain tree species depends on animals such as hippos to eat the seeds, which enhances germination and aids dispersion (Feely, 1965, cited in Gaudet, 1992; Figure 11).

Figure 11. The distribution of some floodplain tree species depends on animals such as hippos to eat the seeds, which enhances germination and aids dispersion. Photo credit: Dennis Zemba.

Food webs: Riparian habitats provide leaves, fruits, seeds, flowers and branches to rivers and streams. A number of freshwater fishes and invertebrates depend on this terrestrial plant material for shelter and food. Numerous species also feed on the aquatic stages of terrestrial insects, many of which need aquatic habitat for their early development (Figure 12). Decaying riparian vegetation also provides an important source of energy for aquatic bacteria and fungi (Cooper, 1996). Reid (1989) cites the role of the Korup rainforest in Cameroon in generating detritus for small macrocrustacea, who, in turn, are a major dietary item for deep-forest fishes.

The Importance of Rivers to Terrestrial Conservation: Ephemeral Rivers in Namibia

Numerous arid and semi-arid areas in Africa have ephemeral rivers or streams, flowing only after good rains (Cooper, 1996). Namibia, the most arid country south of the Sahara (Brown, 1996), has a number of ephemeral rivers in its interior. The ephemeral rivers in the Namib and Kalahari Desert in Namibia flow only a few weeks every year. Created by floods following heavy rainfall of several days duration, these rivers are essential for terrestrial wildlife, and comprise a diverse and globally unique desert ecosystem (Jacobson et al., 1996). The rivers transport organic material and sediments to the desert, causing germination and recruitment of riparian vegetation, and recharging groundwater. The ephemeral rivers enable relatively mesic species to penetrate into the arid desert habitat (Hines and Kolberg, 1996). Even after the river disappears, the riparian vegetation and resulting springs provide food and water for a number of rare species, including rhino and elephant, who travel from one river to the next in a nomadic fashion. Ephemeral pans are also ecologically important, providing breeding and feeding grounds for migrant birds during their wet phase (Hines and Kolberg, 1996). Such systems are extraordinarily sensitive to hydrologic perturbations. Unfortunately, pressure for damming Namibia's rivers is increasing given increasing water demands from agriculture, industry, and households. The challenge the country faces is how to maintain its scarce water resources for its people and wildlife, given a population growth rate of 3%, among the highest in Africa, and the accompanying water demands. Research has shown that ecosystems of perennial rivers can be maintained downstream of dams with periodic man-made flooding; such flooding, however, transports only water, not sediment. The conservation challenge for these ephemeral rivers is determining if it is possible to release organic material and sediments with man-made flooding in such a way that this fragile ecosystem could be maintained. In addition, an appropriate land use plan for the region is necessary. Fortunately, there is broad interest in improving catchment management in Namibia, both within government and outside.

D. The Link Between Freshwater and Marine Ecosystems

Just as aquatic systems are linked to terrestrial ones, so, too, are freshwater and marine systems linked to each other. Here, the links are between nutrient flow, food webs, habitat quality, and life stages. First, coastal lagoons, estuaries, and deltas rely on an adequate freshwater level. Without enough freshwater, temperature and salinity can increase and oxygen decrease, with potential high fish mortality (Salm, 1989). Second, the high productivity of these areas depends on nutrients, organic material and sediment from upstream (Postel, 1995). Third, estuaries help filter silt from rivers and reduce the effects of sedimentation on other marine ecosystems. Fourth, mangroves depend on significant amounts of freshwater inflows to provide a sufficient amount of water, nutrients, and a stable substrate. Numerous species of marine fishes use mangroves and estuaries as nursery and breeding grounds. Finally, freshwater flooding can benefit coastal ecosystems by increasing nutrient availability, both from upstream and from the physical mixing of the floodwaters into the ocean bringing up nutrient-rich deeper waters into the euphotic zone (Crivelli et al., 1995). It is important to note that nutrient flow is not a one-way process. Reimchen (1995) showed that temperate anadromous fish transport nutrients into streams, and predatory mammals can transport these fish onto riparian zones, providing nutrients that foster tree growth. Insects also enhance this two-way effect through the upstream flight of adults to lay aquatic eggs.

E. It Makes Conservation Sense

"Aquatic ecosystems can be restored, faltering species populations can be reinvigorated with them. All we need is sustainable practices in watersheds and water bodies, and the willingness to share the planet's surface with other species."

McAllister et al., 1997

To date, the emphasis in African biodiversity conservation has been on improving the management and protection of terrestrial biodiversity. One could suggest that for this goal alone, conservationists, governments, and donors should be concerned with aquatic problems, since terrestrial wildlife is dependent upon water resources for survival. In other words, it is important to maintain water quality and quantity simply to succeed in terrestrial conservation. In fact, monitoring the health of a river can be a useful and simple means of monitoring the ecological integrity of the adjacent terrestrial ecosystem, as changes occurring anywhere in the system are likely to impact the river (Karr, 1997).

Figure 12. Numerous freshwater species feed on the early aquatic stages of terrestrial insects, such as dragonflies, while terrestrial species feed on the later stages. Photo credit: Caroly Shumway

Aquatic conservation efforts in Africa are urgently needed and could not be more timely. A number of key global initiatives target freshwater and marine systems in the late 1990s. IUCN's Species Survival Commission (SSC) is starting a new freshwater biodiversity initiative (Species, 1997). A key part of this initiative will be SSC's Fishes for the Future Project, developed with ICLARM and WCMC, which will try to assess the status and conservation needs of all of the world's freshwater fish species. The SSC Coral Reef Fish Specialist Group is undertaking a similar assessment for coral reef fish species. The Convention on Biological Diversity focused on inland water ecosystems as one of their main thematic areas in 1998.

Why should donors support aquatic conservation efforts in Africa? There are three reasons:

1) The continent has a rich, but threatened aquatic biodiversity;

2) Perhaps nowhere else are people more dependent on aquatic ecosystems and their supporting wildlife; and

3) Conservationists in Africa have developed approaches to conservation and sustainable development that are at the forefront of modern conservation efforts worldwide.

For example, African conservationists and developmental specialists helped initiate such innovative concepts as the restoration of natural hydrological cycles with artificial floods, and bioregional management, as expressed in river basin development. Some approaches originated from terrestrial conservation work, such as community-management within and outside protected areas, integrated conservation and development projects, and sustainable wildlife utilization programs. These types of efforts have now been applied to the aquatic realm, as described below. But the experience of NGOs and donors in these areas, and the lessons learned (both failures and successes) could be invaluable in helping to shape aquatic conservation and management efforts in Africa. While I have summarized published lessons learned, incorporating my own experience, there is nothing like hearing the lessons first-hand. Perhaps NGO training of other NGOs would be a way to pass on this knowledge.

Further, perhaps existing terrestrial efforts of international and local NGOs and donors could even expand into adjacent aquatic sites. For example, projects supporting ecotourism could incorporate aquatic sites into the package. The large tourism industry is already well-developed in some African countries, and there is high potential for further environmentally-friendly development at this scale, as well as smaller, more grass-roots ecotourism programs. Africa's lakes, wetlands, hot springs, rivers, and coral reefs all have potential for well-designed tourism projects -- at least in certain sites. Cruises, non-motorized water sports, nature trips, and guided, controlled sport-fishing to select habitats with overnight camping are all possibilities. Most importantly, by expanding existing projects, some aquatic conservation efforts could "piggy-back" onto the hard, time-consuming, but *essential* effort of finding communities interested in conservation and sustainable development, and establishing community trust.

Examples of African success stories in aquatic conservation and sustainable development include:

- In the Tanga region of Tanzania, the government is working together with IUCN to develop three pilot coastal zone management programs (Gorman and Ingen, 1996). Problems in the area included overfishing and destructive fishing practices, coastal erosion, and declining fuelwood. Three villages are attempting community-based resource management and developing alternative jobs that do not depend on coral reef fishes. Women have benefited from the successful introduction of seaweed farming (Intercoast Network, 1998). The first year of the program involved discussions among the various stakeholders and building of trust. The villagers are now implementing solutions themselves, with the government in a supporting role. Elders are inspecting fishing gears, fishermen patrols have virtually stopped dynamite fishing (People and the Planet, 1997), and degraded mangrove areas are being replanted. Training activities have included both local residents and government personnel, helping to build trust between the groups. Irish Aid is supporting expansion to other villages (Intercoast Network, 1998). IUCN is currently working to develop similar co-management systems in the Bijagos Archipelago, Guinea-Buissau (IUCN, 1996).

- Namibia created a guano platform between Cape Cross and Walvis Bay. The platforms are a good breeding site for birds, supporting 40% of the coastal population of white-breasted cormorants, large flocks of kelp gulls, and a coastal colony of pelicans. The platforms benefit conservation and provide considerable economic benefit, yielding 1,500 tons of guano a year (Tarr, 1996).

- Communities along the Phongolo floodplain in Natal, South Africa, are actively involved in hydrological management of the artificial releases from the dam (Bruwer et al., 1996). Seventy thousand people along the Phongolo River depended on natural flooding for farming. A rich wildlife depended on flooding, too. A dam, constructed in the 1950's, caused great ecological damage, including erosion, desiccation of higher floodplain areas, flooding of other areas, and the dying off of riparian species. The dam made flood-recession agriculture impossible. In 1982, the Department of Water Affairs and Forestry decided to artificially reflood the floodplain. In 1983, the Mboza Village Project started as the first democratically structured project in the region, with the focus being ecological reconstruction and development. In 1987, the project launched water committees, comprised of elected representatives of five user groups: farmers, fishers, livestock owners, women, and health personnel. The goal of the committees are to promote development through sustainable management of the area's natural resources. The water committees negotiated the size, duration, and timing of flood releases among a variety of stakeholders, including specialists in ecological planning. There are now six water committees along the river. The J.L.B. Smith Institute for Ichthyology and the National Parks Authority Conservation Division (responsible for administration) are working with the water committees to protect the floodplain fisheries. The project has had a multiplier effect: Mozambique wants the combined water committees to assist in setting up similar committees for the Rio del Maputo. Such community-based hydrological management can be replicated elsewhere.

Chapter 4.
Overview of Important African Freshwater/Marine Habitats

Lake Nakuru, Kenya. Photo credit: Dennis Zemba.

A. Freshwater Habitats

1. Geographic overview of diversity

The best geographic analyses to date describe the distribution of fish species. Roberts (1975) divided Africa's ichthyofauna into ten provinces (excluding Madagascar), based largely on river drainage patterns (Figure 13). Daget (1984) further refined this concept. According to Reid (1989), however, these analyses were conducted without much data from the Korup river, Cameroon. His data suggest some modification may be necesssary at least for the Lower Guinean province. Note that while the Great Lakes are placed in provinces according to their drainage system, with Lake Victoria draining to the Nile, Lake Tanganyika to the Zaire, and Lake Malawi to the Zambezi, the species numbers cited below exclude the Great Lakes. The following overview is based on Stiassny (1997). For more detail, see the CLOFFA volumes (Daget et al., 1984; 1986a,b; 1991), the PARADI symposium (1993), and Lévêque (1997).

The Zairean province is the most species-rich, with 690 species described, roughly 80% of which are endemic (review: Teugels and Guégan, 1994). Lowe-McConnell (1987b) divided this province into six regions: 1) Lower Zaire; 2) the rapids and falls between Matadi and Pool Malebo (aka Stanley Pool); 3) Pool Malebo; 4) the Central basin from Pool Malebo to the Kisangani falls; 5) the Upper Zaire, or Lualaba; and 6) the Upemba Lakes and Lualaba floodplains. Pool Malebo and the rapids between Boma and Pool Molebo are well-studied and known to have considerable endemics. Other parts, such as the southern tributaries Inkisi and Mpozo, and the Fwa river, a tributary of the Kasai, have been poorly studied.

The second richest ichthyofaunal province is the Lower Guinean province, with at least 340 species. Except for the Cross River, however, the area has been poorly studied and increased effort should be given to surveying this province. The habitats are highly threatened by logging and a growing population. Areas of biological significance include the Cameroon crater lake Barombi Mbo, with its unique cichlids constituting West Africa's only species flock (Trewavas, 1972, cited in Reid, 1989), Lakes Bermin and Ejagham (although poorly studied), and the deep forest pools in Korup National Park (Reid, 1989). Reid (1989) found 140 species in the Korup rivers of Cameroon (including the Akpa-Yafe, Ndian, and Upper Cross), with 90 species in the Upper Cross alone. Reid (1995) recently surveyed the fishes of in the montane area of Gashaka Gumti National Park, Nigeria.

The Upper Guinean province was once home to over 200 species, but deforestation, dams, and exotic species have taken a severe toll on its freshwater inhabitants. Threatened habitats of importance for endemics includes the Guinean and Liberian Highlands (e.g., Fouta Djallon, Mt. Nimba, and Wologizi Mountains). Stssny recommends conserving any remaining forest cover for rivers and streams.

The Sudanian (or Nilo-Sudanian) province has between 270 and 300 species, but most are widespread, with the exception of the northern Rift Valley lakes. The smaller rivers and streams in the Ethiopian highlands have been poorly studied. A species flock of *Barbus* spp. inhabits Ethiopia's Lake Tana (Nagelkerke, 1994), and several endemics live in the Danakil Depression. Three endemics live underground.

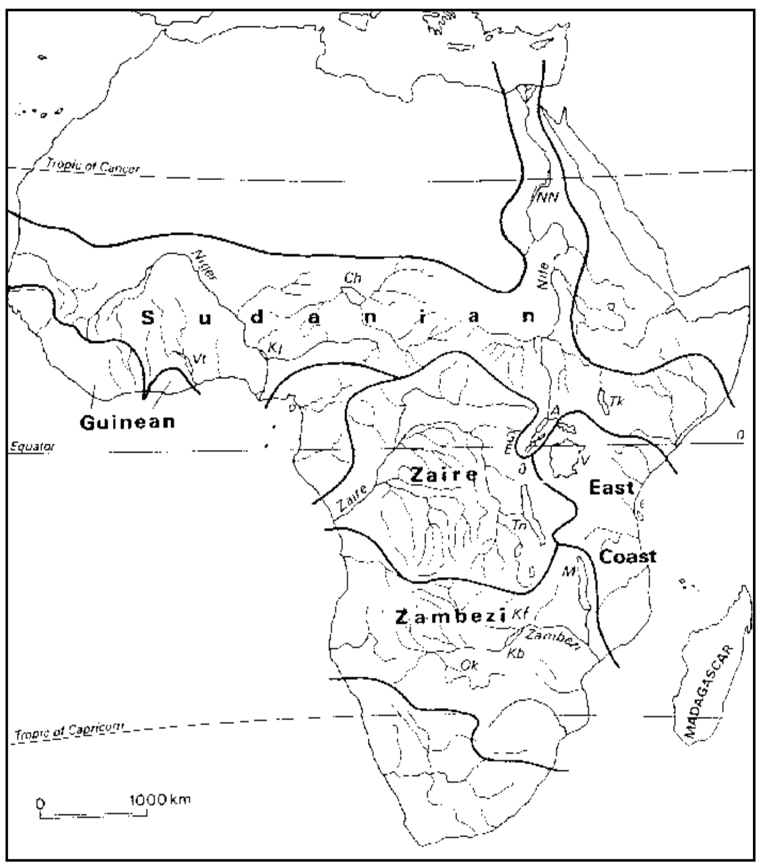

Figure 13. Ichthyofaunal regions. From Lowe-McConnell, 1987b. Reprinted with the permission of Cambridge University Press.

Table 3. Fish Species Diversity By Country

Country	Area (KM)	No. FW Species	No.FW Species/1000KM	Source
Algeria	2,381,740	20	0.00840	1
Angola	1,246,700	207	0.166	1
Benin	110,620	84	0.759	1
Botswana	566,730	54	0.0953	1
Burkina Faso	273,800	99	0.362	1
Burundi	25,650	209	8.148	1
Camaroon	465,400	342	0.735	1
Central African Rep.	622,980	45	0.0722	1
Chad	1,259,200	134	0.106	1
Congo	341,500	315	0.922	1
Cote d'Ivoire	31,800	167	0.525	1
Djibouti	23,180	4	0.173	1
Egypt	995,450	88	0.0884	1
Equitorial Guinea	28,050	55	1.961	1
Ethiopia	1,101,000	66	0.0599	1
Gabon	257,670	169	0.656	1
Gamgia, The	10,000	93	9.3	1
Ghana	227,540	224	0.984	1
Guinea	245,860	172	0.7	1
Guinea-Bissau	28,120	55	1.956	1
Kenya	569,690	255	0.448	1
Lesotho	30,350	8	0.264	1
Liberia	90,750	115	1.267	1
Libya	1,759,540	9	0.00511	1
Madagascar	581,540	75	0.129	1
Malawi	94,080	361	3.837	1
Mali	1,220,190	123	0.101	1
Mauritania	1,025,220	8	0.0078	1
Mauritius	2,030	28	13.793	1
Morocco	446,300	39	0.0874	1
Mozambique	784,090	253	0.323	1
Namibia	823,290	102	0.051	2
Niger	1,265,700	166	0.131	1
Nigeria	910,770	278	0.305	1
Rwanda	24,670	42	1.702	1
Senegal	192,530	127	0.66	1
Sierra Leone	71,620	117	1.634	1
Somalia	627,340	35	0.0558	1
South Africa	1,221,040	153	0.125	1
Sudan	2,276,000	105	0.0461	1
Swaziland	17,200	40	0.756	2
Tanzania	886,040	682	0.77	1
Togo	54,390	60	1.103	1
Tunisia	155,360	17	0.109	1
Uganda	199,550	291	1.238	2
Zaire	2,267,600	962	0.424	1
Zambia	743,390	335	0.451	1
Zimbabwe	386,670	114	0.295	1

From McAllister et al., 1997. Reprinted with permission from Ocean Voice International.

The East Coast province has 100 species, with medium levels of endemism, but the species are relatively restricted in distribution. Forested mountain areas (eg., Mt. Kenya-Aberdare highlands, Mt. Kilimanjaro, Tanzanian Southern Highlands) are known to have higher numbers of endemics, but have been poorly studied, as have the coastal rivers of southern Mozambique. Skelton (1994) summarizes the little that is known for this area. A more comprehensive assessment is needed.

The Zambezian province, with its 150 species, can be further divided into four regions: the upper Zambezi (above the Victoria Falls), Lake Kariba (between the falls and Kariba Dam), the middle Zambezi (between Kariba and the Cahora Bassa Dams), and the lower Zambezi (from Cahora Bassa to the delta). The upper and lower Zambezi are richer in species than the middle (review: Skelton, 1994). According to Stuart et al. (1990), the Zambezi river supports a number of threatened freshwater fishes. *Tilapia guinasana* is a threatened species that is found in a few sink holes in Namibia. Seventy species are known for the Okavango Delta. The delta is threatened by plans for water diversion and overfishing.

The Quanza province has 110 known species, including some endemic cyprinids in the Lucala River, but the area has been poorly studied. Stiassny considers this a priority area for further research.

The Southern (Cape) province has thirty-three species, most of which are highly restricted endemics (review: Skelton, 1994). The most restricted are those in the Southwest Cape.

The Maghreb province has only forty species recorded (review: Doadrio, 1994). The conservation status of these species is unknown.

A more recent analysis, conducted by World Wildlife Fund-U.S. (Abell et al., 1999, in press), is shown in the map section, pages 37-41. This map of freshwater ecoregions and bioregions reflects the results of a 1998 workshop of scientific experts, and consultation with other freshwater experts. An ecoregion represents "a geographically distinct assemblage of natural communities that share a large majority of their species, ecological dynamics, and environmental conditions" (Abell et al., 1999, in press).

Table 3 summarizes freshwater fish species diversity by country. Taking into account all freshwater ecosystems, but considering only those countries with over 100 freshwater fish species, the top five countries in terms of freshwater species richness per unit area are: 1) Burundi, 2) Malawi, 3) Sierra Leone, 4) Uganda, and 5) Ghana (McAllister et al., 1997, based on FishBase 96: Froese and Pauly, 1996). These estimates include the Great Lakes.

2. Freshwater species

Table 4 lists African countries with the most threatened fish and amphibian species, from the IUCN Red List of Threatened Animals (IUCN, 1996). To date, IUCN's assessment of fish has focused largely on freshwater species (SSC home page, 1998). This estimate may still be low. The 1993 International Symposium on Biological Diversity in African Fresh and Brackish Water Fishes recommended reviewing inventories of fresh and brackish water fishes in relation to the Red List (Reid, 1994).

Table 4. Numbers of Threatened Fish and Amphibian Species by Country

Country	Threatened Fish Species	Threatened Amphibian Species
Uganda	28	0
South Africa	27	9
Cameroon	26	1
Kenya	20	1
Tanzania	19	1
Madagascar	13	1
Seychelles	0	4

Data from SSC, 1998.

In general, the African freshwater species under greatest threat of habitat loss are the ones living in forested stream habitats. These species generally have higher endemicity, and a correspondingly more restricted distribution than species living in the larger riverine system (Stiassny, pers. comm.). Because they evolved in relatively small and isolated environments, they are particularly vulnerable to the introduction of exotics (SSC home page, 1998).

3. Rivers and streams

Worldwide, rivers and streams are probably the most neglected biological systems of all, with Africa, again, being no exception (Figure 14). Ten river systems drain much of Africa, with four major rivers dominating tropical Africa: the Niger, the Nile, the Zaire, and the Zambezi. **The Zaire river basin is one of the most species-rich areas in the world**, with 80% of its species being endemic (Lowe-McConnell, 1987b). The various species represent a diversity of fish families.

Figure 14. Rivers and streams are probably the most neglected biological systems of all. Photo credit: Dennis Zemba.

The upper Lualaba-Zaire basin is second only to the Amazon in riverine complexity and is home to many endemic species. Up to 700 species can be found within the distance of a few kilometers (Kaufman, pers. comm.) For purposes of comparison, only 150 occur in all of European inland waters.

In general, the further downstream, the greater the number of species, probably because of the greater diversity of food sources available in lowland rivers with floodplain habitats (Ruwa, 1996). Current biodiversity estimates for African rivers and streams may be much too low. Recently, Teugels and colleagues showed that previous researchers had underestimated species number in the Cross River basin in Cameroon and Nigeria by 73% (Teugels et al., 1992, cited in Stiassny, 1996).

The flow of many rivers, such as the Orange, Zambezi, Tana, Juba, Nile, Gambia, and Senegal, varies widely during the year, with mean maximum discharge often ten times that of the minimum discharge (Scudder, 1991). Over 90% of Africa's river course length is made up of short rivers less than 0.9 km long, many of which flow only seasonally (Stiassny, 1996).

Some deltas, banks, and floodplains, such as the Senegal River Delta and the Inner Niger Delta, support a wealth of wildlife and are of international biological importance. (See the wetlands section for more details.) Additional rivers and streams of importance include the Niger River, which has been identified as an important site for Sirenians by the IUCN Species Survival Commission (SSC) specialist group (IUCN, 1991a). Madagascar's streams and estuaries contain primitive cichlids, which are as important evolutionarily to advanced cichlids as Madagascar's prosimians are to other primates (Kaufman, pers. comm.). As discussed in section 5D., Madagascar's freshwater fishes are the most threatened vertebrates on the island.

Major river drainages on Africa's East Coast include the Tana and Sabaki rivers in Kenya, the Rufiji and Ruvuma rivers, Tanzania, and the Xamberzi and Limpopo rivers, Mozambique, whose catchment includes South Africa, Zimbabwe, and Botswana (Ruwa, 1996).

Nearly 40% of Africa's freshwater fisheries come from its rivers and floodplain areas (Ruwa, 1996). The **Niger** river, tributaries and associated floodplains, support more than 54,000 fishermen and supply most fish eaten by people in Nigeria, Mali, and Niger. Fish in the **Kafue** river and floodplain in Zambia sustain 670 fishermen and make up more than 20% of the total annual inland catch. The **Shire** river and floodplain in Malawi provide livelihood for nearly 4,500 fishermen and supply over 30% of the annual inland catch (Welcomme, 1979). The Elephant marsh within the Shire floodplain also contributes significantly to Malawian catches (Leveque et. al., 1988). The **Gambia** river supports 16,000 artisanal fishermen and provides over 8,100 metric tons of fish.

4. Lakes

Certain lakes - Ntomba and Mai-Ndombe in the **Zairean** basin and the **Great Lakes** (Lakes Tanganyika, Malawi, and Victoria) - are particularly important for the evolution of Africa's endemic fishes (Figure 15). Ntomba (a.k.a. Tumba) and Mai-Ndombe are the site of a former center of African fish evolution and contain a number of endemic species. Interestingly, the richness of the fauna in Lake Ntomba appears to be due to food and nutrients from the surrounding forest; the water in the lakes is impoverished in nutrients (Lowe-McConnell, 1987b).

The Great Lakes are known for their extraordinary diversity within the family Cichlidae, which dominates the fish fauna in these three lakes and in many adjacent smaller ones. Each of the lakes contains well over 150 cichlid

Figure 15. Lake Victoria. The New England Aquarium, 1998. Photo credit: Alexander Goldowsky.

species. The variety of cichlid species far surpasses that of the finches - 13 species in all - used in Darwin's classic evolutionary model. In addition to cichlids, the lakes also support other endemic fishes and, at least in Lake Tanganyika, a diverse invertebrate fauna, including large numbers of endemic crustaceans and molluscs. Unfortunately, associated animal populations such as hippos, crocodile, python, otter, whale-headed stork, sitatunga and monitor lizards have been reduced in the Great Lakes basin (Kaufman et al., 1996).

Figure 16. Julidochromis marlieri (burundi)*, one of the spectacular Tanganyikan cichlids. Photo credit: Keegan Armke, Armke's Rare Aquarium Fish.*

Lake Tanganyika is the world's longest (650 km) and second-deepest (1,500 meters) lake. The lake contains the greatest overall species diversity (considering all taxa), and the oldest and most differentiated fish fauna of the Great Lakes (Figure 16). The Lake did not dry up during the mid-Pleistocene period, so speciation was able to continue for a longer period of time in Lake Tanganyika than the other Great Lakes. In addition, the lake basin was invaded multiple times by various fish lineages. The biological riches of Lake Tanganyika occur mostly in the upper 200 meters, since the lake is anoxic below this depth. Lake Tanganyika has an unusually high yield of fish relative to its algal production. In fact, fish productivity and fish biomass are actually higher in this tropical lake than in temperate lakes. This situation is unusual since tropical lakes have a reduced supply of oxygen relative to temperate lakes. Coulter (1981) speculates that the productivity may be due to the lake's age and corresponding endemicity, coupled with the high rates of trophic transfer from mixing by frequent and severe storms.

Lake Malawi, the world's ninth largest lake (575 km n-s, 685 m deep), is considered the world's richest lake for fish species. The lake contains at least 600 identified species of fishes and perhaps another 400 unidentified. More than 90% of the species are haplochromine cichlids (Ribbink, 1988; Lowe-McConnell, 1993b), with the rest from nine other fish families. The lake is also home to 20 endemic gastropods. The lake's artisanal and commercial fisheries yield 40,000 tons of fish per year. Like Lake Tanganyika, the water is anoxic below 250 meters. The upper 250 meters undergoes an annual pattern of stratification and partial mixing; complete mixing has never been observed. Could the explosive species radiation have occurred rapidly? Evidence from Lake Nabugabo, Uganda, and Lake Victoria suggests that extremely rapid radiation can occur (Cromie, 1982; Owen et al., 1990; Johnson et al., 1996; Kaufman et al., 1997). The southern arms of Lake Malawi appeared to have dried out twice in the last 1000 years, once between 840-940 years ago, and again between 140-490 years ago (Kaufman et al., 1996). Endemic species are found around islands in areas that were dry just 500 years ago (Lowe-McConnell, 1993b; Owen et al., 1990).

Lake Victoria, Africa's largest lake and the second largest lake in the world, has a surface area of 68,635 km^2, which is larger than all of Switzerland. The lake is relatively shallow, with a maximum depth of 79 m. As recently as 1970, the lake was known to contain at least 350 fish species, of which more than 300 were endemic haplochromines (Kaufman, 1991b) (Figure 17). Geological evidence suggests that the lake nearly dried up 13,500 years ago and that many of the species may have evolved since this short time (Owen et al., 1990; Johnson et al., 1996). The area surrounding the lake is also particularly rich in butterflies, mammals and birds. More than 500 passerine bird species are known to occur in the region, 15 of which are endemic.

Figure 17. A haplochromine cichlid from Lake Victoria. This is Harpagochromis sp.guiarti complex*. The New England Aquarium, 1998. Photo credit: Paul V. Loiselle.*

Unfortunately, Lake Victoria has recently undergone the greatest vertebrate mass extinction of modern time. Evidence suggests that a confluence of factors, principally the introduction of the Nile perch, have led to extinction of almost all of the deepwater cichlid species, as well as nearly half of the species known from waters less than 20 m deep (See Case Study, Annex). Some of the haplochromine species are maintained in a tiny, but important refugium lake, Lake Nawampasa. This lake is only 1 km by 5 km, yet it preserves over 36 haplochromine species representing most of the described genera of the Lake Victoria system (Kaufman et al., 1997).

Two of the Great Lakes, Tanganyika and Malawi, are true Rift Valley lakes, located in rock fissures. Other Rift Valley lakes include Kivu, Edward, George, Albert (formerly Mobutu) and Turkana. Lakes Victoria, Nabugabo and Kyoga are considered associated lakes. Several of the lakes of the Great Rift Valley (in Ethiopia, Kenya, and Tanzania) contain high levels of alkaline soda, inhospitable to most aquatic life but a thriving environment for bacteria, algae and alkaline-tolerant crustaceans. These **soda lakes** are highly productive. Although species diversity is low, population numbers are large (Melack, 1996). The crustaceans in these lakes, along with the algae, are the food staple of huge flocks of greater and lesser flamingoes. More than half of the world's flamingoes live in the Gregory Rift, with Lakes Magadi, Turkana, Bogoria and Baringo all being important flamingo habitats. The enormous flocks of flamingoes which can number over one million create a massive ring of pink around the lakes. This visual extravaganza ranks as one of the most spectacular natural sights in Africa, and is an important tourist attraction, particularly Lake Nakuru, Kenya (Figure 18). This 256 sq. km. lake supports a spectacularly large population of flamingoes as well as other birds such as cormorants, ducks, spoonbills and avocets. Lake Nakuru National Park, which is also a rhinoceros sanctuary, is considered "the greatest ornithological spectacle in the world" (IUCN, 1990a). Tanzania's Lake Natron is the only breeding site for lesser flamingoes in East Africa. Lakes Natron, Magadi, Elementeita, Nakuru and Bogoria form an interconnected group of ecosystems, as birds populations move from one lake to another (Melack, 1996). Lake Magadi also contains alkaline-tolerant endemic fish. Lakes Nakuru and Bogoria are now protected; conservation of Elementeita is under discussion (Oglethorpe, pers. comm.).

Shallow freshwater lakes surrounded by papyrus swamps and seasonal lakes often provide essential wetland habitats (Melack, 1996). For example, the swamps bordering Lake Chad's shores are one of the three most important West African sites for Palearctic migratory birds. Kenya's Lake Naivasha supports large numbers of waterfowl, mammals, higher plants, zooplankton and macroinvertebrates (Melack, 1996). (See the wetlands section for more details.)

Additional lakes of importance include the following. **Crater lakes** and **montane lakes** support a high number of endemic species. Cameroon's crater lake Barombi Mbo harbors 17 endemic species of fishes, 11 of which are cichlids. In general, Cameroon's crater lake fish assemblages are threatened (Kaufman, pers. comm.). Madagascar's lakes also contain some of the country's most threatened endemics, with half of its endemic freshwater fishes and its only freshwater turtle threatened. The Madagascar Lakes Alaotra, Kinkony and Ihotry are important for waterbirds. Both Tanzania and Uganda contain a number of important lakes for waterbirds; Botswana's Lake Ngami is also an important site. Comoros' Lake Dziani, included in IUCN's directory of wetlands of international importance, has a diverse and abundant bird population. Ethiopia's Lake Tana is also important due to its Barbus species flock.

Figure 18. The enormous flamingo flocks of Lake Nakuru are an important tourist attraction. Photo credit: Dennis Zemba.

5. Freshwater wetlands

Wetlands are transitional systems (i.e., ecotones) between terrestrial systems and open water systems (Figure 19). As a result, they attract species from both systems and are often highly productive regions with high species richness (Harper and Mavuti, 1996). The African continent features vast wetlands covering hundreds of thousands of square kilometers. These wetlands can be broadly categorized as freshwater wetlands (which include swamps, floodplains, riverine forest, and swamp forest), mangroves, and coastal wetlands (including lagoons, estuaries, and tidal mudflats). Only fresh-

Figure 19. Freshwater wetlands are often highly productive regions with high species richness. Photo credit: Dennis Zemba.

water wetlands are considered here; mangroves and coastal wetlands are covered in following sections. All of these wetlands are seriously stressed by man's activities, as indicated by the number of threatened and endangered wetland birds and other fauna.

Africa has two distinctive types of freshwater swamps: 1) shaded swamps, in which photosynthesizing parts of plants are above water, shading the water from sun and wind; and 2) unshaded swamps, which support submerged water weeds and floating plants (Beadle, 1984). Important swamps include the Sudd Swamp (also considered a floodplain), the Okavango Delta, Lake Chad, and the Bangweulu swamps.

The most common type of shaded swamp in central, eastern, southern Africa, and in Madagascar below 2,300 m is the papyrus swamp (*Cyperus papyrus*). These habitats surround most shallow freshwater lakes. Papyrus swamps have very low levels of oxygen due to rapid growth and decomposition of the papyrus (Chapman et al., 1995). These swamps may act as a barrier to the dispersal of species intolerant of low oxygen conditions and, as such, may help protect endemic lacustrine species (Kaufman et al., 1996). The swamps provide feeding grounds for many fish and support a large variety of other animals including birds, frogs, insects and some mammals (Figure 20). They also provide other benefits, including water purification and the reduction of sediment loading into lakes. Drainage and cultivation threaten the existence of papyrus swamps in places. According to Kaufman et al. (1996), papyrus drainage has led to soil erosion and acidification and a reduction in water quantity for rural communities.

"A floodplain is any region along the course of a river where large seasonal variations in rainfall results in overbank flooding in to the surrounding plains" (Gaudet, 1992). Roughly 1%, or 340,000 km^2 of Africa's surface area is floodplain (Thompson, 1996). Seasonal floodplains are found along many of the larger African rivers, making up nearly half of Africa's total wetland area. (Thompson, 1996). These wetlands have distinctive grass and reed vegetation that are critically important to local wildlife populations and vice versa. The distribution of some floodplain tree species depends on animal activity. For example, the hippopotamus influences the distribution of *Acacia albida* along the Luanga and Zambezi river valleys in Zambia. The hippo and other wildlife eats the seeds, enhancing germination and fostering dispersion (Feely, 1965, cited in Gaudet, 1992). These wetlands are also often the site of large seasonal game migrations, with the migration patterns of a number of ungulates such as gazelle, lechwe and tian, based around the production of floodplain grasses after flood recession (Harper and Mavuti, 1996). Generally, each floodplain supports a diverse range of grass and other plant species. The Sudd Swamp, for example, features five different communities: two made up of grass, one permanent swamp area with papyrus, one semi-permanent swamp, and open water

Figure 20. Papyrus swamps are the dominant habitat surrounding most of Africa's freshwater lakes. New England Aquarium, 1998. Photo credit: Mark Chandler.

(Sutcliffe, 1976, cited in Gaudet, 1992). Floodplains also provide nursery grounds for riverine fishes (Ruwa, 1996).

"A riverine forest is an ecosystem...dependent on river processes of erosion, sediment transport, flooding inundation, and alluvial deposition" (Medley and Hughes, 1996). It, too, is a transitional ecosystem, and as such, is often rich in species. East Africa's only well-developed riverine forest is Kenya's Tana River, home to a rich diversity of species now biogeographically isolated from the tropical moist forests of the coast and west-central Africa. Many species inhabit the area: 250 types of birds, several of which are rare and endemic; 175 woody plant species; and 57 mammals derived from three biogeographic centers of diversity, including four endemic primates, two of which are endangered (Medley and Hughes, 1996). The Tana River Delta is threatened by an existing dam, along with proposed shrimp farms and rice cultivation schemes (Raal and Barwell, 1995).

Swamp forests are found in still waters around lake margins and certain parts of floodplains. These typically consist of *Ficus* species, borassus palms, and *Syzigium* (IUCN, 1990b). Extensive areas are found in the Zaire basin and the Niger Delta. The Guineo-Congolian (i.e., Zairean) swamp forest has a diversified endemic flora. Cameroon's swamp forests along the Nyong River are unusual and important representatives of this type of habitat.

The major centers of endemism in Africa's freshwater wetlands include:

- Okavango Delta (Botswana)
- Inner Niger Delta (Mali)
- Sudd Swamp (Sudan)
- Lake Chilwa (Malawi), a shallow lake that is an important site for water birds. Lake Chilwa is being considered as a possible Ramsar site
- floodplains in the Central African Republic
- floodplains of Lake Victoria/Lake Kyoga (Uganda, Kenya, Tanzania)
- The inland deltas and floodplains of Malagarasi, one of the most extensive wetlands in Africa (Tanzania)
- The southern swamps of the Democratic Republic of the Congo (formerly Zaire)
- The Mweru Wa'Ntipa wetland and others in Zambia

Important wetland fisheries include: Lake Chad (yielding 115,000 tons), Lake Chilwa, the Bangweulu Swamp and Mweru Wa'Ntipa in Zambia, the Niger Inland Delta (the 1980 estimate in Mali was 100,000 tons), the Okavango Delta, and swamps in the central Zaire basin. Estuarine fishing is limited except in areas such as West Africa, Mozambique, and Madagascar.

In West Africa, the largest and most important swamp is the **Inner Niger Delta**, located in the valley of the Upper Niger south of Timbuktu. The delta, along with the shores of **Lake Chad**, the fourth largest lake in Africa, and **Diawling-Djoudj** in northern Senegal and Mauritania, comprise the three most important sites in West Africa for Palearctic migratory birds.

The 17,000 km^2 of the Inner Niger Delta includes a complex of shallow lakes. In the dry season, this wetland is particularly important for waterfowl since it is the last stretch of water in the central part of the delta to go dry. The delta is an important site for migratory birds (including threatened cranes) and warthogs, and supports the largest surviving population of West African manatees. The area is a wintering ground of great importance for a large variety of Palearctic migrants, as well as birds which migrate inside Africa. The delta contains a large proportion of the world's wintering population of garganey (500,000) and pintail ducks (200,000).

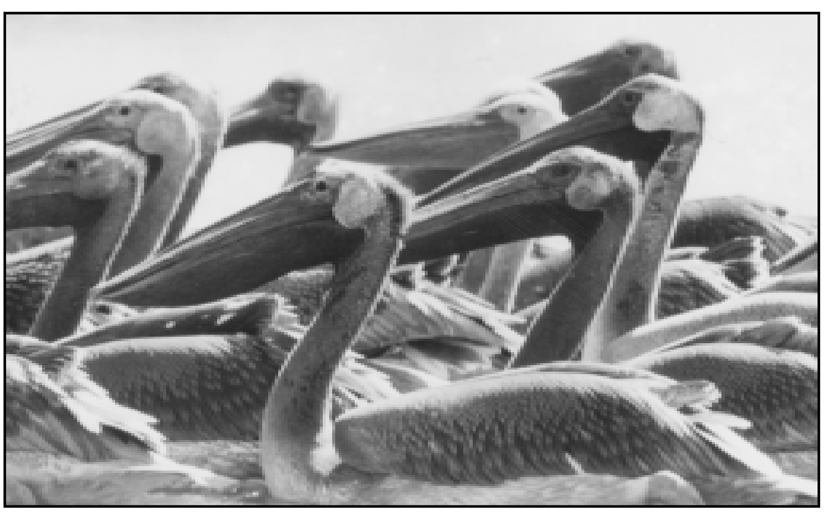

Figure 21. The Djoudj National Park in Senegal supports over three million waterfowl, including pelicans. Source: World Bank, 1993. Photo credit: Curt Carnemark.

Much of Lake Chad is surrounded by swamp. Half of the lake is in Chad, the other half is in three other countries. The lake is an important site for migratory birds (including threatened cranes), antelope and fishes. Due to drought and desertification, however, the lake has shrunk from its former 28,000 sq.km. to 10,000 sq.km. Another important wetland site in Chad is Lake Fitri (50,000 ha), which has been declared both a Biosphere Reserve Site and a Ramsar site.

The Djoudj National Park supports over three million waterfowl (Figure 21). The proposed Diawling Park, within the Senegal River Delta complex, is adjacent to Djoudj. The Senegal River Delta contains diverse habitats, including large floodplains, saline and intertidal flats, dikes and sand dunes. The area is heavily populated, with more than one million people.

Figure 22. East African wetlands are remarkably diverse. Unfortunately, very few are protected. Photo credit: Caroly Shumway.

Other West African sites of importance include the diverse wetlands in Gambia and Nigeria's Hadejia-Nguru wetlands which is an important site for Palearctic migrants and other birds. In 1995, this site supported 259,000 water-related bird species (Polet and Thompson, 1996). Togo's Parc National de la Keran and its Reserve de Faune de Togodo, though small, are important sites for migratory birds as well (Frazier, 1996).

While East Africa's wetlands are smaller in size than wetlands in the other regions, they are important for their habitat diversity (Harper and Mavuti, 1996). Very few wetlands in East Africa are protected (Figure 22). The diverse areas include Uganda's many wetlands, including the lowland valley swamps around Lakes Kyoga, Victoria and George, and the Nile Valley; Kenya's extensive inland wetlands, covering over 12,000 sq.km., including the Lorian swamp and Amboseli (Harper and Mavuti, 1996); Rwanda's two great swamps, the Mugesera-Rugwero and the Akagera; the Ethiopian highlands (Harper and Mavuti, 1996), and Mozambique's wetlands consisting of riverine floodplains, large stands of mangroves, papyrus swamps, numerous coastal lakes of varying degrees of salinity and seasonal pans.

In Central Africa, the most important swamp is Sudan's **Sudd Swamp**. This swamp is the largest swamp in the world (over 150,000 km^2 or 1,650,000 ha), and is an important area for wildlife and people. The swamp supports some of the greatest concentrations of wildlife in Africa, with the richest bird life of any African wetlands. It is an important site for threatened cranes. The Sudd Swamp also supports about 400,000 pastoralists of the Dinka, Nuer and Shilluk tribes. Another important Central African wetland of tremendous biological importance is Zambia's **Bangweulu Swamps.** The Bangweulu wetlands at the head of the Luapula river are among the biggest in the world. This is an important site for large mammals and birds and is the main breeding site for the threatened wattled crane. Lake Bangweulu is a shallow lake; its depth does not exceed five meters. Zambia's **Kafue Flats** are not only important for threatened cranes, but are also the country's most valuable agricultural site (Scudder, 1991). Dependent on annual flooding, these highly productive wetlands and their wildlife provide numerous benefits to local people -- supporting an important fisheries, irrigation, water supply, agriculture, communal grazing, tourism and hunting activities. There are also extensive swamps in the central **Zaire Basin** (Harper and Mavuti, 1996), particularly at the confluence of the Zaire and Oubangui rivers.

In Southern Africa, the most important wetland is the vast **Okavango Delta**, covering 15,000 km^2. This is one of the most important wetland sites in Africa for wildlife and people. Seventy to eighty species of fish are found in the delta and nearby Lake Ngami. The delta supports important fisheries (with 280 fishermen dependent on the resource), and is an important tourist attraction. The delta supports many large mammals and birds whose continued existence depends upon the maintenance of the ecosystem. The delta and Chobe National Park are the main breeding sites for the rare slaty egret and the wattled crane. The delta has had little human interference due to the tsetse fly (Beadle, 1984). The delta drains into the northwest corner of the Kalahari Desert, one of Africa's largest deserts.

Additional southern African freshwater wetlands of importance include several wetlands in Namibia. Wetlands are the rarest ecosystem type in this arid country, making up just 4% of the area (Hines and Kolberg, 1996). The country's wetlands include: the perennial rivers of the northern and southern borders and the Caprivi Region; the ephemeral rivers of the Namib and Kalahari desert; the Cuvelai drainage system of Omusati, Oshana and Etosha; the ephemeral wetlands of the eastern Otjozondjupa Region, Grootfontein and the Omuramba Owambo system; and the ephemeral pans of the southern Kalahari (Hines and Kolberg, 1996). The Caprivi wetlands are the country's largest permanently wet areas covering over 5,000 km^2. The area supports Namibia's greatest diversity of birds (430 species, including 2 of Africa's most endangered birds, the wattled crane and the slaty egret) and amphibians (26 species). The seasonally flooded Okavango River wetlands are important because of the rich diversity of wildlife and the fact that the Okavango River provides the main source of water for the Okavango Delta. The Etosha pan (along with Lake Oponono and the Cuvelai delta) is an important breeding site in wet years for up to one million lesser flamingoes. This area supports 340 bird species, including the endangered wattled crane, 114 mammals, including populations of some rare and endangered large mammals (black rhino, among others), 47 fish species, 16 amphibian species and 45% of Namibia's population (Hines and Kolberg, 1996). Namibia's Orange River Delta is the sixth richest southern African wetland for waterfowl. As the Orange River is the only perennial river in the area, the delta supports some unusual plants (Frazier, 1996). Finally, Lake Liambezi, the Linyanti swamp, and the eastern floodplain of the Zambezi in the easternmost part of the country in Caprivi are also important for birds, supporting at least 73 Red List species, and large populations of mammals (Hines and Kolberg, 1996). The Mamili National Park (Namibia's largest conserved wetland area) protects the Linyanti swamp, which has a great diversity of wetland habitat, including reed swamps, open-water habitats, ephemeral wetlands and seasonal floodplains (Tagg, 1996). The Park has Namibia's largest population of buffalo, as well as elephant, hippo, lion, crocodile, lechwe, impala and Cape hunting dog. Botswana's Lake Ngami is an important site for waterbirds. This lake is one of the few breeding sites for pelicans, a seasonal feeding ground for flamingoes, and an important wintering site for Paleoarctic migrants. Zambezi's wetlands are also globally important (Acreman and Hollis, 1996).

The most important island wetlands are Madagascar's wetlands, which harbor some of the country's most threatened species. Both people and two of the most endangered birds in Madagascar, the pochard and grebe depend on the Lac Alaotra swamp. The floodplain lakes Lac Kinkony and Lac Ihotry are important sites for water birds.

B. Marine/Coastal Habitats

1. Geographic overview

West Africa: Large marine ecosystems, or LMEs, are areas defined by their unique hydrography, community food webs, bathymetry and productivity (Sherman and Alexander, 1986). The west coast is divided into three LMEs: the Canary Current, the Benguela Current, and the Guinea Current (Okemwa, 1995). (See Map section.) Both the Canary and Benguela Currents move cool water towards the equator and generate permanent areas of upwelling off the southern coast of Mauritania, Senegal, the Democratic Republic of the Congo, Angola and Namibia (Wells and Bleakley, 1995). The Benguela Current also causes strong upwelling along the southern coast in winter (August), with weaker upwelling in summer (November to February). These areas are highly productive fishing grounds, particularly along the coast of southern Angola and Namibia. The cool waters from these two currents preclude formation of any true coral reefs or extensive seagrasses along the west coast.

The Guinea Current links the countries in the Gulf. The five large rivers and plentiful rain of central West Africa generate considerable freshwater runoff and large areas of warm, saline water in the Gulf. This freshwater input supports the most extensive mangroves in Africa, as well as tidal swamps, lagoons, estuaries and mudflats. Upwelling occurs along the northwest part of the Gulf in the summer. The area supports important commercial stocks of pelagic and demersal fishes, particularly in northwest Africa. Offshore fisheries yield over 2.4 million metric tons/year valued at $3.7 billion dollars. Gambia, Senegal, Ghana and Nigeria have some of the richest coastal fisheries in West Africa. The soft, muddy sediments along much of the west coast provide rich habitat for soft-bottomed species such as shrimp, molluscs (World Bank, 1996).

The World Bank (1996) lists the most important coastal threats in West Africa as: coastal pollution, erosion, overexploitation and degradation of marine resources, and deteriorating urban water quality and sanitation.

East Africa: East Africa's only LME, the Somalia Current LME, has an annually-reversing monsoon cycle. From November to March, the northeast monsoon generates a fast, southward flowing current, resulting in nutrient-rich upwelling in Somalia and northern Kenya. The monsoon also transports larvae from the Somali coast and Arabian Sea to Somalian and northern Kenyan reefs. In the southeast monsoon, these reefs receive larvae from

Figure 23. Schooling fish. Photo credit: Les Kaufman.

the south (World Bank, 1996). Upwelling can also occur off parts of Somalia from April to October. The cooler waters inhibit coral growth along much of Somalia's northern coast. Similarly, northern Kenyan reefs are primarily rocky/algal reefs, with low coral cover and diversity lower than the south (World Bank, 1996). According to McClanahan (1996), the reefs in northern Kenya and Somalia are ecologically and oceanographically distinct from those in southern Kenya and Tanzania, with Malindi being the boundary. The latter reefs have high coral diversity and good coral cover. Patch reefs are found on the west coast of Tanzania's Zanzibar, Pemba and Mafia islands, with well-developed fringing reefs on the eastern sides. These reefs may be sources of larvae to other reefs along mainland coast (McClanahan, 1996). Patch and fringing reefs are also found in the Seychelles, Mauritius, Rodriguez and the Comoros Islands.

Figure 24. Namibia's coastal waters support abundant concentrations of pelagic fish, seals, dolphins, and seabirds. Photo credit: Dennis Zemba.

The Mozambique and Madagascar Currents are thought to be involved in the movement of larvae to Mozambique coasts from the mangrove and prawn-rich coast of Madagascar (Gaudian et al., 1994). In contrast to West Africa, the east coast is drained by only a few large rivers. Both Kenya and Mozambique support important coastal fisheries, with the Tana, Sabaki and Zambezi river discharge areas being highly productive fisheries grounds (McClanahan, 1996). The most productive fisheries areas near the Zambezi River are the Sofala, Maputo and Beira Bays in Mozambique (McClanahan, 1996). The Cargados Carajos Shoals in Mauritius are an important, highly productive area for commercial and artisanal fisheries (Gaudian et al., 1994). Coasts in Djibouti and Eritrea along the Red Sea and the Gulf of Aden have been poorly studied. However, the area is important because it is part of an ecotone between the Red and Arabian Sea. Eritrea's government has made protection of marine and coastal biodiversity a high priority (Figure 23).

The World Bank (1996) lists the most important marine threats in East Africa as destructive fishing practices, eutrophication and siltation, and marine oil pollution from tanker traffic and ballast discharge. McClanahan and Obura (1995) consider the greatest threat to be overfishing. Seventy-five percent of fish caught in Kenya are immature (Obura et al., 1995). While the region has 40 marine protected areas and 23 coastal protected areas, many of these are just paper parks. According to Gaudian et. al (1994), only a few protected areas in Kenya are effectively managed.

<u>Southern Africa</u>: Southern African waters make up the Agulhas Current LME. A number of studies have shown

that this current is responsible for the southward larval dispersal of a variety of fish species along the east coast of South Africa (Hutchins, 1991; van de Elst, 1976; 1981; Heydorn et al., 1978; Garratt, 1988). The southernmost part of South Africa is of extreme biogeographic interest because of the confluence and interaction of three major ocean systems: the Indian, Atlantic, and Southern Oceans (Gawler and Agardy, 1994). Both South Africa and Angola support important coastal fisheries, while rich pelagic fishing grounds are found off Namibia, Angola and South Africa (World Bank, 1996). According to Toole (1996), "Namibia's coastal waters support some of the greatest concentrations of marine life found anywhere in the world," with abundant pelagic fish, seals, dolphins, and seabirds (Figure 24). Like East Africa, the area has few large rivers. As a consequence, the area has few estuaries and brackish wetlands.

2. Marine species

Marine species of special interest are those that are endemic, have global or regional significance, or are threatened or endangered.

Endemics: Four different groups of endemic marine fish faunas, the mangrove faunas and the tropical reef faunas, are found in the Indopacific off of East Africa. Madagascar, and the islands to its north and east, have high reef fish diversity, with the highest number of endemic species of damselfish, butterflyfish, and angelfish (McAllister et al., 1994; McClanahan and Obura, 1996). Many endemic species dwell near the islands of Mauritius, Reunion, and Rodrigues (Briggs, 1974). Fairly high levels of endemism in fishes also occur around the Ascension and St. Helena Islands (Gawler and Agardy, 1994). Endemic molluscs inhabit the Indian Ocean islands, including Mauritius (Gawler and Agardy, 1994). Endemic seaweeds are found in Senegal, Angola, South Africa and the St. Helena and Ascension Islands (Wells and Bleakley, 1995).

Globally or regionally important populations: Millions of migratory birds, particularly waders, depend on the mudflats along the west African coast (Figure 25). (See coastal wetlands section and Hughes and Hughes, 1992, for further detail.) Mauritania, Gambia, and Senegal are home to globally important populations of seabirds, including slender-billed gulls, gull-billed terns, and the endemic royal tern. The Tinhosas islets, near Principe in the Gulf of Guinea, support large populations of boobies, noddies, and terns. Regionally important populations on the western coast include the great white pelican, Caspian tern, and white-breasted and reed cormorant (Cooper et al., 1984). Large bird colonies on the east African mainland reside on islands off Kisite/Mpungati, Kenya; Kiunga, Kenya (which has the largest population of the roseate tern, *Sterna dougalli*); and Lathan Island, Tanzania. In southern Africa, important breeding seabird populations are found at Shark Island, Namibia; Bird Island, Labert's Bay, and Marcus Island, South Africa. Ascension Island is the most diverse and abundant seabird nesting site in the South Atlantic region, with large populations of boobies, frigatebirds and sooty terns (Wells and Bleakley, 1994; Gawler and Agardy, 1994). Unfortunately, the population of boobies have declined throughout the western Indian Ocean. Several other islands and islets support large seabird colonies, including numerous islands in the Seychelles, St. Brandon, Round, Serpent and Coin de Mire islands off Mauritius, Tromelin and Ile du Lys in Reunion, Ile Magnougni in the Nioumachoua islands and Ile M'chaco in the Comoros, and Nosy Mangage in Madagascar (Gawler and Agardy, 1994).

Threatened and endangered species: The disappearance of habitat imperils many African marine species, including sea turtles and crocodiles, the Mediterranean monk seal, the dugong, West African manatee, pygmy hippo, and some seabirds (Gawler and Agardy, 1994). The decline in their range and available habitat is of real concern (Figure 26). West African waters are home to cetaceans, manatees and sea turtles. A globally important population of the endangered Mediterranean monk seal inhabits the Madeiran Archipelago, up to northern Mauritania. A recent epidemic wiped out nearly 60% of the population in two months, leaving just 90 individuals remaining (Species, 1997). The monk seal's breeding colony, located on the west coast of the Cap Blanc Peninsula, is protected by a satellite reserve linked to Banc d'Arguin. A few non-breeding individuals live in the Banc d'Arguin itself. Threatened species in East Africa include sea turtles (five species), the Indo-Pacific hump-backed

Figure 25. The mudflats along the West African coast are critically important for millions of migratory birds, particularly waders. Photo credit: Les Kaufman.

Figure 26. Threatened African marine species include marine turtles, crocodiles, seals and dugongs. This is the green sea turtle, Chelonia. *New England Aquarium, 1988. Photo credit: Paul Erickson.*

dolphin found in mangroves and delta habitats (Senegal, Somalia, Mozambique) and other cetaceans (at least fifteen species, but their distribution is not well known), the coelocanth, the dugong, and threatened shore and sea birds, including the Mascarene petrel, the Madagascar fish eagle, and the Mauritius kestrel (Gawler and Agardy, 1994). South Africa has the highest number of threatened marine and coastal species, including Heaviside's dolphin, the dusky dolphin, the jackass penguin, three species of marine turtles, eight species of threatened fishes, two species of threatened clam, and two species of tern (Gawler and Agardy, 1994).

Threatened sea turtles live off West, East, and Southern Africa. Marine scientists at the IOMAC International Workshop in Marine Scientific Cooperation in the Indian Ocean recommended regional cooperation in sea turtle conservation, particularly in mapping nesting sites and feeding grounds (Obura et al., 1995). The primary nesting sites for green and hawksbill turtles are on islands, with Ascension Island being globally important for both species, and Europa, Tromelin and Aldabra for green turtles alone (Gawler and Agardy, 1994). The largest population of hawksbills occur on the granitic islands and in the Amirantes, Seychelles. Green turtles are also found in the Primeiros and Segundos Islands, Mozambique. Other important sites for sea turtles are found in Madagascar, Equatorial Guinea's Bioko Island, and Mozambique's Bazaruto Archipelago, which supports four species. Most turtle species are also found in Kenya and Tanzania, although the numbers are smaller. Important sites for both sea turtles and seabirds include: Mauritius' St. Brandon Island, the Seychelles, Senegal, South Africa, Sudan's Suakin Archipelago, and Ethiopia's Dahlak Islands.

Figure 27. Mangroves are primarily found on protected shores where the wave action is broken. Photo credit: Caroly Shumway.

Threatened seabirds in East Africa include: the Mascarene petrel, the Madagascar fish eagle, and the Mauritius kestrel, among others; in South Africa, the jackass penguin and two species of tern (Gawler and Agardy, 1994). Namibia's coast is an important site for seabirds.

Important sites for marine mammals include: West African lagoons [manatees and the endemic dolphin *Sousa teuzsii* (Binet et al., 1995)], Mozambique's Bazaruto Archipelago (the most important remaining habitat for dugongs), Madagascar (dugongs), Ethiopia's Dahlak Islands (dugongs), Namibia's Cape Cross (seals, Heaviside's dolphin) and South Africa (seals, Heaviside's dolphin, and southern right whale). After reviewing the predicament of marine mammals in east Africa, threatened by habitat loss and incidental take (including illegal driftnet operations by Asian boats), the IOMAC recommended surveys of Mozambique, Pemba Island and the coast of Tanzania, northwest Madagascar, Somalia, Sudan and Eritrea (Obura et al., 1995).

3. Mangroves

"Mangrove" is a broad ecological term used to describe the over fifty species of trees from five families worldwide that have adapted to live in salt water (Robadue, 1995; Rutzler and Feller, 1988). These families have independently evolved the capacity to survive in salt water (Ruwa, 1996). The major element of a mangrove community is generally comprised of a pure stand of a particular mangrove species; each stand may have a unique associated fauna. Mangroves are pollinated by insects and bats (Ruwa, 1996). Mangroves prefer shores protected from wave action (Figure 27). They are most extensive on the deltas of large rivers but also occur along small bays and lagoons. Mangroves are found discontinuously from Senegal to Angola on the west coast, and from Somalia to South Africa on the east coast. Extensive stands are also found in Madagascar.

East Africa and Madagascar have more species of mangrove than the West coast, supporting from eight to eleven species depending on the author (8: Ruwa, 1996; 9: Stuart and Adams, 1990; 11: World Bank, 1996). West Africa supports six species (Stuart and Adams, 1990). West Africa, however, has much more extensive mangroves due to the extensive riverine system not present in the east. It has 4,950,000 ha versus nearly 1,200,000 ha in East Africa (Kelleher, 1993). The biggest mangrove areas are found in watersheds with the highest rainfall, between Guinea-Bissau and Sierra Leone and between Nigeria and Cameroon (FAO, 1994). Estimates of amounts also vary from report to report (e.g., Kelleher, 1993; Wells and Bleakley, 1994; Gaudian et al., 1994; Stuart and Adams, 1990; Ruwa, 1996.) The West African species are completely different from the East African ones. In addition, the West African mangroves are remarkable for supporting some Indo-Pacific lineages of fish in the Atlantic Basin, such as the mudskipper (Kaufman, pers. comm.).

Table 5. Distribution of Extensive African Mangrove Forests
Extensive mangroves (greater than 100,00 ha)

Nigeria	3,238,000
Mozambique	500,000
Madagascar	325,560
Cameroon	306,000
Gabon	250,000
Sierra Leone	250,000
Guinea-Bissau	100,000-236,000
Guinea	223,000-285,000
Senegal	169,000
Tanzania	115,500-133,540
Angola	110,000

Areal extent given in ha. (Compiled from Kelleher; 1993; Gaudian et al., 1994; Wells and Bleakley, 1995).

Eight West African countries have extensive mangrove areas, defined here as over 100,000 ha. These are, in decreasing order, as follows: **Nigeria, Cameroon, Gabon, Sierra-Leone** (with the most important being those along the Sherbro River), **Guinea-Bissau, Guinea, Senegal, and Angola** (Table 5). Very few of these areas are currently protected (Wells and Bleakley, 1995). Although Nigeria's mangroves are being rapidly exploited, the country still has 970,000 ha along coastal lagoons, and 500,000 ha along the **Niger Delta** (Figure 28). In terms of intact stands, most authors cite **Guinea-Bissau** as having important stands along its coast, estuaries, and offshore islands, particularly those in the Bijagos Archipelago, along with **Guinea's** coastal mangroves. Guinea's mangroves, like Nigeria's, are being rapidly exploited, but the country now has a mangrove management program in place (Wells and Bleakley, 1995).

Additional mangroves of importance are found in **Gambia** and **Senegal**, along the Gambia and Casamance rivers (Kelleher, 1993). They are found from the mouth of the Gambia river to 250 km upstream. Important and extensive mangrove areas occur in the Delta du Saloum National Park, along the Gambia River in the south. The delta is an important fish spawning ground and is home to many seabirds, along with 1,000 pairs of lesser and greater flamingoes and wintering waders. Manatees, humpbacked dolphins, olive ridley, green, and loggerhead turtles, and crocodiles are also found there. **Sierra Leone** also has large areas of mangroves (Wells and Bleakley, 1995).

On the east coast, countries with extensive mangrove areas include **Mozambique,** of which 79% are along the Zambezi river (Gaudian et al., 1994); **Madagascar** and **Tanzania**. (Note that different authors provide different estimates of extent. For example, Ruwa (1996) states that Madagascar has the greatest mangrove area on the East Coast, followed by, in order, Tanzania and then Mozambique.) Kenya has

Figure 28. Although Nigeria's mangroves are being rapidly exploited, the country still has 970,000 ha along coastal lagoons, and 500,000 ha along the Niger Delta. World Bank, 1993. Photo credit: Curt Carnemark.

65,000 ha, particularly in the Lamu, Kwale and Kilifi districts (Gaudian et al., 1994). All of the eastern species are found at all locations (Ruwa, 1996). The most extensive and important mangrove forests on the east coast are found in Tanzania, particularly the **Rufiji Delta** (3,200 ha, Gaudian et al., 1994), and along **Madagascar's** west coast. The pristine stands of Tanzania's Rufiji Delta are the most extensive stands of the Indian Ocean. In addition to mangroves, the delta contains a number of diverse wetland habitats, including freshwater riverine wetlands, riverine forests, swamps, and floodplains. Tanzania's Zanzibar Island has 4,700 ha (Gaudian et al., 1994.) In Madagascar, important areas include Baie de Bombetoka and Baie de la Mahajamba (Gaudian et al., 1994). Currently, only one small area is protected.

4. Coastal wetlands and associated habitats

Coastal lagoons and swamps, rich in wildlife, are found at the edge of deltas of some of the major rivers and where sand bars and mud banks form a sea barrier. They occur along the west coast from Senegal to Angola and on the east coast from Mozambique to South Africa. The most extensive coastal lagoons are in Mozambique, Madagascar, between Cote d'Ivoire and eastern Nigeria, and Gabon (Binet et al., 1995). Several are of particular interest.

Mudflats are ecologically important for converting primary production from adjacent mangrove and/or seagrass beds into secondary production, supporting important fish stocks such as emperors, rabbitfish, and goatfish (Gawler and Agardy, 1994). Mud and sand flats provide habitat for bivalves, and are important feeding grounds for shrimp, crabs, overwintering waders, and shorebirds. The biologically most important coastal wetland in West Africa is Mauritania's vast **Banc d'Arguin** (12,000 km^2). The park includes shallow mudflats, seagrass beds, and the northernmost mangroves of the African Atlantic coast. This ecotone is an important and unusual transition area between salt marsh temperate communities and tropical mangroves (FIBA, 1996). The area is critically important for the world's largest population of the endangered Mediterranean monk seal (100 out of 500 worldwide), for waterfowl and for its importance to the country's productive fisheries. Banc d'Arguin supports the largest concentration of wintering wading birds in the world (over two million, largely from Europe and Asia) and one of the most diverse communities of nesting waterbirds in Africa. Between 25,000-40,000 pairs of birds of 15 different species nest here. The area is highly productive due to upwelling. The mudflats are an essential spawning ground and nursery for pelagic and demersal fish and crustacean stocks, which are important in the fisheries economy of the entire West African coast (FIBA, 1996) and the most important economic resources for Mauritania, providing an estimated $34 million/year. Several species of sea turtles, dolphins (including the rare Guinean dolphin) call the region home.

Guinea-Bissau's coast supports an estimated 960,000 Palaearctic waders, 12% of the eight million Palaearctic birds that migrate to the West African coast. The country's **Bijagos Archipelago** features large stands of mangroves and inter-tidal mudflats and is the second most important West African habitat for migratory birds after Banc d'Arguin. The Archipelago also contains marine hippos and five species of sea turtles.

Additional coastal wetlands of importance include:

- Ghana's coastal wetlands - important for water birds and as a resource for the local people. The coastal wetlands provide the most important wintering ground in Africa for the threatened roseate tern. Six of Ghana's coastal wetlands are of international importance -- Esiama Beach, Muni Lagoon, Densu Delta and Salt Pans, Sakumo Lagoon, Songaw and Ketaw Lagoons.
- Gabon and Guinea's coastal wetlands, for waterbirds and Palearctic migrants. Guinea's Ile Blanch has coral communities, rare species of fish and sea turtles (Frazier, 1996).
- Namibia's Namib sheltered coastal wetlands, lagoons, and estuaries, particularly Walvis Bay Lagoon and Sandwich Harbour, whose abundant snails and worms provide food for hundreds of thousands of wading and migratory birds (Frazier, 1996). The area supports the rare Damara tern.
- Kenya's Tana River Delta, important for local and migratory birds, as well as for Kenya's fisheries (Gaudian et al., 1994). The area is threatened by the Tana Delta irrigation project, along with proposed rice and shrimp cultivation schemes (Raal and Barwell, 1995).
- Mozambique's Zambezi River Delta, important for waders and migratory birds (Gawler and Agardy, 1994).

Seagrasses are flowering plants that have adapted to salt water (Ruwa, 1996). Seagrass provides habitat to post-larval and juvenile fish and numerous invertebrates. Seagrass detritus supports a rich detrital food web. The west coast has few extensive seagrass beds. On the east coast, seagrass beds are found in all countries, with those in the Bazaruto Archipelago, Mozambique reportedly being the most extensive (Gaudian et al., 1994). Seagrass beds are threatened by fishing with explosives, and the use of bottom traps and beach seines (UNEP, 1989, cited in Gawler and Agardy, 1994).

Figure 29. Kenyan coral reef. Photo credit: Dennis Zemba.

5. Coral reefs

True coral reefs are found only on the east coast of Africa, Madagascar, Comoros and Seychelles (Figure 29). Fringing and patch reefs occur along the east coast from Sudan to Mozambique. Destruction has been rampant. Not many reefs are still in excellent condition, except for a few in Kenya, Tanzania and Mozambique (Samoilys, 1988b). The entire East African coastline is thought to be an inter-related ecosystem (Samoilys, 1988b), making it incumbent upon all of the governments to work together to stop their destruction (Figure 30). The destruction of coral reefs in Tanzania is severe and widespread. Massive dynamiting has forced Tanzanian fishermen north onto Kenyan fishing grounds.

Important sites include:

- Madagascar's southwest coast - Madagascar has high coral diversity, with over 60 coral genera (Gaudian et al., 1994). (It is possible that this high diversity simply reflects increased taxonomic effort at this site. McClanahan (pers. comm.) has recent data suggesting strong similarity in coral diversity among Kenya, Tanzania and Madagascar's reefs.) Madagascar's southwest barrier reefs are the most extensive in the Indian Ocean and among the largest in the world (200 km). Extensive fringing reefs are also found on the north coast (Gaudian et al., 1994). As previously noted, the area has high fish diversity, with the highest number of endemic damselfish, butterfly, and angelfish species in Africa (McClanahan and Obura, 1996).
- Kenya - The southern area, from Msambweni to Malindi, is the world's largest continuous fringing reef (McClanahan and Obura, 1996). The greatest fish diversity is found in the Shimoni region (Samoilys 1988a,b).
  - The Lamu region includes estuaries, bays, seagrass, in addition to coral reefs, and supports a threatened population of dugongs.
  - The Kiunga region includes coral reefs, mudflats, seagrass beds, littoral communities and extensive mangroves. This site supports a large number of dolphins, along with sea turtles and dugongs (WWF home page, 1997).
- Tanzania - The area from Mafia to Pemba Island has the highest species diversity of the entire Indian Ocean, as measured by coral genera and fish species (Agardy, pers. comm.)
  - Mafia Island - This area, recognized by IUCN as a

Figure 30. True coral reefs are found on the east coast of Africa from Mozambique to the Red Sea, Madagascar, and the islands of the western Indian Ocean. This is a Red Sea underwater scene. New England Aquarium, 1989. Photo credit: Paul Erickson.

biologically important site, is one of the least disturbed of the East African reefs.
- Zanzibar and Pemba Islands (Gaudian et al., 1994)

- Sudan - along the coast as well as islands. Suakin Archipelago has extensive coral reefs, as well as being an important site for marine turtles.
- Mozambique - The Bazaruto Archipelago, isolated reefs between Inhambane and Bazaruto, the Primeiras Segundo Archipelago, the coast between Angoche and Pemba, and the Quirimbas Archipelago (Gaudian et al., 1994).

Other sites include:

- Somalia - Somalia's coastal areas used to be the most pristine on the continent, but their current status is unknown. The country's coastal resources include coral reefs, seabird colonies, seagrass beds, turtle nesting beaches and possibly a sizeable population of dugongs.
- Djibouti
- Comoros (particularly Chissioua Quenefou, which has rich reefs and six major sea turtle nesting sites; and the south Cost of Mohéli, including the Nioumachoua Islets)
- Seychelles
- Eritrea

Although the West Coast has no true reefs, it has coral communities along the offshore islands and some of the rocky mainland coasts. These are comprised of either stony corals or ahermatypic (non-stony) corals which do not build reefs (Gawler and Agardy, 1994). Two hundred thirty-nine species of reef fish are present on the west coast, of which 70% are endemic, an extraordinary level of endemism for a geographically limited marine fish fauna (Nunan, 1992, cited in Wells and Bleakley, 1995). Eighteen coral species are known, half of which are endemic, in the Gulf of Guinea and Cape Verde Islands (Gawler and Agardy, 1994). Communities containing some rare and endemic species, but low species diversity, are found near the Cape Verde Islands, islands in the Gulf of Guinea, at certain sites off the coast of Ghana, Gabon, Cameroon, and along the northern coast of South Africa (Wells and Bleakley, 1995). Wells and Bleakley recommend identifying priority sites between Cameroon and Gabon.

C. Summary Maps

The maps immediately following provide a summary of the biologically and socioeconomically most important freshwater and marine ecosystems.


Freshwater Bioregions and Ecoregions of Africa
Freshwater Bioregions
Freshwater Ecoregions
WWF

MAJOR WETLANDS

MAJOR RIVERS AND STREAMS

MAJOR LAKES

MAJOR FLOODPLAINS

Modified from Adams, 1996. In: Acreman and Hollis, 1996. © IUCN.

MAJOR CURRENTS

MAJOR CORAL REEFS

MAJOR MANGROVES

D. Internationally Recognized Protected Areas

The first two tables list sites recognized under various international agreements (IUCN, 1990a; updated, Frazier, 1996); the third table lists African marine and coastal areas considered to be national or regional priorities for protection (Gaudian et al., 1995; Wells and Bleakley, 1995); and the last table provides a useful detailed description of Africa's important lakes, inland wetlands and mangroves (IUCN, 1986).

The Global List of Wetlands of International Importance

Country	Wetland of International Importance
Burkina Faso	Mare Aux Hippoppotames, Mare d'Oursi, Parc national du "W"
Chad	Réserve de la Biosphère du lac Fitri
Comoros	Lake Dziani
Gabon	Petit Loango, Setté Cama, Wongha-Wonghé
Ghana	Owabi
Guinea	Ile Blanche, Owabi
Guinea-Bissau	Lagoa de Cufada
Kenya	Lake Nakuru, Lake Naivasha
Mali	Lac Horo, Séri, Walado Debo/Lac Debo
Mauritania	Banc d'Arguin, Parc National du Diawling
Namibia	Walvis Bay mudflat, Sandwich Harbour, Orange River Mouth, Etosha Pan, Lake Opnono, and Cuvelei Drainage
Niger	Parc national du "W"
Senegal	Bassin du Ndia l, Delta du Saloum, Djoudj, Gueumbeul
South Africa	Barberspan, Blesbokspruit,De Hoop Vlei, De Mond/Heuningnes estuary, Kosi Bay estuary, Lake Sibaya, Langebaan, Natal Drakensberg Park, Orange River Mouth, Seekoeivlei, St. Lucia System, turtle beaches/coral reefs of Tongaland, Usutu/Pongolo floodplain, Verlorenviei, Wilderness Lakes
Togo	Parc National de la Keran, Reserve de Faune de Togodo
Uganda	Lake George
Zambia	Bangweulu Swamps

IUCN, 1990a; updated: Frazier, 1996; also see Davies and Day, 1998

Biosphere Reserves

Country	Wetland
Burkina Faso	Forêt classée de la mare aux hippotames
Kenya	Amboseli, Kiunga Marine Nat. Reserve and Biosphere Res., Malindi/Watamu Marine Nat. Reserves and Biosphere Reserve
Madagascar	Reserve de la Mananara Nord
Senegal	Delta du Saloum
Tanzania	Lake Manyara National Park
Uganda	Queen Elizabeth National Park

IUCN, 1990a; updated: Frazier, 1996; also see Davies and Day, 1998

The following table lists African marine and coastal areas considered to be national priorities for protection. Areas considered to be of highest regional priority are highlighted in bold (Gaudian et al., 1994; Wells and Bleakley, 1995). Note that for East Africa, Gaudian et al. consulted with regional experts, with the caveat that conservation in Somalia was not considered due to political instability. For West African sites (including Southern Africa marine regions), Wells and Bleakley based regional priorities on a literature review.

Region	Country	Existing protected areas needing management support	Proposed new marine protected areas
EAST AFRICA	Comoros	None	**South Coast of Mohéli, including the Nioumachou Islets** Grand Comore Chirononi, south Anjouan
	Kenya	**Kiunga Marine Natl. Res. and Biosphere Res.** Diani/Chale Marine Natl. Res.	Tana River Delta Ras Tenewi
	Madagascar	Nosy Atafana Marine Park	Lokobe Strict Nature Res. **Grand Recif and coastal zone, Toliara** Baie de Bombetoka Baie de la Mahajamba
	Mauritius	None	**Cargados Carajos Shoals** Le Chaland Blue Bay Marine Park Balaclava Marine Park, Turtle Bay
	Mozambique	**Parqe Nacional de Bazaruto** Inhaca Island (Ilhas de Inhaca e dos Portugeuses Faunal Res.)	The Primeras and Segundos Islands Nacala-Mossuril Bartolemu Dias
	Ile de la Réunion	Ile de Europa	
	Seychelles	Curieuse National Park Baie Ternay Port Launay St. Anne	
	Somalia	None	Bajunie Archipelago Maydh Island
	Tanzania	**Mafia Island/Rufiji Delta** Tanga area	Kilwa Kisiwani Mbegani Ras Buyeni Lindi Mtwara/Ruvuma Latham Island Pemba Islands Unguja

(continued on next page)

WEST AFRICA	Angola	No information available	Bengo River Delta Chicamba Mangroves Zaire River Delta
	Benin	Are no MPAs	Reserve de la Biosphere du Djessin Wetlands of the coastal plains Lake Nokoue and Porto Novo
	Cameroon	Douala-Edea Faunal Reserve	Bakossi Peninsula Mangroves Rio del Ray
	Congo	Are no MPAs	Kouilou Estuary Mangroves
	Côte d'Ivoire	Are no MPAs	Azagny Nat. Park **Aby Lagoon** Azuretti Mangroves Cape Palmas
	Dem. Rep. of the Congo		Parc National Marine None
	Equ. Guinea	Are no MPAs	South coast of Isla de Bioko
	Gabon	Sette-Cama Hunting Area	Akanda Mangroves Elobey Islands Mondah Reserve Ozouri
	The Gambia	**Niumi-Sine Saloum Nat. Park**	
	Ghana	Are no MPAs	Anlo-Keta Lagoon Complex Densu Delta Muni Lagoon Sakumu Lagoon Songor Lagoon
	Guinea	Are no MPAs	Ile Alcatraz Blanche Island Iles Tristao Konkoure Estuary Rio Kapatchez Rio Pongo
	Guinea-Bissau	Bijagos Archipelago Hunting Res.	**Bijagos Archipelago Biosphere Res.** Rio Cacheu
	Liberia	Are no MPAs	Cape Mount Cestos-Senkwen
	Mauritania	**Banc d'Arguin Nat. Park** Diawling National Park	Aftout es Saheli
	Namibia	Are no MPAs	Sandwich Harbour Walvis Bay wetland Swakopmund Saltworks Orange River Mouth Cape Cross Lagoons

(continued on next page)

Nigeria	Are no MPAs	Wetlands, including 3 sites: **1) Lagos and Lekki lagoons** **2) Cross River wetlands/delta** **3) Niger delta, esp. Taylor's Creek, Stubb's Creek**
Senegal	**Delta du Saloum Nat. Park** Langue de Barbarie Nat. Park Gueumbeul Special Res. Iles de la Madeleine Basse-Casamance Nat. Park	
Sierra Leone	Are no MPAs	**Bunce River** Yawri Bay-Shesnge/Kagboro Creek Area Turtle Islands
South Africa	None	Richtersveld Namaqualand Coast Elands Bay Coast Longebaan Coast Cape Peninsula Coast De Hoop Coast Garden Route Coast Woody Cape Coast Southeast Coast Mtamvuna Coast Maputuland Coast
Western Sahara		Cap Bojador Côte des Phoques Laadeim Coast
Togo	Are no MPAs	Lakes Togo, Vogan, and coastal lagoons
Trista de Cunha	None	
Ascension Isl.	Are no MPAs	Boatswain Bird Islet
Canary Islands		
Cape Verde Isl.	Are no MPAs	Ilheus Branco and Raso **Ilheu Rombos** **Ilheu Sal** **Sal Rei, Boavista Isl.** **Sao Vincente Isl.**

Table 6, from IUCN (1986), although old, provides useful detail on Africa's important lakes, inland wetlands, and mangroves. The table, which includes globally as well as nationally important sites, lists the importance of the sites for particular species, threats and recommended actions. Priority A is given to areas considered of global importance because they either have major wildlife resources, are unique examples of an ecosystem or are the best protected area example. Priority B is given to areas which are representative samples of their biotic types, while priority C is given to areas that are of regional or national interest.

Site	Country	Flora	Game	Waterbirds breed	Waterbirds feed	Fish	Croc/Turtle	Sirenians	Total	Cut/Drain	Pollution	Introduction	Over-fishing	Development	Protection status	International significance	Priority action	Comment
SODA LAKES																		
Natron	TZ			2	2				4	?	?			•	nil	•	A	establish Protected Area
Nakuru	KY	1	2	1	2	1			7		•	•			NP2	•	B	check pollution
Magadi	KY			1	2				3	•				•	nil		B	too late
Amboseli	KY	1	2	1	1				4	?					NP2		B	
Manyara	TZ	1	2	1	2	1	1		8		?		•	?	NP2	•	B	
Ezasi	TZ		1	1	1				3						nil		B	
Elementaita	KY				2				2					•	nil		B	
Chew Bahir	ET	1	2	1	1				5	•					nil		A	include in P.A.
Sagata	TZ	1	1	1	1		1		5				•	•	nil		B	
Bogoria	KY		1	1	2	1	1		6				•		NP2		B	protect water
Baringo	KY		1	1	1	1	1		5	•	•	•	•	•	nil		B	create P.A.
Rukwa	TZ	1	1	2	2	1	1		8			?	•	•	nil		B	
Balangida	TZ			1	1	?	?		2			?	?	?	nil		C	low priority
Zwai	ET		1		1				2		?		?		nil		C	
Langano	ET		1		1				2		?		?		nil		C	
Abiata	ET		2	2	1	1			6				•	•	nil		B	include in N.P.
Shala	ET		2	2	1	1			6				•	•	nil		B	include in N.P.
Awasa	ET				1	1	1		3				?	?	nil		C	
Abaya	ET				1	1	1		3				?	?	nil		C	get part in N.P.
Chamo	ET				1	1	1		3				?	?	nil		C	get part in N.P.
SALT PANS																		
Nxai Pan	BT	1	1		1				3						NP2		B	
Kapura	ZM	1	1		1				3						6		B	
Uwanda	TZ	1	1		1				3						4		B	
Makgadikgadi	BT	1	1		1				3						4		B	
Moremi	BT	1	2	1	2		1		7				•	•	4	•	A	maintain
Malora	MW	1	2		1				[illegible]						8		B	
Etosha	NM	1	2	1	2				6						NP2	•	A	maintain
Mweru Wantipa	ZM	1	1		1		2		5				•	•	4		B	
INLAND FRESHWATER SWAMPS AND FLOODPLAINS																		
Malagarasi	TZ	2	2	1	1	1	1		8	•				•	nil	•	B	needs P.A.
Bangweulu	ZM	1	2	1	1	1	1		7	•				•	pt6	•	B	improve management
Kafue Flats	ZM	1	2	1	1	1	1		7	•				•	pt6	•	B	maintain
Liuwa Plain	ZM	1	2	1	1	1	1		7	•				•	pt2	•	B	maintain
Okavanga	BT	1	2	1	2	1	2		9	•	•	•	•	•	pt2	•	A	limit spraying
Ouebi Scebeli	SM	1	1		2	1			5					•	pt4		B	establish P.A.
L. Abbe swamp	ET	1	1	1	1				4					?	nil		B	join Mille Sardo
L. Assale	ET	1	1		1				3					?	nil		B	needs survey
In. Niger Delta	ML	2	2	2	2	1	1		10	•			•	•	nil	•	A	join Elephant W.R
Oueme Delta	BN	1	1		1	1	1	?	5					•	nil	•	B	needs survey
Pungue plain	MZ	1	1	1	2				5					?	pt2		B	more protection
Lac du Bam	BF	1	1		1				3					?	nil		C	
Upper Volta	BF	1	2		1	1			5				•	•	pt2		B	
Sudd	SD	1	2	2	2	1	2		10	•				•	pt	•	A	extend Shambe G.R
Machar marshes	SD	1	1		1				3					?	nil		C	
Lotagipi swamp	SD	1	1		1				3					?	nil		C	
Lufira valley	ZR	2	1	1	1				3					•	pt4		B	
Cuvette Centrale	ZR	1	2	1	1	1	1		7				•	•	pt		B	establish P.A.s
N. Zaire swamps	ZR	1	2	1	1	1	1		7						nil		B	establish P.A.s
Upemba Swamps	ZR	2	1	1	1	1	1		7				•		2		B	maintain N.P.
Chari plain	CM	1	2		1				4	•				•	nil		B	needs attention
L. Chad	CH –	1	2	1	2	1	1		8	•			•	•	pt4	•	B	more P.A.s needed
Mba Illi plain	CM	1	2		2				5	•				•	nil		B	needs survey

Table 6. Important aquatic sites. From Review of the Protected Areas System in the Afrotropical Realm, 1986. © World Conservation Union (IUCN) and the United Nations Environment Programme (UNEP).

Site	Country	[illegible columns]	Status		Priority	Comments
Nyong river	CM	[illegible]	prq		B	establish P.A.
Logone plain	CM	[illegible]	prj	•	B	protect hydrology
Kafue plain	ZM	[illegible]	nd		B	

FRESHWATER LAKES

Site	Country	[illegible columns]	Status		Priority	Comments
Turkana	KY	[illegible]	pt	•	B	maintain
Albert	ZR+	[illegible]	pts		B	N.P. protect lake
L. d'Alaq & Mad	MR	[illegible]	rd		B	protect lakes
L. Kita	MR	[illegible]	rd		B	rehabilitate
Naivasha	KY	[illegible]	rd		B	
Edward	ZR+	[illegible]	pts		B	extend N.P. to lake
Kivu	ZR+	[illegible]	rd		C	
Tanganyika	ZR+	[illegible]	rd	•	A	needs protection
Malawi	MW+	[illegible]	pts	•	A	no introductions
Chilwa	MW	[illegible]	rd		C	too late
Mweru	ZR+	[illegible]	pts	•	A	extend N.P. to lake
Tana	ET	[illegible]	rd		B	
Volta	GH	[illegible]	pts		B	extend Digya N.P.
Bosumtwi	GH	[illegible]	rd		C	survey
Victoria	UG+	[illegible]	rd	•	A	needs attention
Kyoga	UG	[illegible]	rd		B	
Kariba (art.)	ZW+	[illegible]	[illegible]		C	well attended
Mburo	UG	[illegible]	NPs		B	
Chad	CH+	[illegible]	rd	•	B	[illegible]
George	UG	[illegible]	rd		B	
L. Abbe	ET	[illegible]	rd		B	needs survey
Kainji	NI	[illegible]	pts		B	extend NP
Ossa	CM	[illegible]	[illegible]		B	
Oku	CM	[illegible]	prq		B	establish P.A.
Barombi Mbo	CM	[illegible]	prq		B	
Guier Diagle	SN	[illegible]	rd		B	
[illegible]	ZR	[illegible]	rd		B	survey
[illegible]	ZR	[illegible]	rd		B	survey
[illegible]	ZR	[illegible]	rd		B	survey
Lac Tumba	ZR	[illegible]	rd	•	A	establish P.A.
Mai-Ndombe	ZR	[illegible]	rd		B	survey needed
[illegible]	[illegible]	[illegible]	rd		B	survey
[illegible]	ZM	[illegible]	[illegible]		B	maintain
L. [illegible]	RM	[illegible]	[illegible]		B	
Zimbabwe lakes	ZW	[illegible]	[illegible]		B	maintain

WESTERN MANGROVES

Site	Country	[illegible columns]	Status		Priority	Comments
Saloum Delta	SN+	[illegible]	NPs	•	A	maintain
Basse Casamance	SN	[illegible]	NPs		B	maintain
Gambia estuary	GM	[illegible]	prq		B	provide reserve
Guinea coast	GU	[illegible]	rd		A	needs protection
G. Bissau coast	GB	[illegible]	rd	•	A	needs protection
[illegible] River	SL	[illegible]	rd		C	too damaged
Sherbro River	SL	[illegible]	prq	•	A	establish P.A.
Cape Mount	LB	[illegible]	[illegible]		C	improve
Greenville	LB	[illegible]	rd		C	low priority
Assini	IC	[illegible]	NPs		B	maintain
Volta Delta	GH	[illegible]	rd		B	needs P.A.
Lagos	NI	[illegible]	rd		C	needs P.A.
Niger Delta	NI	[illegible]	rd		B	needs P.A.
Cross Delta	NI	[illegible]	prq		B	proposed reserve
Douala Edea	CM	[illegible]	[illegible]	•	B	maintain
Rio [illegible]	EG	[illegible]	rd		C	political impasse

Site	Country	Flora	Game	Waterbirds breed	Waterbirds feed	Fish	Croc/Turtle	Sirenians	Total	Cut/Drain	Pollution	Introduction	Over-fishing	Development	Protection status	International significance	Priority action	Comment
Zaire estuary	ZR +	1		1		1	1		5	*			*		nil		B	needs P.A.
Azagny	IC	1	1		1		1	2	7						NP2		B	maintain
EASTERN MANGROVES																		
Gulf of Aden	SM	1			1	1			3	*			*	*	nil		B	
Tadjoura Gulf	DJ	1			1	1			3	*			*	*	nil		B	
E. Somalia	SM	1	1		1		1		4	*			*	*	pr2		B	maintain Dolori
Kenya coast	KY	2	1	2	1	1		1	8	*				*	2	*	A	maintain parks
Tanzania coast	TZ	1		1	1	1			4	*			*	*	6		B	upgrade
Rufiji Delta	TZ	2	1		1	1			5	*			*	*	nil		B	establish P.A.
Lindi	TZ	1			1	1			3	*			*	*	nil		C	
E. Mozambique	MZ	1	1		1		2		5	*			*		nil		B	
Zambezi estuary	MZ	2	1	2	1	1	1		8	*			*	*	8	*	B	upgrade reserve
Rio Buzi estuary	MZ	1		1	1	1	1		5	*			*	*	nil		B	
São Sebastião	MZ	1		1	1				3	*			*	*	pt4		C	
Inhambane Bay	MZ	1		1	1				3	*			*	*	nil		C	
Lourenzo Marques	MZ	1			1	1			3	*			*	*	4		C	improve Maputo
Natal coast	SA	1	1		1				3	*				*	nil		B	
W. Madagascar	MD	2	1	3	1	1	1		7	*	*		*	*	nil	*	A	establish Tulear P.A.
Aldabra Atoll	SY	1	1	2	1	1	1	1	7					*	2	*	B	maintain
COASTAL FRESHWATER SWAMPS AND LAGOONS																		
Limpopo Delta	MZ	1	1	1	1		1		5				*		nil		B	survey
Zambezi Delta	MZ	1	2	1	1		1		6				*		pt4	*	B	extend P.A.
Aby Lagoon	IC	1	1	1	1		1	2	6					*	nil		C	survey needed
St. Lucia	SA	1	2	1	1	1	1		7					*	4		B	maintain
Kosi/Sibayi	SA	1	1		1	1	1		5					*	nil		C	low priority
Ghana coast	GH	1	1		2	1	1	?	6	*				*	nil		B	needs survey
Diawling Delta	MR	1	1	1	2	1	1	?	7				*		pr2		A	establish P.A.
Djoudj Delta	SN	1	1	1	2	1	2	1	8			*	*	*	NP2	*	B	increase P.A.s
Lekki lagoon	NI	1	1	1	1	1	1	?	6		*		*	*	nil		B	needs survey
Coastal lakes	SL	1	1		1		1	?	4					*	pr1		B	Mabesi/Mape
Petit Loango	GA	1			1		1	1	4		*		*	*	4		B	improve
Azagny	IC	1	1	1	1		1	2	7						NP2		B	maintain

Chapter 5.
Threats To Africa's Aquatic Ecosystems

Aquatic ecosystems are vulnerable to the effects of landuse activities beyond their boundaries, such as deforestation and the resulting erosion. © World Resources Institute.

The productivity and diversity of Africa's aquatic ecosystems, so important to the livelihood, if not survival, of its peoples face multiple threats. These threats are partially a result of desperate poverty, partially a result of misguided donor efforts, and partially a result of greed. Threats include: poor land use planning and inappropriate policies; the introduction of exotic species; overfishing; deforestation; agricultural, municipal and industrial pollution; conversion of sites for agriculture and aquaculture; changes in the water regime resulting from water diversion and large-scale irrigation; global climate change; and synergistic effects.

Unfortunately, solutions to these threats are hindered by two additional problems: 1) "the tragedy of the commons" (Hardin, 1968) and 2) transboundary effects. The first problem is that aquatic systems are generally considered common property to the effect that no one feels ownership or responsibility for damage. While a number of societies have found ways to overcome the tragedy of the commons (see Becker and Ostrom, 1995, for design principles), the ability of even long-standing communities to manage small areas can be impeded by migrants and economic refugees who do not share the community's concern over long-term damage to the environment or resource. The second problem is that the impacts of damage extend beyond a nation's border. For example, 40% of the world's population lives in river basins shared by two or more nations. Thus even if one nation addresses the problem, its effort could be negated by the (in)action of the adjacent country. Transboundary issues confounding the management of aquatic areas in Africa include: marine pollution in the Gulf of Guinea; the pollution of rivers and the resulting coastal effects downstream; lacustrine pollution; the conservation of migratory species; dams and their effects on riverine, wetland and coastal biodiversity downstream; and an illegal international trade in toxic wastes (World Bank, 1996).

Aquatic ecosystems are more difficult to protect than terrestrial ones because they depend on the quality and quantity of water which can be affected at every step of the pathway between a water catchment and the given system. By their very nature, then, aquatic ecosystems are more vulnerable than terrestrial ecosystems to the effects of land-use activities beyond their boundaries -- at times spanning entire watersheds. Wetlands in particular require a delicate balance of water levels and water flow, sedimentation, microclimate, and other factors. For example, pollution from factories can affect a downstream wetland. The effects can be far-reaching. River plumes, under the influence of Coriolis forces, can hug the coast for hundreds of kilometers (FAO, 1994). Similarly, changes in siltation levels and runoff patterns resulting from developments far upstream can affect the balance of a mangrove forest on the coast. Seagrass beds, mangroves, salt marshes, and estuaries are also easily damaged by pollution because of their shallow waters and restricted circulation. Numerous African estuaries are already severely damaged.

Freshwater species resemble island species in their vulnerability to environmental stresses. They have a limited range (often to a single watershed, lake or river system) and low population numbers (Stiassny, 1998). Marine systems are not only affected by land-use activities, but because of the fluid nature of the ocean, they can be affected by nutrients, pollutants and sediments from other countries or regions. Coral reefs are vulnerable to damage primarily because their recovery is so slow. It can take at least fifty years for coral reefs to recover from destruction; the length of time depends on the extent of damage and the availability of coral and other larvae. Worldwide, it is estimated that 10% of the total 600,000 km^2 of coral reefs are dead, with another 30% likely to show serious degradation within the next twenty years (OCA/PAC/UNEP/IUCN, 1992). The East African/Madagascar reef system is one of the world's regions considered at greatest risk over the next ten to twenty years. Coral reefs are also vulnerable because of their restrictive physical requirements -- they can only live under a very narrow range of temperatures, salinity, and clarity of water -- and because of the extraordinary complexity of their food chain. The assemblages of fishes that live on reefs appear fragile and unstable; they are easily disturbed by damage and do not necessarily recolonize in the same assemblage (Hughes, 1994).

A. Policy Deficiencies and Inadequate Planning

Above all else, aquatic systems require integrated planning. Too often, however, governmental agencies consider aquatic systems only for a single purpose rather than for multiple uses benefitting a variety of sectors. In Africa, IUCN notes that "very little dialogue seems to be underway... which attempts to integrate the multiple use of such potential areas for optimum economic returns without impairing the ecological attributes of such lands" (IUCN, 1991b). This problem can be confounded by limited environmental regulations, limited enforcement capacity, and by political instabilities precluding long-range planning for sustainable development. The World Bank (1996) notes that environmental regulations and legislation are only just being developed in Ghana, Nigeria and Tanzania.

Overlapping jurisdiction: A number of government agencies (fisheries, tourism, urban sanitation and water, and agriculture) can have responsibility over aquatic areas and resources, leading to confusion, inertia, and ineffective planning. Overlapping jurisdiction can occur horizontally (within the same level of government) and vertically (across different levels of government, from local authorities to regional). In the case of wetlands, for example, despite increasing efforts to conserve these areas, many wetlands are lost because of competing government priorities. Governments can have a stated commitment to wetland conservation, while at the same time, their national agricultural policy favors wetland drainage!

A force behind inappropriate river basin or wetland development is a political one -- that of some donors who favor expensive engineering projects because they utilize equipment and workers from the donor country (Scudder, 1994). Soft loans or grants are also a powerful force for wetlands conversion. In a number of cases, such loans or grants are given to development projects in wetlands which are undertaken with no cost benefit analysis. In the late 1970s, for example, the World Bank and a number of European governments supported the development of the Bura irrigation scheme on Kenya's Tana River. In 1982, the cost had increased by 180%, negating the predicted rates of return and compromising the viability of the investment. By the mid-1980s, the project was judged a failure by President Moi. The project has caused important floodplain wetlands to be destroyed (Ndirangu, cited in IUCN, 1990b).

Subsidies often lead to waste and misuse of aquatic resources. These include agricultural subsidies for pesticides, fertilizers, and water, forestry subsidies which can exacerbate deforestation and erosion in marginal and vulnerable areas, and tax relief for overseas investors with little incentive to sustainably manage a given resource.

B. Introduction of Exotic Species

"Introductions, like extinctions, are forever."
Marsden, 1993

The invasion of exotics is believed to be the second greatest threat to global biodiversity after habitat loss. Islands, coastal estuaries and lakes are at particular risk (Glowka et al., 1994). Exotic fishes have been deliberately introduced into African freshwaters for a number of reasons, almost always with good intentions: for fish culture; to fill apparently "empty" niches and produce more or bigger fish; to control unwanted organisms; to improve sports fisheries; and to control fish production in ponds through the introduction of predators (Leveque et al., 1988). Hamman (1997) reports that ninety-three aquatic species (70% of which are fish) have been introduced or inappropriately translocated in Southern Africa. He criticizes both government and conservation authorities for their active involvement in the practice, and notes that conservation authorities are under constant pressure to allow the use of exotics for aquaculture purposes. Introductions may also be accidental. Interbasin water transfer occurred in South Africa. Almost all of the country's major river systems are connected by a series of tunnels, pipes and canals, resulting in the invasion of at least five fish species into the Orange River, previously known for its high number of endemic species (Brutton and van As, 1986, cited in Allan and Flecker, 1993). In the marine realm, the main threat of introductions of exotic species is accidental -- the dumping of the ballast water of ships. As ships move from port to port, they unwittingly carry a number of hitchhiking species in their ballast water, including phytoplankton, invertebrate and vertebrate larvae, and small fishes (Carlton, 1985, 1989).

Figure 31. The invasion of water hyacinth in Lake Victoria has resulted in a loss of hundreds of fishing and transporting jobs. The New England Aquarium, 1998. Photo credit: Alexander Goldowsky.

Exotic plants are also a threat to aquatic ecosystems. In Africa, two South American species have caused havoc: water hyacinth (*Eichhornia crassipes*), particularly in Lake Victoria, and *Salvinia molesta*. Both species rapidly colonize water bodies, forming a dense floating mat of interlocking plants (Harper and Mavuti, 1996). These species crowd out native vegetation, reduce light penetration, limit water column mixing, and increase detrital inputs (Kaufman and Ochumba, 1993). Kaufman and Ochumba (1993) report that "a single water hyacinth plant can produce 140 million daughter plants per year, enough to cover 140 ha with a wet weight of 28,000 tons." The seeds can survive for thirty years in mud, making the plants almost impossible to eradicate completely. Water hyacinth invaded the Kagera River, Rwanda in the late 1980's, and quickly made its way to Lake Victoria. IRIN (1997) reports that water hyacinth now covers one percent of Lake Victoria (Figure 31). The plant completely covered Kisumu, Kenya's main port, causing the loss of hundreds of fisher and transporter jobs. According to the Kenya fisheries department, the weed-choked landing sites forced fished communities to relocate, "just like a refugee crisis." The department estimates that fish landings, which dropped 10% last year, will drop another 20% this year. The Ugandan Railways Corporation spends $2000 a day to remove the weed from the marine pier at Port Bell, near Entebbe (Africa News Service, 1996b).

Paradoxically, one of the best mechanisms for selective control of these species is biological control -- control through the use of a highly selective insect that specializes on feeding on these species (e.g., *Salvinia* can be controlled by the Brazilian curculionid beetle, *Cyrtobagous salvinae*, and *Eichhornia* can be controlled by two weevil species, *Neochetina bruchi* and *Neochetina eichorniae*, GEF, 1996).

Seldom have the economic and biological implications of introductions been thought through; both are expensive. For example, in the last century in the U.S., exotic species have cost an estimated $97 billion in damage to natural resources and industrial productivity (A statement of concern, 1996). A single aquatic species -- the zebra mussel -- cost more than $100 million in the U.S. Great Lakes in six years (IUCN, 1997). In 68% of U.S fish species extinctions over the last century, introduced species were a contributing factor (Miller et al., 1989), while an estimated 34% of all global molluscan extinctions are attributed to exotic species (Tentacle, 1996). On the biological side, we may **never** know enough to anticipate all of the risks, particularly the unforseen and complex interactions of the invading species with the existing food web. Ecosystems with a high biodiversity tend to have a complex and unstable food web with longer food chains, high levels of competition, predation, parasitism, and symbiosis (Gaudet and Harris, 1981). Ecosystems already stressed by either anthropogenic or natural causes are more likely to suffer deleterious consequences following introduction of exotics.

Figure 32. Aquatic introductions in Africa have proven to be both economically and biologically costly. The introduction of the Nile perch in Lake Victoria led to the demise of hundreds of haplochromine cichlid species. The New England Aquarium, 1998. Photo credit: Peter Johnson

Comparative studies of terrestrial exotic species across taxonomic categories have shown that invading species can affect virtually all ecosystem functions and structural properties, including alteration of biogeochemical cycling (feral pigs, invasive nitrogen fixers, salt accumulators); hydrological cycles (invasive trees); and soil erosion rates (feral mammals) (Drake et al., 1988). Studies of aquatic exotic species have shown that both predatory and herbivorous species can cause serious ecological damage to endemics, through predation, competition for food or breeding spaces, the degradation of habitats and food webs, or the spreading of diseases and parasites (Leveque et al., 1988; Commission for Environmental Cooperation, 1996). In addition, introduced species can degrade the gene pool (EDF, 1994), such as when hatchery-bred fish, with limited genetic variability, interbreed with wild populations.

Worldwide, the introduction of exotic species, especially top predators, into lakes has often been both economically and biologically disastrous. The introduction of the bass into Lake Atitlan, Guatemala, caused the disappearance of local fish populations (cited in Witte et al., 1992). Exotics, along with pollution and overfishing destroyed the endemic cyprinid fishes in Lake Lanao, Philippines, in less than twenty-five years. (In some cases, however, introductions may be economically beneficial, at least in the short term, but biologically damaging, such as the introduction of exotic sportfishes into the U.S. Great Lakes which greatly increased the economic value of these lakes.) Introductions are also damaging to stream ecosystems. A review of thirty-one case studies of fish introductions to streams showed that 77% of the time, native species showed a decline in number (Ross, 1991, cited in Allan and Flecker, 1993).

In general, terrestrial introductions have also been economically and biologically disastrous, such as the rabbit and giant toad in Australia and the gypsy moth in the U.S., but a few successes have occurred as well, such as the introduction of pheasants and brown trout to the U.S. In some cases, aquatic introductions have increased yields of human food. Leveque et al. (1988) argue, however, that the beneficial effect of introducing fishes from the standpoint of increasing yields has been overestimated, since the effect of the introduction cannot be separated from the often concomitant expansion of fishing effort and the improvement of fishing gear. The most successful introductions from the standpoint of increasing yields have been in artificial lakes and ponds, or in lakes depauperate in species. Barel et al. (1985) note that except in these cases, all examples of the introduction of fish with the intent of increasing yields of human food have been at best unsuccessful and often “simply disastrous.”

The aquatic introductions in Africa have proven to be both economically and biologically costly. As described in the box below, the continent’s Lake Victoria can wear the dubious title of the world’s costliest introduction in vertebrate history (Figure 32). In a number of other cases, introductions have achieved the desired results, but at a cost not originally envisioned.

Introduced Species and African Lakes

Lake Victoria: The tale of the loss of the haplochromines in Lake Victoria is a tragic and cautionary account of mismanagement of one of the world’s richest biological sites. Of the 596 threatened freshwater fishes listed by the IUCN Red Data Book in 1988, nearly half of them are from Lake Victoria (Kaufman, 1991c). The cast of characters to blame include the introduction of exotic species, overfishing, poor land-use practices, and climatic events precipitating further human-induced changes (see Kaufman and Ochumba, 1993; Cohen et al., 1996). For a detailed description of these anthropological effects on the lake’s ecosystem, see the Case Study, Annex.

Lake Kyoga: In 1963, two different species were introduced into the shallow Lake Kyoga, a herbivirous tilapiine and the predatory Nile perch. The introduced fishes virtually eliminated seven abundant endemic species, leading to a collapse of a once-thriving native species fishery (Fryer, 1972a). In addition, it was recently discovered that Lake Kyoga harbored its own haplochromine fauna, now greatly diminished (Kaufman et al., 1997). Although the introductions initially led to greatly increased fish catches in the 1970’s, the catch has drastically declined (Witte et al., 1992).

Lake Kivu: Lake Kivu, a deep lake between the Democratic Republic of the Congo (formerly Zaire) and Rwanda, had a depauperate fish fauna (sixteen species, seven of which are endemic) and low fish biomass even though it had high primary productivity. The lake lacked planktivorous fish in contrast to nearby Lake Tanganyika which had two species. Arguments were made that by introducing a planktivorous fish into Lake Kivu, the zooplankton biomass could be exploited for human consumption through eating of the planktivorous fish; otherwise the zooplankton protein would be lost to humans. Proponents of introduction ignored the fact that Lakes Kivu and Tanganyika had entirely different life histories, with Tanganyika being one of the oldest lakes in the world and supporting a simple and stable food chain, and Kivu being a very young lake, no more than 15,000 years old, with a Victoria-like endemic cichlid radiation (Snoeks et al., 1994). The Tanganyika sardine (Clupeidae) was introduced into the lake between 1958 and 1960. The sardine has now wiped out the zooplankton and is feeding on its own young as well as possibly the young of some endemic cichlids. The population of sardines is likely to collapse.

C. Overfishing

"The widely documented disappearance of aquatic species around the globe, related to both overfishing and failure to protect habitat, does not provide reassurance that most nation states are able to manage effectively."
Pinkerton, 1994

Overfishing can be divided into three different types (Lowe-McConnell, 1987b): **growth overfishing -** where the young fish (recruits) are caught before they reach a reasonable size; **recruitment overfishing -** where the parent stock is so reduced that not enough young are produced by the fishery to maintain itself; and **ecosystem overfishing -** where species distribution is drastically changed, altering the efficiency of the system.

In ecosystem overfishing, the niche inhabited by the originally abundant species is not fully taken up by other species, changing the system's productivity. The impacts can be direct, involving the affected species, or indirect, involving competitors, prey or symbionts (Sobel, 1996). A recent global analysis has clearly shown the ecosystem impacts of overfishing. Over the last forty-five years, humans have "fished down" marine food webs, leading to a change in landings from high-level piscivorous bottom fish to low-trophic level invertebrates and planktivorous pelagic fish (Pauly et al., 1998). Pauly et al. showed a mean decline of 0.1 trophic level per decade.

Fishers and managers are often unaware that prey choice and feeding rates of fish can affect ecosystem processes (McClanahan and Obura, 1996). Coral reef ecosystems, with their extraordinarily complex food webs, can be easily damaged by overfishing. For example, large slow-growing top predators such as snappers and groupers have been decimated in tropical marine waters, with a resulting increase in small, short-lived noncommercial fish, penaeid shrimp and cephalopods (FAO, 1994). Similarly, when fishermen removed too many triggerfish from Kenya's coral reefs, their prey, sea urchins, exploded. Over fifteen years, the number of sea urchins increased 500% (McClanahan and Muthiga, 1988). Triggerfish predation on sea urchins is believed to control sea urchin abundance, which in turn, affects algal cover and reduces live coral cover. Sea urchins outcompete herbivorous fish in algal grazing. Evidence suggests that increased numbers of sea urchins also affects coral recruitment and bioerosion of coral reefs (Sammarco, 1980 and Glynn et al., 1979, cited in McClanahan and Muthiga, 1988).

Certain <u>fishing methods</u> are also of concern due to their destruction of habitat and/or their indiscriminate nature

Figure 33. Some fishing methods can have devastating effects on coral reefs, including the beach seine, dynamite, and cyanide. © South Pacific Regional Environmental Programme.

(Figure 33). The beach seine is damaging to coral reefs, for example, because its small mesh size collects fish indiscriminately and because it involves walking on and overturning corals. The use of dynamite to catch reef fish (common in Kenya and, to a lesser extent, Tanzania) clearly destroys the habitat on which they depend . Trawling, long-line fishing, and drift-netting result in the catch of many species besides the target species; this bycatch is usually not utilized. Bycatch can comprise 40% or more of marine catch (Kaufman and Dayton, 1997). McAllister (1995) notes that four tons of fish are thrown away for every ton of wild shrimp caught. Trawling also destroys nursery grounds, injures attached organisms, knocks over boulders, fills in hollows, burying organisms, and creates turbidity which can damage filter feeders (McAllister, 1995; Watling and Norse, 1998).

Most governments do not manage fisheries sustainably, and as a result, fish populations are declining throughout the world. In 1990, world catch dropped for the first time since 1976 (FAO, 1994); by 1993, the catch decreased by 7% (McNeely, 1997). In 1992, the U.N. Food and Agriculture Organization (FAO) declared nearly all commercial fish species "depleted", "fully exploited," or "over-exploited" (Fiji Times, 1993), with over one-third "over-exploited" (WWF, 1995). In 1996, IUCN's Species Survival Commission recommended adding 131 marine species (out of 152 examined) to its threatened list (IUCN, 1996). Species most at threat include those with low rates of production (generally large top predators), and those that depend upon niches altered by fishing (Huppert, 1995). Africa is no exception; all of its major fisheries have been intensively over-exploited. The World Bank (1996) notes that "with few exceptions, African coastal fisheries have reached or exceeded their maximum sustainable yields."

The overexploitation of Africa's freshwater fish began with large-scale fishing brought upon by the use of twine netting. Older year classes of most fish populations, which comprise the spawning population, have now been depleted and catch yields have correspondingly declined (recruitment overfishing). By 1975, the older year classes of most of the larger and slower-growing species had been depleted in Lake Tanganyika, Malawi, and Victoria, as well as in other established fisheries. Overexploitation of a given species leads to immature populations, with a fast turnover and high fecundity; the result is a smaller and faster-growing species. Ecosystem overfishing has also occurred in both fresh and marine waters, changing the population structure and relative abundance of the species, often for the worse. To date, regulating overfishing has been difficult. Enforcement tends to be weak because fisheries departments in Africa are understaffed and underfunded in comparison with other natural resource departments.

Africa's problems are exacerbated by the fact that the effects of overfishing are felt much more quickly in tropical waters than temperate waters. Tropical fish generally tend to have shorter life cycles than those of temperate waters, so fewer age groups are represented in catches. The tragedy is that the recent overexploitation of Africa's fishes -- fishes which provide a significant portion of the continent's protein needs -- has taken place commensurate with the rapid increase in its human population. Thus, just as increasing sources of protein are needed, fish productivity is declining due to overfishing. This is true for both freshwaters and inshore marine areas. In general, marine pelagic areas are still underfished (Brainerd et al., 1992).

There are four primary reasons for management failure that apply to fisheries worldwide (Figure 34):

1) failure to recognize environmental variability; 2) failure to incorporate both scientific uncertainty and measurement error in stock assessments (Hilborn and Peterman, 1995); 3) lack of political will in implementing scientific recommendations; and 4) market forces beyond the control of management. In addition to these four, one must also include the tragedy of the commons, as described previously, short-sightedness and greed.

In Africa, an additional problem is the fact that licensing of foreign fleets provide a much-needed source of revenue to governments. The governments are afraid that managing fishing in their waters may antagonize the fleets, and so are reluctant to enforce management guidelines. This problem is particularly acute for countries on the west coast, including Guinea-Bissau (Agardy, pers. comm.).

Conventional fishery models are based on stable fish populations. Many fisheries still rely on the principle of maximum sustainable yield, even though it has been discredited over the last 20 years (Roberts, 1997). This principle is based on the concept that each species overproduces the number of young needed to sustain itself, and that only the excess should be harvested (IUCN, 1996). Stock recruitment models assume that the abundance of recruits is influenced by the abundance of their parents. Yet fish population size is not determined solely by the number of spawning fish present (EDF, 1994). In fact, the relationship between recruits and their parents is only clearly linear at very low spawning stock levels, as occurs with severe overexploitation. At such levels, a decline in the abundance of spawning fishes has an immediate and direct negative effect on the abundance of recruits (Parsons, 1996). At this point, however, it may already be too late for management intervention.

The conventional management approach has failed, largely because it does not adequately address the considerable natural variability in stocks and in environmental conditions that affect stocks. There are three principle sources of uncertainty in fisheries: 1) scientific uncertainty about stock dynamics; 2) measurement error in stock assessment; and 3) environmental variability affecting stock

Figure 34. There are many reasons why current fisheries management has failed to prevent overfishing worldwide. Ghana fishing industry. Source: World Bank, 1993. Photo credit: Curt Carnemark.

productivity (Rosenberg and Restrepo, 1995). Factors affecting the distribution and abundance of fish populations include physical and chemical variability, food availability, and quality of habitat (EDF, 1994); for example, the pelagic fishery along the African west coast is affected by the intensity of the seasonal upwelling (FAO, 1994). In tropical systems, one also has to contend with the complexity of species interactions. In addition, fishing can have both direct and indirect effects on populations by altering the dynamics of competition and predation at each life cycle stage. The abundance of any given species appears to be highly variable: possibly nonlinear or even chaotic (Wilson et al., 1994; Fogarty, 1995). This natural environmental variability on stock levels can obscure the initial effect of overexploitation, with the result that overexploitation is not apparent until it is severe and often biologically and socioeconomically irreversible (Ludwig et al., 1993). Roberts (1997) cites an additional problem with the conventional single-species approach: the gear used to catch a species is often unselective, impacting a number of species.

Although environmental variability can be addressed to some extent by maximizing average yield over several years (Fujita and Zevos, 1996), stock dynamics are also affected by political and economic interests, the availability of markets, and the behavior of fishermen in complying with regulations. Thus, even if science could predict stock levels with certainty, this by itself won't prevent overexploitation. In particular, short-term political and economic decisions often play a role. As Ludwig et al. (1993) note, "many practices continue even in cases where there is abundant evidence that they are ultimately destructive." For example, although maximum sustainable yield assessments have been made in the African Great Lakes, the limit is often ignored when reached. Why? Because politicians have more interest in maintaining high employment in the short-term, even though the long-term consequences can be economically and biologically devastating. This problem isn't unique to Africa: Safina (1993) describes the mismanagement of tuna in the West Atlantic by the adjacent developed countries.

Overcapitalization is a persistent problem in fisheries around the world. From 1970 to 1989, the global industrial fishing fleet increased twice as fast as global landings (FAO, 1994). Ludwig et al. (1993) cogently outline how such overcapitalization occurs. In good years, government encourages additional investment in vessels or processing, neglecting to account for natural variability. When stock levels drop, industry appeals to government for financial assistance. As jobs and money are at stake, typically governments and/or donors respond with subsidies or tax incentives which tend to increase overharvesting. In sum, "*the ratchet effect is caused by the lack of inhibition on investments during good periods, but strong pressure not to disinvest during poor periods. The long-term outcome is a heavily subsidized industry that overharvests the resource*" (Ludwig et al., 1993). As FAO noted in 1993, the annual operational losses of the fishery sector reached $22 billion in the late 1980's and early 1990's, due largely to subsidies in industrialized countries (FAO, 1993). High discount rates are a factor in subsidization as well.

Additional problems in African fisheries of conservation relevance include:

1) problems related to management capacity, including poorly trained technical personnel; lack of enforcement; lack of data and long-term research on the monitoring and management of fisheries; lack of research and monitoring equipment; incomplete knowledge of stock levels; and

2) lack of infrastructure for handling/processing facilities, which causes waste. In most African countries, between 15-25% of the catch is lost due to spoilage, wastage at the time of capture, insect infestation, or improper handling and storage. Some countries have post-harvest losses of up to 50%, particularly those where smoking and drying are the normal preservation methods.

D. Deforestation

The deforestation occurring throughout Africa damages both freshwater and marine ecosystems. The deforestation of riparian areas (forests near rivers) due to grazing, dams, or embankments can cause stream temperatures to fluctuate widely, reduce dissolved oxygen concentrations, and reduce the contribution of terrestrial nutrients, including leaf litter, to aquatic food webs (Higgens et al., 1992; EDF, 1994; Allen and Flecker, 1993). The erosion that results from deforestation can change the shape of a stream or river, harming the quality of spawning grounds and habitat. Sedimentation also can smother spawning grounds and reduce habitat complexity of rocky substrates. Sediments harm freshwater food webs in a variety of ways. They reduce light penetration and hence the rate of photosynthesis (Cairns, 1968; Fuller, 1974; Berwick and Faeth, 1988). They cover benthic algae, reducing foraging efficiency in herbivorous fish (Grobbelarr, 1985). They reduce the nutritional value of detritus (organic waste) (Graham, 1990). They also interfere with the feeding apparatus of filter-feeding organisms. The sedimentary particles themselves can abrade the bodies of aquatic organisms (Harman, 1974; Bruton, 1985). Fortunately, maintaining a sufficient strip of riparian forest can do much to minimize these effects (Allan and Flecker, 1993).

Numerous studies have shown that deforestation and the resulting sedimentation have contributed to the endangerment and extinction of endemic mollusc species in North American rivers and streams (Cooper, 1984; Schmidt et al., 1989; Taylor, 1989). Similar results have now been documented for species in Lake Tanganyika and Madagascar streams (Figure 35; also see box next page). The northern part of Lake Tanganyika in Burundi and the Democratic Republic of the Congo (formerly Zaire) is nearly 100% deforested, with rates of soil erosion ranging between 28 and 100 metric tons/ha/year (Cohen et al., 1993). In the central region, between 40-60% of the area has been deforested (Figure 36). Nearly all of this sediment discharges into the lake. Cohen and colleagues (1993) examined impacts of deforestation and resulting sedimentation on species richness in ostracods (a particular group of crustaceans richly represented in the lake, with perhaps 200 endemic species), fish, and diatoms in Lake Tanganyika (Cohen, 1995). In highly disturbed sites, ostracod numbers significantly declined by 40-62%, relative to undisturbed, while fish numbers tended to decline by 35-65%. To prove that species diversity declined as a result of deforestation, Cohen (1995) examined paleological data. Undisturbed sites showed no change in species richness over time, in contrast to disturbed sites. Rare species appeared to be particularly vulnerable to forest disturbance.

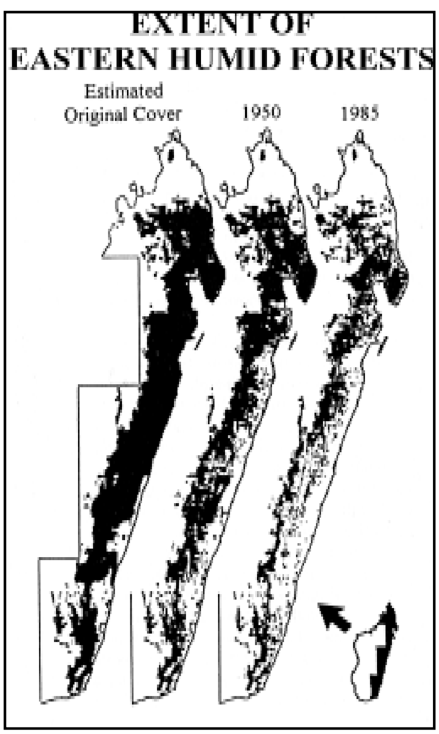

Figure 35. The effects of deforestation on Madagascar's eastern humid forests. From Stiassny and Raminosoa, 1994, with permission.

Figure 36. The deforestation of Lake Tanganyika caused sediment to discharge into the lake. Photo credit: Caroly Shumway.

In marine systems, sedimentation can kill corals and their symbiotic zooxanthellae which require clear waters for optimal growth. Sedimentation can affect reefs by killing colonies, by preventing settlement, by affecting sexual reproduction, or all three (NRC, 1995). In general, corals cannot cope if the levels of silt exceed the limits of the coral's cleaning mechanism (Samoilys, 1988b), or if the coral faces multiple anthropogenic or natural stresses. Some corals can, however, recover from sedimentation, and some show little impact, making it difficult to predict *a priori* effects at a specific site (McClanahan and Obura, 1997). Sedimentation also directly and indirectly reduces the amount of light reaching the corals by promoting the growth of planktonic algae and affecting the photosynthetic ability of coral's symbiotic zooxanthellae. Sedimentation can also smother and exceed the clearing capacity of filter-feeding organisms. Finally, sedimentation can silt coastal lagoons (Crivelli et al., 1995).

E. Agricultural, Municipal and Industrial Pollution

Pollution from farms, cities, and factors can affect adjacent aquatic areas as well as areas further downstream. The wetlands of Gonarezhou National Park in Zimbabwe Pollution, for example, have been damaged by silting and pollution from agriculture in the basin of the Lundi and Sabi rivers which feed the park (IUCN, 1990b). Pollution can harm aquatic life both immediately (acutely) and over the long term (chronic). Chronic effects are the result of long-term exposures to lower toxicity, resulting in changes in behavior or reproductive fitness of the population. These effects can arise from estrogen-mimicking compounds such as polychorinated biphenyls (PCBs) that alter hormonal systems and can damage reproductive, developmental, and immune systems, as well as from tumor-causing compounds (Colborn et al., 1996).

Case Study: The Rivers and Streams of Madagascar

Madagascar, the planet's fourth largest island, is well known for its extraordinary and unique terrestrial biodiversity resulting from having been separate from Africa for 150 million years and India for at least sixty million years. Less well known is that *the island harbors a richness of freshwater fishes that are the most threatened of the island's vertebrates* (Stiassny and Raminosoa, 1994). The fishes are biologically and socio-economically important, providing food and income for local residents (Kiener, 1963; Kiener and Richard-Vindard, 1972). Like the terrestrial fauna, the fishes exhibit high levels of endemicity (thirty-six exclusively freshwater endemics and seven euryhaline) and occupy critical basal phylogenetic positions (Stiassny and Raminosoa, 1994). "Basal taxa" are sister groups to species-rich groups that are essential in better understanding the evolutionary and ecological history of particular fishes. These groups can provide the only possible evidence for understanding the evolution of certain character transitions. Unfortunately, basal groups tend to be low in abundance and limited in distribution, making them very vulnerable to environmental stresses (Stiassny, 1994).

The majority of freshwater endemics (61%), including most of the basal taxa lived exclusively in the rivers and streams of the eastern and north-eastern humid forests. The area, once completely covered with dense humid forest, is being rapidly deforested by slash and burn agriculture (tavy), mostly for dry land rice cultivation. Of the original 11.2 million ha of eastern rain forest, only 3.8 million ha remained in 1985 (Figure 11). Tavy may have been sustainable in the past, but is no longer, given increasing population pressures. Deforestation affects the fishes by destroying their sources of food and degrading their habitat. The freshwater fishes feed on allocthanous material (i.e., food coming from terrestrial sources) and on the aquatic stages of many terrestrial insects (Reinthal and Stiassny, 1991). As the forests have disappeared, those freshwater endemics unable to take refuge in downstream brackish areas have become locally extinct, or in in cases of species with limited distributions totally extinct. Most of the formerly abundant species are now rare, and many are no longer found (Stiassny, 1997, in press). A 1991 survey of fifty-six sites found just five endemic freshwater species, only in areas where the forests are still intact (Reinthal and Stiassny, 1991).

Although deforestation is the major threat, introduction of exotic species has hastened the decline of native freshwater fishes (Reinthal and Stiassny, 1991). Twenty-seven species have been deliberately or accidentally introduced to date. The combination of loss of forest cover and the presence of exotics seems to completely eradicate most native species. A compounding problem is the spread of water hyacinth in the last decade. Even though only 5% of original island vegetation remains (Myers, 1988), the remaining forests face increasing pressure. Given the current annual growth rate of 2.8%, Madagascar is estimated to grow from twelve million in 1990 to 29.4 million people by the year 2020. At current deforestation rates, little of Madagascar's forest cover will remain in ten years and only that on the very steepest slopes will survive the next thirty-five years. *Stiassny and Raminosoa (1994) state that "if current trends continue, few of Madagascar's endemic freshwater fishes will survive the millennium".*

Agricultural threats include both pesticide and fertilizer runoff. The chemicals in pesticide runoff become more concentrated and toxic as they work their way up the food chain. They accumulate in the bodies of fish and other higher-level organisms. Pesticide residues have been detected in fish from northern Lake Tanganyika, particularly after the cotton harvest. Fertilizer runoff increases the nutrient loading in waters, thereby causing eutrophication and algal blooms. This impacts fisheries and drinking water and reduces biological diversity.

Municipal pollution also increases eutrophication. Jonathan Cole of the Institute of Ecosystem Studies has shown that the greater the number of people living along a river, the greater the amount of nitrates in the river (Cole et al., 1993).

Eutrophication exerts a toll on visual aquatic organisms. The sensory impact of changes in water quality due to increasing nutrient levels is of particular concern for species which use visually-guided behaviors in reproduction. Seehausen et al. (1997) document a startling change in species diversity in Lake Victoria that seems to be best explained by changes in light conditions on visually-guided mate choice. Figure 37 shows the relationship between the available light spectrum and species diversity from various points around the lake.

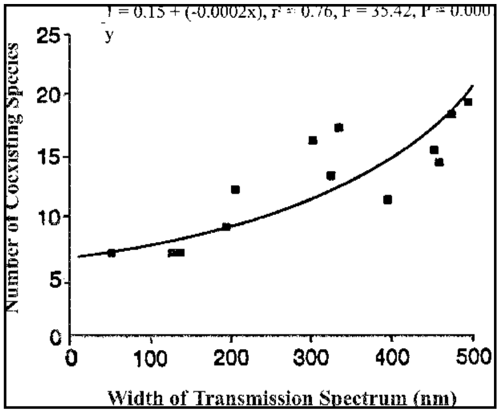

Figure 37. The relationship between species diversity at various points in Lake Victoria and light levels, which are affected by eutrophication. Reprinted with permission from O. Seehausen, J.J. M. van Alphen, and F. Witte (1997) Cichlid fish diversity threatened by eutrophication that curbs sexual selection. Science 277: 1808-1811. Copyright 1997 American Association for the Advancement of Science.

Industrial pollution mainly threatens coastal waters, as the oceans are utilized by most nations worldwide as a vast dumping ground for waste. More than 90% of all chemicals, refuse, and other material entering coastal waters remain there in sediments, wetlands, fringing reefs, and other coastal ecosystems. The most widespread and serious chemical pollutants are halogenated hydrocarbons (such as pesticides, herbicides, and PDBs), heavy metals, petroleum products, and fertilizers (NRC, 1995). These substances can cause tumors and disease in estuarine and coastal fish. In addition, plastic and other debris, such as pieces of nets, entangle and kill a variety of marine animals. Industrial pollution can also harm inland waters, such as in the Bujumbura area of Lake Tanganyika (Figure 38).

F. Conversion of Sites for Agricultural Production

The rapidly increasing human population in Africa puts heavy demand on increased food production. This, in combination with increased demands for cash crops for export, has led to the agricultural conversion of many critical wetlands. Conversion not only damages the environment but seldom works, mainly due to the development of acid sulphate soil conditions. Many mangrove areas have soils containing large amounts of pyrate sulphur. When the soil is exposed to the air, the resulting oxidations release sulphuric acid. The soils become extremely acid and very high in soluble salts. This condition often leads to nutrient and fertilizing problems, resulting in the impairment and even failure of crops such as rice, coconut, as well as others. Even if drained land does produce reasonable yields for several years, long-term sustainability on the site is virtually impossible because of the resulting environmental degradation. Wetland drainage can have additional effects as well: disrupting the water supply of nearby towns; affecting the quality of water; and altering the microclimate.

Following drainage of mangrove soils for rice cultivation in Senegal, acid sulphate soils emerged and rice crops failed. “Diseases that were previously almost unknown in the mangrove area, such as dystentery, bilharzia, and typhoid fevers, became endemic” (Richards, 1985). Guinea and Guinea-Bissau could face similar problems are they are now also clearing their mangroves for rice cultivation.

The natural rise and fall of rivers and streams can be used to advantage in farming. IUCN notes that if properly managed, natural wetland agriculture (i.e., agriculture that takes advantage of the normal flooding cycle, rather than draining the site) can yield substantial benefits to rural communities. Natural wetlands farming occurs in the Inland Delta of the Niger in Mali, the floodplains of the larger rivers in the Sudan and Sahel Savannah zones, and the estuarine swamps of the Upper Guinea coast. In the large floodplains, “complex systems of flood-advance and flood-retreat agriculture have been developed” (Richards, 1985). In Sierra Leone, floating rice is

Figure 38. Pollution can cause both acute and chronic effects in aquatic organisms. Photo credit: Caroly Shumway

Figure 39. Industrial pollution can greatly impact the African Great Lakes, since they have a very low turnover of water. Photo credit: Caroly Shumway.

grown in a mixed cropping system in swamps. "This traditional system has proved better adapted to local conditions than large scale cultivation attempted by the... government" (IUCN, 1990b). In the inner delta of the Niger River in Mali, rice cultivation has for centuries been closely adapted to the annual flood, by cultivating varieties able to withstand the rising waters. Each village also has rice varieties adapted to local soil conditions (Gallais and Sidikou, cited in IUCN, 1990b).

G. Conversion of Sites for Aquaculture

Improperly sited aquaculture projects can greatly damage freshwater ecosystems. If cultured stocks escape to the wild, they can affect native gene pools. In addition, the potential spread of pests and diseases poses a serious risk to wild stocks, since the spread of farmed species happens all too often. As Bartley and Minchin (1995) acknowledge, "experience has shown that complete containment of exotic species in aquaculture facilities is nearly impossible."

Economic analyses of aquaculture often neglect the economic cost of conversion. For example, such analyses generally do not take the full economic benefit of mangroves into account (Dixon, 1989). Usually only the marketable mangrove forestry products are considered. However, this ignores the economic benefit mangroves provide to fisheries, both within mangroves and in nearby coastal and estuarine ecosystems. Further, this neglects the fact that some products or services, such as nutrient flows to estuaries, do not have market prices (Table 6). In sum, as Dixon (1989) says, "The decision as to whether or not mangroves should be converted is made by comparing the minimum partial estimate with the total expected benefit from conversion. No wonder mangroves are being lost at such a rapid pace."

As a concrete example, large areas of mangrove have been cleared worldwide for the establishment of shrimp mariculture. Half of the loss of mangrove habitats is attributable to this cause alone (Weber, 1995). This profitable industry is primarily sustained by exploiting postlarvae, water and intertidal areas as a free, common property resource (Robadue, 1995). The concession fees charged for mangrove areas assign only minimal values to postlarval fishery or to water quality. Since mangroves are so undervalued, many shrimp growers find it more profitable to increase production by continually converting mangroves into new grow-out ponds rather than invest in improving the productivity of existing ponds. In addition to the destruction of mangroves, shrimp farming reduces the area of estuaries due to the diking of sand and mud flats to create ponds and water intake channels and changes estuarine flow by channelization and by controlling the flow of water into the ponds. Waterfowl numbers decline due to habitat degradation and, in some cases, through routine shooting of those birds believed to eat shrimp.

The destruction of the mangroves and estuaries eventually affects the productivity of the shrimp farming itself. Recent studies in Ecuador, the Americas and Japan show that clearing mangroves leads to lower wild shrimp yields (Figure 40

	Location of goods and services	
	On-site	Off-site
Marketed	1 Usually included in an economic analysis (e.g., poles, charcoal, woodchips, mangrove crabs)	2 May be included (e.g., fish or shellfish caught in adjacent waters)
Nonmarketed	3 Seldom included (e.g., medicinal uses of mangrove, domestic fuelwood, food in times of famine, nursery area for juvenile fish, feeding ground for estuarine fish and shrimp, viewing and studying wildlife)	4 Usually ignored (e.g., nutrient flows to estuaries, buffer storm damage)

Table 7. The relation between location and type of mangrove goods and services and traditional economic analysis. (From Dixon, 1989, after Hamilton and Snedaker, 1984).

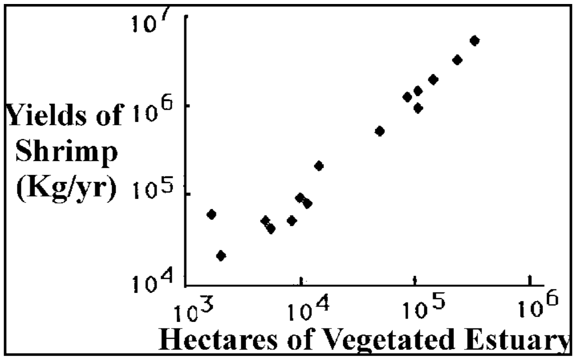

Figure 40A. The relationship between intertidal vegetation and penaed shrimp yields from the estuaries of the northern Gulf of Mexico. Turner, 1989. Reprinted with permission from The University of Rhode Island, Coastal Resources Center.

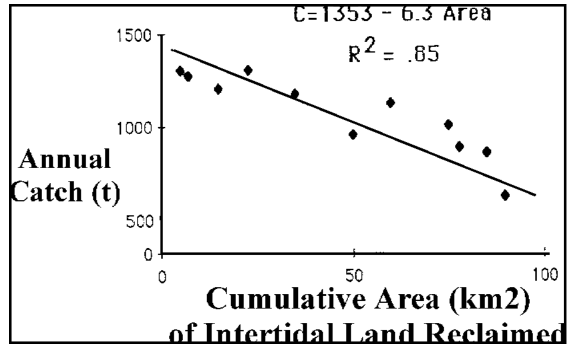

Figure 40B. The decline of shrimp yields in Japan as related to reclamation of intertidal lands in Japan. From Doi, 1983, as cited in Turner, 1989. Reprinted with permission from The University of Rhode Island, Coastal Resources Center.

A,B, from Turner, 1989). These studies show that, at least in Ecuador, the single greatest threat to the sustainability of shrimp farming was declining water quality due to in part to shrimp farming (Robadue, 1995)! Shrimp farming degrades water quality by introducing nutrients, antibiotics and other chemicals (Robadue, 1995).

The highly sulfuric soils of mangrove areas cause problems for aquaculture operations as well. In general, aquaculture ponds created on acid sulphate soils tend to be uneconomic to operate. Such soils severely inhibit the efficiency of phosphate fertilizers, leading to reduced growth of algae. In addition, the high acidity can kill the fish. [Note, however, that AID-funded CRSP research has apparently identified means of improving aquaculture on acid-sulphate soils with new construction techniques (AID/R&D/Ag)].

H. Water Diversion

Large dams are constructed for various reasons: to increase agricultural production from large-scale irrigation, generate hydroelectricity, control floods and assure water supplies (Figure 41). Worldwide, the number of large dams (over 15 m high) has increased from 5,000 in 1950 to 38,000 today (Postel, 1996), and it is estimated that over 60% of riverine and stream flow will be regulated by the year 2000 (Stiassny, 1996). Most African rivers are now dammed. This includes both tributaries of the Nile, the Niger basin (e.g., Bakolori on the Sokoto, Lagdo on the Benue, and the Selingue, Sotuba, Markala, Karamsasso, Kainji and Jebba on the Niger), the Zambezi basin (on the Kafue at Kafue Gorge, and the Zambezi at Kariba and Cahora Bassa), the Senegal at Manantali and Diama, the Volta at Akosombo, the Bandama at Kossou, and the Chad basin at Hadejia-Jama', among others (Adams, 1996).

The benefits of large dams are usually not as large as expected, and their adverse effects are often severely underestimated (Table 8). These include:

- <u>Habitat degradation and reduced biodiversity:</u> Dams directly impact riverine channel characteristics and habitat

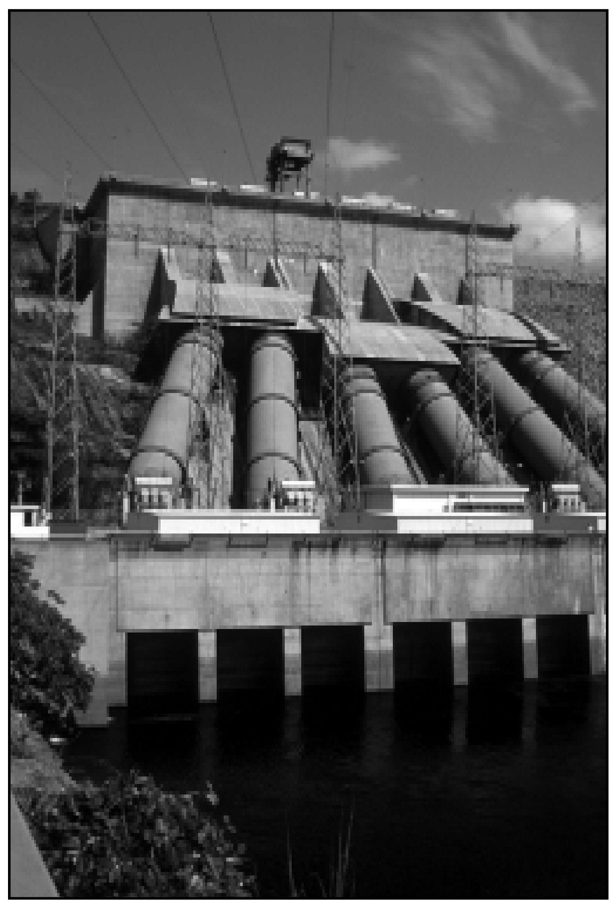

Figure 41.The benefits from dams are usually smaller than expected, while their adverse effects are often severely underestimated. Volta Dam and hydroelectric power plant, Ghana. World Bank, 1984. Photo credit: Yosef Hadar.

Table 4: The impact of dams on fish, pasture, and agriculture production on African floodplains

Floodplain	Area in 1960 (ha)	Area remaining in 2020 (ha)	Expected loss of production
Senegal delta	300,000	30,000	90%
Senegal valley	550,000	55,000	90%
Niger delta	3,000,000	2,700,000	10%
Niger valley	300,000	150,000	50%
Sokoto and Rima	100,000	50,000	50%
Hadejia Komadugu	380,000	38,000	90%
Logone	1,100,000	660,000	60%

(Modified after Drijver & Rodenburg, 1988)

Table 8. The impact of dams on fish, pasture, and agriculture production of African floodplains. From IUCN, 1990b.

quality and greatly modify the river's influence downstream (Crivelli et al., 1995; Postel, 1996). They alter the timing and volume of river flow, which reduces the sediment and nutrient transport downstream, alters temperature and salinity, and at times even increases the river's acidity due to plant decomposition (Fearnside, 1989, cited in Allan and Flecker, 1993). Riverine species richness strongly covaries with the mean annual discharge and the total surface area of a river's drainage basin (Oberdorff et al., 1995), and is influenced by habitat diversity, flow regime, temperature and channel morphologies (Gorman and Karr, 1978; Horwitz, 1978; Matthews, 1985; Schlosser, 1985; all cited in Oberdorff et al., 1995). Given that water diversion affects nearly all of these characteristics, the extensive water diversion occurring may profoundly affect African riverine species richness. The shallow soda lakes and other lakes in East Africa are also sensitive to hydrological changes (Melack, 1996).

The greatest biological cost of dams may be their impact on wetland-dependent animals. Dammed areas provide foraging sites for many wetland bird species but do not provide suitable shallow breeding areas (Williams, cited in IUCN, 1990b). Dams also affect floodplain-associated fish, many of which will only spawn if an annual flood occurs (Ward and Stanford, 1989). Annual flooding provides a rich food source for spawning fish and their young. The increased water level results in the release of terrestrial nutrients into the water, generating increased plant production, which in turn supports epiphytic organisms and dense colonies of creatures in the plant roots (Scudder, 1991).

Coastal lagoons and estuaries depend on an adequate freshwater level. A decline in freshwater can increase temperature and salinity, decrease oxygen, and subsequently kill fish (Salm, 1989). Loss of freshwater can also cause estuaries to silt up (Davies and Day, 1998) or suffer saline intrusion. Flooding can be beneficial to coastal ecosystems by increasing nutrient availability. The physical mixing of the floodwaters into the ocean brings up nutrient-rich deeper waters into the euphotic zone (Crivelli et al., 1995). Bernard (1990, cited in FAO, 1995) demonstrated that the quantity of suspended solids (made up of both organic elements and mineral sediments) is the limiting factor in primary production in estuaries.

Mangrove ecosystems have also been greatly disturbed by the reduction of freshwater inflows. The loss of such inflows affects the three most important factors in maintaining mangrove ecosystems: a sufficient amount of water, a sufficient supply of nutrients, and stability of the substrate. Mangrove ecosystems degrade without periodic pulses of freshwater. They can also be degraded by saline fronts caused by the dams.

- Decline of fisheries: Studies have shown that fish yield is directly related to river and catchment size, with rivers with extensive floodplains having a higher yield than those with smaller floodplains (Ruwa, 1996). Riverine fisheries: In addition to degrading riverine habitat, dams directly block fish migration, both of marine fish that spawn in rivers and riverine fish that spawn in marine realms. According to Cooper (1996), they can also "disrupt the hydrological and chemical cues needed to induce migratory and spawning behavior in fish". Finally, the profound changes caused by dams exacerbates the spread of exotic fish species. Floodplain fisheries: The economic impact of dams on floodplain fisheries is rarely considered when these projects are designed. Construction of the Kainji Dam in Nigeria resulted in the loss of 50% of the fish catches in lands extending to 200 km downstream of the dam (FAO, cited in Scudder, 1994). Lacustrine fisheries: Since lakes are dependent on riverine input for their water supply, dams also play an impact here. For example, the combined impact of water diversion along the Logoni and Chari Rivers (for irrigation) and extended drought has reduced the area of Lake Chad by 75% over the last 30 years (Postel, 1996). This lake and its tributaries support some of the richest fisheries in the world. Coastal fisheries: Rivers deliver freshwater, nutrients, and sediment to coastal lagoons and estuaries and the sea, providing important benefits to coastal fisheries (Postel, 1995). Dams greatly reduce all three of these factors. Studies from around the world have shown a direct relationship between the extent of river discharge and fishery yields in estuaries and deltas (Crivelli et al., 1995). Both the shrimp fishery in Mozambique and the sardine fishery of the Nile delta have been impacted by dams that reduced nutrient flow to the coastal waters (Da Silva, 1986, cited in Scudder, 1994; Halim et al., 1995). Dams in Western and Central Africa, for example, are estimated to have reduced sediment supply to lower catchment areas by 70% (Collins and Evans, 1986, cited in World Bank, 1994).

- Destruction of long-established indigenous patterns of floodplain agriculture, including irrigation and livestock production: Different types of floodplain agriculture have been practiced in Africa for several thousands of years, without apparent environmental damage (Scudder, 1991). The Kainji Dam caused the loss of over one thousand tons of yams in the lower Anambra basin (Awachie; cited in Scudder, 1994). In northern Nigeria, the construction of the Bakolor Dam resulted in an estimated crop loss of $7 million (at 1974 prices) on the Sokoto River floodplain (Adams, cited in IUCN, 1990b).

  In addition, poorly planned water diversion can increase a country's debt and erode river channels and coastal zones. It can leave residents of reservoir sites without homes, spread waterborne disease, and reduce the total amount of water because of increased evaporation from the reservoir and irrigated lands.

I. Global Climate Change

Although not immediate, global warming threats to aquatic biodiversity are serious indeed. Aquatic habitats will change more over the next 100 years than they have over the last 10,000. The Intergovernmental Panel on Climate Change (IPCC) estimates that the mean earth surface temperature will increase between 1-3.5°C over the next century. Sea level will rise by 15-95 cm. Although local stresses are of greater threat for the next 10-40 years, plans for mitigation and adaptation are needed now, since they will require several decades to take effect (World Coast Conference, 1993). Those ecosystems already stressed by human impacts are considered to be the most vulnerable (Markham, 1996).

Desertification: While human influences are the main cause of desertification, global climate change is likely to accelerate both desertification and increased periods of drought in sub-Saharan Africa (Loh, 1996), increasing the potential for conflict between humans and wildlife over access to water. This makes it even more essential to practice better water management techniques. A WWF study on climate change and Southern Africa suggests that the Okavango Delta will experience changes in habitat (WWF, 1996).

Rivers: Rivers are likely to experience reduced flow in areas with reduced precipitation or increased air temperatures (Figure 42). Two consequences are reduced habitat for fish and a reduction in the dilution of pollutants (Allan and Flecker, 1993). In addition, some streams may become warmer, killing off species that can tolerate only a narrow temperature range (Ruwa, 1996).

Figure 42. Global climate change is likely to cause reduced flow of rivers and warmer streams in some areas. © World Resources Institute.

Lakes: Global warming models suggest increases of 2-4°C for African lake basins, based on a doubling of CO_2. The warmer water will mix less than current waters, and retain less oxygen in bottom layers. Lakes that weakly overturn or that already have low oxygen activity, such as Lake Victoria, could experience a massive dieoff of benthic organisms (Cohen, 1995).

Wetlands: Wetlands are one of the most vulnerable ecosystems to global warming. A sea level rise of a few centimeters would flood huge areas of marshes and mudflats that are essential shorebird breeding grounds. The IPCC estimates that a one-meter rise in sea level would threaten half of the world's coastal wetlands of biological importance, while a warming of 3-4° would eliminate 85% of all remaining wetlands (Loh, 1996). A WWF report, *Climate Change Threats to Migratory Birds*, identifies Banc d'Arguin and the Zambezi valley as two of 15 critical global habitats most imperiled by global warming. Warming-related changes also include changes in estuarine salinity patterns which could dramatically impact coastal fisheries (WWF, 1995). Some wetlands could suffer the reverse problem: desiccation at edges (Hunt, 1996).

Mangroves: The main aspects of climate change that can be expected to have a negative impact are sea-level rise and changes in precipitation. Mangroves are particularly vulnerable to sea level rise, as sea level position is central to their functional ecology. Different species have different preferences of micro-elevation, which determines salinity and frequency of inundation (Ellison, 1996). The IPCC estimated rate of sea-level rise is nearly five times faster than the rate at which mangroves are able to accommodate, as determined from historical data over the last 7000 years (Ellison and Stoddart, 1991). Together, sea level rise, reduced rainfall, and groundwater depletion could lead to increased salinity, shown to reduce seedling survival and growth and decrease photosynthetic capacity (Ball and Farquhar, 1984). On the positive side, an increase in temperature and atmospheric CO_2 is expected to improve growth and litter production.

Marine: The marine effects of global warming -- particularly sea level rise, ocean warming, and an increase in the frequency and magnitude of tropical storms -- are expected to change the distribution and abundance of certain species; affect the health of ecoystems; and possibly cause decreased primary production in certain areas (Figure 43). <u>Sea level rise:</u> Global warming is expected to cause sea level rise both because of the thermal expansion of seawater and the melting of polar ice. Sea level rise could subsequently cause major changes in physical oceanography (Emery and Aubrey, 1991); flood low-lying coasts; and alter the distribution of habitats. This has clear implications for designating and maintaining marine protected areas. It also has human implications, as many capitals towns, and industries are located along the coast and vulnerable to sea level rise. <u>Warming of seasurface in pelagic waters, and the entire water column in nearshore areas:</u> Although corals may be able to adapt to increasing sea-level rise, their response to increased warming is potentially much more serious, and could cause bleaching and death, particularly in areas already stressed by human impact. While bleaching (expulsion of the coral's algal symbiont) is an adaptive response, if prolonged, it can be deadly. As many corals already live close to their upper temperature limit, long-term increases of only a few degrees can be lethal (OCA/PAC/UNEP/IUCN, 1992). [Note: a recent report suggests that corals can recover from *short* bleaching episodes by acquiring a different algal symbiont (Pennisi, 1998)]. Warming could also affect upwelling and decrease surface layer phytoplankton production (with corresponding effects on fisheries) (Lange et al, 1990; Bakun, 1990; Roemmich and McGowan, 1995; Williamson and Holligan, 1990). Warming can also affect both the timing and spatial pattern of migration for those marine species sensitive to ocean temperature gradients. Finally, warming also threatens to cause breaks in timing between ecological processes that are currently linked. For example, differential warming of atmospheric/terrestrial habitats and seawater (which is physically buffered from fast rates of temperature change) could cause shifts in the migratory patterns of bird species such that the migration no longer coincides with food availability. <u>Storms:</u> IPCC estimates that the number of tropical storms may increase by 50%, with a 20% increase in storm strength (Agardy, 1996).

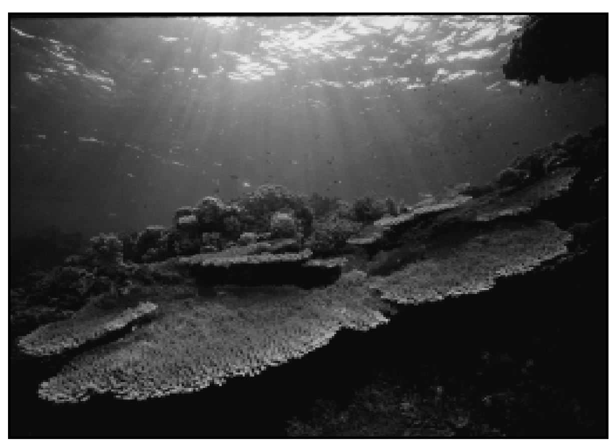

Figure 43. A rise in sea level resulting from global climate change can have significant effects on the abundance of marine species, the overall health of the ecosystem, and productivity. New England Aquarium, 1989. Photo credit: Paul Erickson.

J. Synergistic Effects

Wildlife seldom faces only one threat. Multiple threats (either multiple anthropogenic threats or a combination of anthropogenic and environmental stressors) often play a role in degrading aquatic ecosystems. More than one threat appeared to be substantially involved in 82% of extinctions of North American freshwater fish (Miller et al., 1989, cited in Allan and Flecker, 1993), and in 40% of currently endangered fish (EDF, 1994), whereas a single threat was clearly involved in only 7% of endangered species in North America. Our current understanding of how threats interact is limited. The stresses caused by a given threat can often render that system more vulnerable to other threats. For example, disturbed ecosystems seem to be more vulnerable to exotics than healthy ones (Baltz and Moyle, 1993; Turner, 1974, cited in EDF, 1994). A combination of anthropogenic and natural events led to: the near extinction of oysters in Chesapeake Bay, Maryland; the decline of the brown seaweed *Fucus vesiculosus* in the Baltic Sea; the invasion of the Chinese clam in San Francisco Bay, California; and the decline of coral reefs in Florida and the Caribbean (NRC, 1995).

Case Study: Multiple Threats to West African Mangroves

West Africa's 25,000 km of extensive mangroves and associated ecosystems (coastal lagoons, tidal estuaries, and deltas) are being rapidly degraded as a result of multiple human impacts, including: overfishing; sewage discharge; pollution from pesticides, fertilizers, and industrial waste; conversion of land for agriculture; fuelwood, oil and mineral extraction; land reclamation; and freshwater diversion. All of these threats are exacerbated by the rapid expansion of the coastal human population, growing at nearly twice the mean annual rate of 2.9% in the region. For nations bordering the Gulf of Guinea, over 60% of the industry is concentrated along the coast (UNDP, 1993). Of 14 lagoons/lagoon complexes in the Gulf, six are highly polluted in parts, with eutrophication a problem (World Bank, 1994). A strong littoral transport system in the Gulf may carry oil pollution, toxic, and solid waste from point sources upstream to other coastal countries, creating region-wide impacts. In the Niger Delta, mangrove deforestation has also caused serious erosion and flooding, destroying fishing villages along the mud coast. Why? Mangroves trap and consolidate sediments. When they vanish, sandy beaches and shorelines become exposed to wind and wave erosion.

Mangroves have been further stressed by the steady decrease in freshwater inputs from rivers impounded upstream. The loss of such inflows affects the three most important factors in maintaining healthy mangrove ecosystems: a sufficient amount of water, a sufficient supply of nutrients, and substrate stability. Water diversion has reduced the supply of sediments to the lower catchment areas by 70%, causing significant downstream effects (Collins and Evans, 1986; World Bank, 1994). For example, construction of the Kainji Dam in Nigeria resulted in the loss of 50% of fish catches extending to 200 km downstream (IUCN, 1990). Over 114 major dams are either underway or planned in the region (Ketel van al., cited in IUCN, 1990).

The rate of mangrove deforestation in many of these countries is extremely high, and complete loss of West African mangroves is a real threat. Loss of mangroves in West African nations to date averages nearly 57 % of the pre-agricultural area (WRI, 1993). Clearing of mangrove areas for agriculture, in particular rice cultivation, is common. The World Bank (1994) estimates that by 2025, 70% of mangroves in Africa will be deforested if no action is taken.

Over 9 million hectares of West African mangroves are interlinked with highly productive coastal lagoons, tidal estuaries and deltas, providing critical breeding grounds and nurseries for larval and juvenile stages of important fisheries species, and essential organic nutrients to these areas. Thus, mangrove deforestation results in a loss of habitat and species diversity, not just within mangroves, but in these linked ecosystems as well. Declines in the production of demersal species along the Coast of Guinea are generally the result of a loss of mangroves, pollution and overfishing. Overfishing by itself, however, can have dramatic effects. Lagoon fishing in Cote d'Ivoire collapsed following the conversion of an artisanal fishery to a largely foreign-owned commercial one. Between 1979 and 1981, landings of the most abundant species, Ethmalosa imbricata, in Aby Lagoon, declined by 90% (World Bank, 1994).

Chapter 6.
What Can Be Done?

Successful conservation efforts in Africa will require careful tailoring to the countries, regions and communities involved. New England Aquarium, 1998. Photo credit: Mark Chandler.

A. How Should Sites Be Selected For Conservation Action?

"Common sense, and sensitivity to the true needs and abilities of the country, and its people, should be applied to the selection of sites."

Salm and Price, 1995

Although aquatic biodiversity conservation is important in every African county, setting priorities for conservation is a practical necessity due to limited conservation dollars and human resources. The success of any action towards conserving biodiversity and achieving sustainability will depend on careful thought given to the countries, regions, and communities chosen, in order to ensure that funds and technical assistance will be used well. McClanahan (pers. comm.) notes that no amount of money will conserve areas that local people are not committed to conserving. I would add, nor will conservation work in areas with counterproductive economic or sectoral policies.

To date, most global or regional priority-setting efforts have focused on terrestrial areas (reviews: Johnson, 1995, and Miller et al., 1995). More recent efforts, however, have addressed aquatic ecosystems (e.g., Olson et al., 1997 for Latin America). Salm and Price (1995) review criteria for selecting marine protected areas. Recent priority-setting efforts in Africa by World Wildlife Fund-U.S. have included both freshwater (Abell et al., 1999) and marine ecosystems (forthcoming, contact Eric.dinerstein@wwfus.org).

It is important to recognize that no single approach or weighting will work for all organizations or fit all conservation objectives. The inclusion or weighting of certain factors depends on the mandate of the organization, the scale of the effort, the conservation goals, the values of the decision-makers, and even the scientific background of the individuals involved. For example, an emphasis on species richness may lead to the neglect of important and productive ecosystems that have a limited number of species (Johnson, 1995). A taxonomist may consider species diversity to be the most important factor, while a marine biologist might rank interdependent ecosystems or productivity more highly, and a development agency might consider developmental importance to be the most important consideration. Hence, to lend transparency and credibility to any priority-setting effort, one needs to explicitly state: 1) the conservation goals and objectives, and 2) the criteria used.

As an illustration of regional priority-setting using just biological distinctiveness and conservation status as the sole criteria, I have listed the indicators used by Olson et al. (1997) in Latin America below. Indicators under biological distinctiveness included species richness, endemism, and ecosystem diversity. Conservation status indicators included:

- degree of fragmentation (barriers to movement of aquatic organisms such as dams, etc.);
- degree of habitat loss;
- water quality;
- hydrographic integrity;
- degree of alteration of associated landscape (e.g., catchment); and
- exotic species, where applicable.

I favor an integrative approach (both with respect to criteria and stakeholders) to develop a broader support for aquatic conservation. This means considering socioeconomic factors, conservation feasibility, and community/government interest *in addition to* biological criteria. Why? As Johnson (1995) notes, "Biologists typically involved in setting conservation priorities often fail to realize a simple fact of life that helps to explain why conservation priorities are so often ignored. In most circumstances, effective conservation is ultimately, for better or for worse, a political process whose chances of success are improved through wider participation." Conservation projects that are successful often hinge on a catalyst for action (be it a charismatic person or disastrous event), and motivated local leaders (Runnells, 1996).

An integrative approach is particularly important in Africa, where the people have a long-lasting connection to and relationship with their biological resources (BSP, 1993). Miller et al. (1995) note that priority-setting efforts have often failed to include non-biological factors that are critical in making conservation decisions, and neglected to include key stakeholders in the priority-setting effort, although more recent efforts have attempted to address these issues (e.g., BSP's priority-setting terrestrial effort in Latin America, BSP et al., 1995). Ideally, priority-setting efforts should consider biodiversity in all sites, including natural areas, as well as managed ecosystems and human settlements (Johnson, 1995).

Any organization with an interest in helping to conserve and sustainably maintain Africa's aquatic resources needs to consider the minimum following criteria: a site's biological diversity, its ecological importance, the degree of threat, its developmental importance, and the feasibility of conservation. Conservation feasibility is an important consideration right from the start, for, as Johnson (1995) notes, "The conservation of biodiversity is less a question of biology than of social, economic, and political factors." Conservation feasibility will also influence the type of conservation approach to make in a given area. Any priority-setting effort, however, should be re-evaluated at regular intervals.

Each of these criteria can be further broken down as indicated below. This rather comprehensive list summarizes criteria used by a variety of sources. Obviously, the number of criteria used needs to be manageable, reflecting both an organization's mandate and its conservation objectives. For example, criteria used to determine the location of the Bunaken Islands Marine Park in Indonesia included: habitat variety, unique coral habitat, coral cover, species diversity and intactness (Salm, 1989). Criteria can be numerically summarized to provide a quantitative aspect to priority-setting, if necessary. One difficulty in Africa is the extreme unevenness of information available. Some sites may appear to have more species simply because more taxonomists or ecologists have worked there.

Conservation feasibility

- Likelihood of reversing or mitigating threat
- Socio- economic feasibility - will local people support such a project?
- Ecological feasibility - is the area large enough to successfully conserve what is intended?
- Are there potential collaborating organizations?
- Institutional feasibility - how supportive is the government and/or community? How supportive are government policies? Does the government have the potential to implement a project or is it overwhelmed with other donor efforts?
- How committed is the government to improving its institutional capacity? What is the level of training?
- History of past conservation efforts in country.
- Land tenure patterns. Are there land disputes at the site? Is land ownership well defined at the site?
- What conflicts of interest may derail a conservation project at the site? Can they be resolved?
- Opportunism - do existing conditions provide justification for action now?

Biodiversity criteria

- Global, regional, and national importance
- Diversity of habitats
- Species diversity
  - species richness
  - number and percent of endemic species. Note that endemism is rare in marine species. Where it occurs, it should be given higher importance (Holthus and Maragos, 1995).
- Diversity of higher taxa (e.g., phyla, class, order, family, genera). In general, richness and uniqueness at a higher taxonomic level should be given more weight than at the species level.
- Scientific importance

Figure 44. Setting priorities for conservation is necessary due to limited conservation dollars and human resources. Photo credit: Dennis Zemba.

Ecological criteria

- Importance of ecosystem for ecological life-support systems and essential ecological processes. Some species-poor areas, such as seagrass beds, support large food webs (Agardy, 1994a).
- Naturalness of the ecosystem - e.g., pristine vs. degraded. How much has the area changed by human influence?
- Ecosystem contains feeding, breeding, nursery or juvenile areas for wildlife
- Interdependence of the ecosystem with others. If a given ecosystem strongly depends upon another ecosystem, both ecosystems should be given high priority for conservation. For example, coral reefs provide nutrient-rich food for pelagic fish, and mangroves provide detritus for both lagoon and reef ecosystems.
- Ecological rarity (uniqueness) of the ecosystem
- Ecosystem contains habitat for rare or endangered species. Note that rare species can be divided into three categories: taxa that are rare across large ranges (e.g., some of the whales, marine turtles); taxa that are rare because their ranges are limited (endemic taxa); and taxa that are locally rare, but common in another country.

- Ecosystems containing species that are both rare and threatened (either by ecosystem deterioration or overexploitation) should be given higher priority than ecosystems providing habitat for rare but non-threatened taxa.
- Integrity of the area - is it a functional unit that is ecologically self-contained?
- Productivity of the ecosystem
- Representativeness of a given habitat type

Degree of threat

- Immediacy of threat
- Rarity of ecosystem because of human-induced loss or degradation
- Degree of existing protection for particular ecosystem
- Richness of rare or threatened taxa
- Number of threats

Developmental criteria

- Importance of ecosystem and its resources to commercially important species - e.g., number of fishermen dependent on a habitat and its resource
- Potential value for tourism development
- Subsistence importance - this includes food, fuel, medicines, building and handicraft materials, fiber, perfume, ornamentation, dyes, poisons, fertilizers, mulch, fodder, etc., the replacement of which, from market sources would be expensive.
- Socio-cultural importance (e.g., traditional importance due to historical, cultural, educational, recreational, spiritual, and aesthetic reasons)
- Public health concerns - will conservation benefit waters used for drinking, bathing, fishing?
- Educational importance - is the site accessible enough to help educate the public about the value of aquatic resources?

B. Improve Institutional Capacity

African governments, NGOs, and communities need financial and technical assistance to develop integrated institutions and policies and make such institutional change happen. Integration is needed both horizontally, across sectors, and vertically, across various levels of government, from regional to municipal. Integration means: spatial integration (between land and waters); integration of objectives (taking into account ecosystem, economic, and social equity considerations); and jurisdictional, legal and decision-making integration (among user-groups, sectors, various governmental levels and nations) (Cicin-Bain, in IOC, 1994; Vallega, 1998).

Support regional, or transboundary, collaboration. Collaboration is particularly important in addressing problems of exotic plant control, water use rights, and agricultural/industrial pollution. While regional discussions have been taking place in Africa with greater frequency, it is now time to capitalize on these discussions and work toward effective regional collaboration. Mechanisms for conflict resolution in addressing transboundary water resources need to be promoted before conflicts arise from pollution and water diversions that could impact national security.

Freshwater: To date, there is no integrated transboundary management of the following river basins: Nile, Niger, and Zambezi (Acreman and Hollis, 1996). While Senegal has developed an integrated program for the Senegal River that tries to balance social, economic, and ecological interests, the plan is only for the left bank! Clearly, this plan will work only if Mauritania and Mali support a similar program for the right (Vincke, 1996). All of the Great Lakes could benefit from active support for integrated management.

Figure 45. Integrated transboundary management is needed for a number of African river basins, including the Nile. Photo credit: Dennis Zemba.

A regional approach would also be invaluable for the control of aquatic alien species. Hamman (1997) strongly recommends that the Southern African Developing Countries (SADC) develop a regional policy towards preventing further importation of exotics and controlling existing ones. No Southern African country has yet developed a national strategy or policy to address the problem, although South Africa recently developed an inter-provincial task group to begin the process.

IUCN (1997) notes that there are 10 separate bi- and multilateral initiatives to address water hyacinth control in Africa that would benefit from coordination. In Lake Victoria, for example, an active water hyacinth effort is stalled due to disagreement among the governments about ways to tackle the program. IRIN (1997) comments: "While experts and governments squabble over funds and methods, the weed threatens to swamp all vital waterways and freshwater facilities in the region."

Marine: The East African countries developed a plan for regional marine action that now needs to be supported (Obura et al., 1995). Regional effort is particularly critical for threatened migratory species such as sea turtles and marine mammals. A regional effort coordinating fisheries management, pollution control coupled with a network of small-scale, community-managed marine reserve development in pilot areas affords the greatest chance of success.

> In August, 1997, the Secretariat for Eastern African Coastal Area Management (SEACAM) started work (Intercoast Network, 1998). This regional organization helps build the capacity to implement integrated coastal management programs. Its goals are better coordination and collaboration between agencies and stakeholders, and sytematic exchange of lessons learned. It has five program areas: 1) capacity building, particularly for local NGOs; 2) database management of East Africa coastal zone management programs, institutions, and individuals; 3) environmental assessment; 4) public sector management, and 5) sustainable financing of coastal management programs. The organization works with stakeholders from Comoros, Eritrea, Kenya, Madagascar, Mauritius, Mozambique, Reunion (Fr.), Seychelles, South Africa and Tanzania. The database will be available both in print and on the Internet. Contact David Moffat for more information (mdmoffat@zebra.uem.mz).

Within a country, enhance inter-agency coordination and management among the myriad of agencies that impact water areas. Better coordination is also needed across different levels of government with mandates affecting water and aquatic resources to ensure that they are not working at cross purposes. Local experts should be consulted to provide guidance on the roles and mandates of existing public and private institutions, and which ones would be likely to benefit the most from capacity-building measures. Wetland management institutions, in particular, should be strengthened, ensuring that wetland managers are involved with land-use planning decisions concerning the catchment and surrounding areas.

Strengthen the institutional capacity of local NGOs involved in aquatic conservation. Local NGOs in this area are rare, but emerging (e.g., Kenya's Clean Water Alliance, OSIENALA of Kenya (aka Friends of Lake Victoria), Nigeria's NGO Coalition for the Environment, the Nigerian Conservation Foundation, Okavango Liason Group). (The International Rivers Network provides a directory of NGOs, technical experts, and other key contacts working on river and watershed issues around the world. Contact http://www.irn.org.) Those that exist are often young and inexperienced. Donor agencies and international NGOs could provide short-term training in: project planning, management, monitoring, and administration; public awareness-raising of aquatic conservation issues; how to model costs and benefits of various development options, and how to be more effective in the political arena. Also, to build trust between government officials and local NGOs, one could support short-term placement of personnel from one organization in another.

> The Secretariat for Eastern African Coastal Area Management (SEACAM) is planning a five-week training program to improve the project development and management skills of local NGOs. The program will cover: identifying potential funding sources, preparing project proposals; project development, management, monitoring and evaluation; financial administration; and communication and dissemination (Intercoast Network, 1998).

Improve the institutional capacity to 1) set water quality standards and 2) monitor water quality. National aquatic monitoring systems need to be developed to measure, among others, nutrient and toxicity levels of agricultural and industrial contaminants, sedimentation, turbidity, and habitat destruction. Training needs to be provided in analytical techniques.

Carpenter and Cottingham (1997, cited in McAllister et al., 1997) suggest the following indicators to assess a

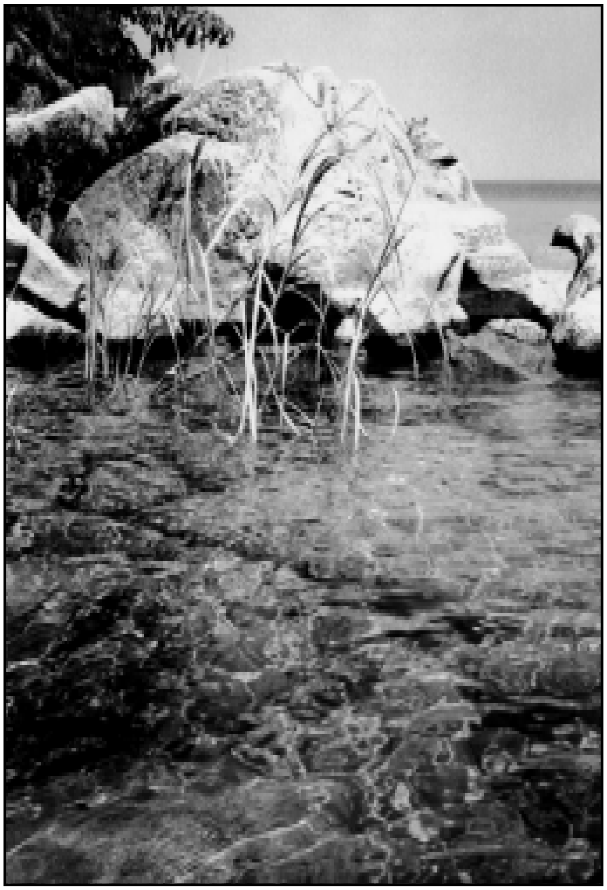

Figure 46. To maintain water quality, national aquatic monitoring systems need to be developed and people need to be trained in analytical techniques. Photo credit: Caroly Shumway.

lake's ecological health: livestock density in the watershed (which measures phosphorus inputs); wetland area/ unit lake area; proportion of riparian zone with forest or grassland (which measures capacity to buffer nutrient input); lake color and humic content; piscivore growth rates (which measures control of planktivores); partial pressure of CO_2 in surface waters (which measures ecosystem metabolism); and oxygen depletion (to assess level of eutrophication). The indicators can be obtained from land use records, from simple sampling methods, or from remote sensing.

Okemwa (1995) suggests the following marine monitoring: 1) regular trawling to measure changes in fish communities; 2) plankton surveys to measure changes at this trophic level, and 3) measures to assess pollution.

Assist with training and education in fisheries and aquatic conservation science, particularly to improve the capacity for monitoring of fish stocks. The need to monitor stocks is urgent, particularly in inland waters. Provide training in co-management methods and participatory rural appraisal methods. Consider establishing scholarships, with the requirement that awardees apply what they learn by providing a certain numbers of years of service in their country following completion.

Provide technical and economic assistance for biological control of exotic plants.

Provide financial and/or technical assistance to community-generated conservation and management initiatives: initiatives that start from the ground up.

C. Encourage Appropriate Policies

Encourage the development of more integrated policies in water and landuse planning.

<u>Support integrated river basin planning and development</u>. Consider all stakeholders in the process, including local NGOs. NGOs need to become involved during initial planning stages so that their views are taken into consideration right from the start (Manley and Wright, 1996).

IUCN (1990b) recommends that countries use the following practices in land-use planning of river basins:

1. Quantify the hydrological balance of the water basin.
2. Identify all of the major ecosystems in the basin, products and services obtained from each part of the system and their minimum environmental requirements for being sustained.
3. Determine the total economic value of the basin's water resources and aquatic ecosystems. Determination may help persuade decision-makers to conserve aquatic systems[1] (Goulder and Kennedy, 1997). If determination of the total economic value is impossible, then, at a minimum, planners should estimate the economic costs of loss or change in ecosystem functioning and value as a result of developmental conversion (Goulder and Kennedy, 1997). CATIE (Tropical Agricultural Research and Training Center), in collaboration with IUCN, is preparing a methodology for the economic evaluation of wetland ecosystems.
4. Integrate compatible uses, separate incompatible ones, and zone accordingly.
5. Identify the short- and long-term environmental impact of any proposed development change. Consider

[1] For example, inadequate valuation of the goods and services arising from mangroves, leads normal market forces to almost always favor mangrove conversion. The economic value of mangroves can be determined relative to its contribution to nearshore and estuarine fisheries, shellfish, and crustacean production.

mitigative actions. For example, in areas where reclamation of mangroves for agriculture is both necessary and sound (i.e., the area has appropriate soils), leave some mangrove systems intact so that they can continue to provide their services.

As the principles, successes and failures of an integrated approach are probably best understood for **integrated coastal zone management (ICZM),** these are described in detail below. More detailed descriptions of coastal zone management can be found in Clark (1992) and Pernetta and Elder (1993). Two recent books provide useful case studies -- both successes and failures -- in coastal management programs in the U.S. (Needham, 1991) and South America (Robadue et al., 1995). UNDP's Strategic Initiative on Ocean and Coastal Management, approved in Dec. 1997, will attempt to document and disseminate best practices worldwide (Intercoast Network, 1998).

Interested donors, NGOs, and foundations could consider supporting emerging coastal zone management programs in Africa. A number of African countries have identified coastal areas as priority areas in their NEAPs and/or have expressed interest in an integrated coastal zone management approach: Gambia, Guinea-Bissau, Ghana, Nigeria, Mauritius, Comoros, Seychelles, Mozambique, Tanzania, Eritrea, South Africa, among others (World Bank, 1996). The World Bank is working to promote ICZM in Ghana, Cote d'Ivoire, Tanzania, Seychelles, Comoros and Mauritius (Linden and Lundin, 1995b). African countries are at various stages in developing such management. Some lack the legal and institutional framework and the human capacity to develop an integrated coastal zone management program at this point (Gaudian et al., 1994); some, such as Kenya, are beginning a pilot integrated effort (Mwandotto, 1996), while others remain unconvinced that ICZM is a useful planning tool. (See the World Bank, 1996 for an assessment of Integrated Coastal Zone Management in East Africa.) The Zanzibar-based Western Indian Ocean Marine Science Association (WIOMSA) sponsored a workshop on local and community-based integrated coastal zone management in March, 1998 (Intercoast Network, 1998).

1. Principles of Integrated Coastal Zone Management

Integrated coastal zone management tries to balance the use of coastal resources such as fisheries and coastal development, while maintaining habitats, biodiversity and ecosystem health. The four most common reasons for starting an ICZM program are: to boost fisheries productivity; to increase tourism; to protect coasts from natural disasters; and to sustain mangroves (Reid et al., 1985). Generally, governments are not motivated to do such planning until there is a conflict among users or a serious decline in a resource (Reid et al., 1985). Waiting for a crisis is unfortunate, though, as coastal development without planning often locks future development into limited options. Ideally, some pilot CZM projects would address areas which have been little impacted; others would address sites with pressing environmental and resource management problems.

Process is critical.

"Consult until people are exhausted."
G. Keller (IUCN, 1996).

According to Clark (1992), a simple coastal zone management program includes the following:

- establishing **arrangements**, including identification of the problems, policies, goals, legal authorization, and an enforcement mechanism;
- a **coordination** office; and
- a **mechanism for review** (for development permits, environmental impact assessments, etc.)

It is not easy to get different groups to trust one another and work collaboratively, particularly when there is longstanding animosity and mistrust. Graham Kelleher, actively involved in management plans for Australia's Great Barrier Reef, notes that one has to be prepared to be "insulted, contradicted, even threatened... You've got to go through the process of distrust before you get to trust" (IUCN, 1996).

Resource users need to feel that the program has: developed a broad understanding of the problems, considered various options for meeting the objectives, acquired a scientific understanding of local coastal dynamics and the effects of development, and most importantly, considered their input (Needham, 1991). Above all else, users need to feel that the decision-making process is fair and open (Needham, 1991). As noted by Clark (1992), "Strong political opposition by fishermen or others who gain their living from marine resources could stall an integrated coastal zone management program. Many of these sectors will have little to gain from coastal resources conservation, and they may see the... program as a problem rather than as an opportunity; e.g. transportation, housing, military, agriculture and manufacturing. To ensure a minimum of opposition from these sectors, strong persuasion may be needed along with assurance that the policies to be formulated will treat them fairly."

Basic guidelines for developing effective group dynamics (modified from Pinkerton, 1994) include:

1) Use a convener perceived to have appropriate stature, and a facilitation style that is locally appropriate;
2) Include representation from all relevant stakeholders;
3) Develop a shared definition of problems and expected outcomes;
4) Undertake joint tasks;
5) Articulate the values that guide each party's interest in the process; and
6) Establish formal rules about how decisions are reached.

Start with a restricted set of problems.

"Planners know that the best of plans often remain on bookshelves and are not put into practice, usually because of a lack of political commitment to the socio-economic changes the plan would require. It is much easier for decision-makers to authorize a planning initiative than to implement it."
Clark, 1992

What seems most daunting about coastal zone management is its extent. How does one begin to implement a program that includes the management of both land and sea? First, such a process is easiest if it is included as part of a national or regional planning effort (World Coast Conference, 1993). Second, although ideally one would consider all lands that influence coastal waters (i.e., all watersheds that drain into the sea), in practice, this can doom a coastal management program due to political and economic resistance.

Experienced marine managers suggest that it is best to begin with a limited program: either limited geographically (e.g., focusing on a single region within a country) or limited in the scope of the controversial problems to be tackled with, or both. For example, instead of incorporating all watersheds into a given ICZM project, policy-makers could include only those watersheds that are the sources of excessive chemical pollution and/or sedimentation (Clark, 1992).

Why limit the number of issues to tackle? Coastal management programs can be derailed by powerful economic interests. The only way to combat this is to develop strong local support through small successes, such as focusing on shore erosion or designating critical habitat for reserves. Tackling simple problems first is also one way to test which processes work and which do not. Finally, simple demonstrated successes help to build community support and help develop local and national expertise (Olsen et al., 1995). For example, the coastal zone management program in Ecuador undertook several local demonstration projects in conjunction with national policy efforts.

How does one sort out priority problems to tackle? Ask the following questions (Robadue, cited in IOC, 1994):

- Is the problem a coastal resource management problem?
- Will addressing this problem have a positive effect on solving other problems?
- Will addressing this problem be well-received by the community?
- Is it simple to carry out?
- Does the problem affect a diverse group of people?
- Will the solution actively engage the community?

Ensure local participation.

To develop political support for the goals of coastal management, it is best if local people are active players in all parts of the program, giving them a feeling of control over the process (Figure 47). At a minimum, all stakeholders should be provided with a forum to express their goals and concerns, and interested representatives of the various stakeholder groups should be involved in both planning and implementation. It is important to recognize traditions and social norms in designing a participatory framework (World Coast Conference, 1993). (See page 80 for more recommendations on ensuring local participation.)

Figure 47. To develop political support for coastal management, local people should have active roles in all parts of the program. © World Resources Institute.

Consider which management structure will work best according to local values and authority.

Designing management structure according to local norms is the easiest way to ensure support and compliance with regulations. Hence the most appropriate structure for any given region or country should be reflective of who has power of authority in an area -- be it by legislative fiat or culturally. For example, numerous states in the United States have experimented with coastal zone management and come up with different management structures. In some states, policy decisions are made by technical experts, while others use councils made up of citizens or local government representatives (Needham, 1991). Ideally, the size of the management unit should make ecological sense, such as defining the scope of management to a given watershed. In this way, fishermen, landowners and other users are more likely to see that they have certain common interests and to be supportive.

In developing an integrated program, it is instructive to consider why previous attempts have failed. There are at least five main reasons why failure is so common:

Economic interests are powerful: Wealthier stakeholders may feel that either they will derive no benefit from coastal zone management or that it will be costly to them, and they may be right, particularly if their economic gain was due to a common property resource. Thus, such groups may choose not to get involved in the management process or may actively fight development of coastal management. For example, Ecuador's Coastal Resources Management Program had difficulty establishing a productive relationship with shrimp mariculture industry despite repeated efforts (Olsen and Coello, 1995). Only a few of the owners of large shrimp farms expressed any interest in an integrated planning process. The owners had access to common property resources for less than $10/ha, compared to potential net returns of up to $2000/ha (Southgate and Whitaker 1994, cited in Olsen and Coello, 1995).

What can be done? In many instances, "apparently competing sectoral interests can, through small modification to their approaches and/or operation be made compatible" (Pernetta and Elder, 1993). For example, both mariculture and tourist swimming require good water quality. However, it is realistic to acknowledge that some coastal resource uses will <u>always</u> be incompatible with others, and that compromises will be necessary.

Political will is lacking: As is clear from the above discussion, just presenting the scientific rationale for a management decision is not enough: powerful economic interests can act to derail legislative efforts (Needham, 1991). Hence, both public acceptance and political astuteness are necessary to achieve management goals. As Clark (1992) has noted, "Coastal resources conservation and biodiversity preservation are more often restrained by political uncertainty and bureaucratic inertia than by a shortage of scientific information."

Important stakeholders are excluded: Coastal planners need to include all stakeholders likely to be affected by coastal management as well as those stakeholders with authority over people's behavior regarding coastal resources. Depending on the area, the list could include fishermen, tribal chiefs, religious authorities, port authorities, housing departments, tourist industries and economic development planners.

Lack of authority is provided to the managing agency: An integrated coastal zone managing agency <u>must be part of, or have influence over</u> all relevant economic development sectors, including finance, agriculture, economic planning, commerce, fisheries, tourism, forestry, and transportation (Clark, 1992). It is not easy to get institutions to cooperate in integrated activities as they invariably defend their turf. Yet it will often be necessary for the coastal managing agency to take a position on coastal development or conservation that negatively impacts one or more of these sectors. If the agency has little power over these groups, management will fail. Generally authority over the coastal zone requires centralization such that the managing agency is above the level of individual ministries or departments.

Sense of community is weak: Managing coastal development is easiest with strong communities where resource users have a sense of obligation to their local group, or where tenurial rights hold over coastal resources. Experience in the U.S. suggests that "society is not willing or able to halt the development process when land is fragmented into thousands of private holdings," particularly in areas undergoing rapid residential growth or rapid development for tourism (Needham, 1991). In these situations, political astuteness and public support are even more critical.

Geographic scope of integration is too limited: Coastal planners need to address problems both on land and in the sea, such as nearshore pollution problems or overfishing.

Other problems can derail integrated coastal zone management programs, as detailed by Hildebrand (1989, cited in Clark, 1992):

- There was a lack of agreement on a satisfactory definition of the coastal zone;

- The coastal zone was treated as a common property resource;
- There was little awareness about coastal zone problems;
- There was no clear motivation for integrated coastal zone management;
- Administration was fragmented;
- Goals were not clearly articulated;
- A short-term management approach prevailed instead of long-range planning;
- There was inadequate information on which to base decisions;
- There were attitudinal problems; and
- The program ran against the political and economic grain of the time.

Finally, an integrated approach is neither easy nor quick. Case studies of nine U.S. coastal zone management efforts showed that none had achieved their goal of environmental protection and conservation after ten years of effort (Needham, 1991)! However, they had achieved some degree of developmental planning, which is a positive start.

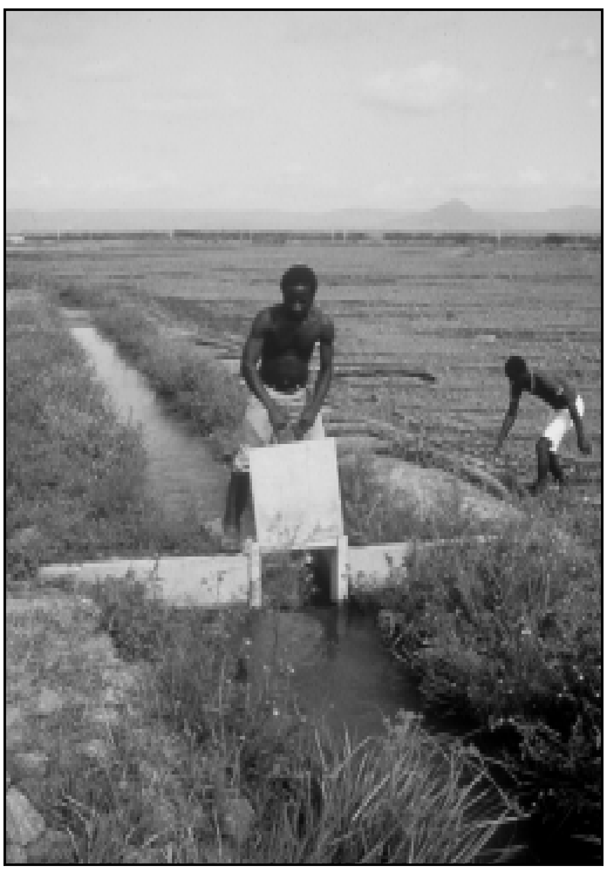

Figure 48. Methods of participatory rural appraisal. World Bank, 1994. From Heywood, 1995, © United Nations Environment Programme.

Assist in the development of national economic and sectoral policies which encourage sound water use, conservation of wetlands and other aquatic ecosystems, and reduction of pollution in these areas. An intersectoral policy framework is needed. Review existing water, forestry, agricultural, tax and other relevant policies to determine how they contribute to the waste and misuse of aquatic resources and loss of aquatic habitat. In particular, identify the impacts of current agricultural drainage policies on wetlands (IUCN, 1990b).

New policies may be needed to: ensure that the total water use is within sustainable limits for both human and ecological needs; establish water quality standards to maintain ecosystem support services and protect human health; establish reasonable limits to water quantities for different users (domestic, industrial, and agricultural); and increase the efficient use of water, particularly for irrigation. In arid environments, for example, farmers can save water with drip or root irrigation lines or low-pressure sprinklers that reduce loss from evaporation, and by timing irrigation releases to more closely match a crop's water needs (Postel, 1995; Bethune, 1996). Provision of tax incentives can encourage the installation of such systems. A number of NGOs and other developmental organizations are working to improve the productivity of indigenous irrigation along floodplains, which takes advantage of the natural flooding process (Adams, 1996).

Perhaps the most important way to conserve water is to price it accurately, eliminating subsidies such that the price reflects the capital, running and environmental cost of providing water. Similarly, economic activities that benefit from the ecological services provided by aquatic ecosystems should be charged for those services. A portion of the fees can be used for conservation efforts. For example, a fee could be placed on fisheries to protect wetland areas, since fisheries are directly supported by the breeding and nursery grounds of many wetlands. With accurate pricing, financial stability can be incorporated into aquatic conservation programs.

Consider market-based incentives, as described in the box below.

Help develop policies limiting and regulating the introduction of exotic species. Donors should examine their own policies in this area, such as distributing tilapia for aquaculture, and not contribute to the problem of species introduction. Given the historical evidence of ecological damage from introduced species, introductions should be avoided, if possible. Native species should first be evaluated for aquaculture purposes before considering the introduction of exotics. However, if biologically, socially,

A New Approach: Using Market Forces to Protect Aquatic Biodiversity

Market-based incentives can encourage the conservation of both water and aquatic flora and fauna. Such an approach can include allocations, tax incentives, the charging of user fees, and the establishment of property rights to what were previously considered common property resources. Examples of two such mechanisms are described below.

Compensated water transfers -- Policy makers can set up economic incentives to encourage equitable and efficient water use. The use of market mechanisms to meet new incremental demands can help reduce the pressure for additional and environmentally destructive water projects. If it costs money to increase water use, agricultural interests, cities and villages have an incentive to invest in water conservation programs. Such an approach has recently been tried in the Central Valley of California. This watershed provides riverine, wetland, and estuarine habitat critical to the survival of a diverse range of aquatic and riparian species. Today, however, only about 10% of the original 4-5 million acres of wetlands remains (Williams, 1989). The construction of dams on every river and the diversion of water for agricultural and urban use greatly reduced and altered habitat in the Central Valley watershed, and led to severe population declines for many of these species (EDF, 1994). In 1992, the Central Valley Improvement Project was enacted. The act provides economic incentives for water users to voluntarily transfer their water to other environmental, agricultural or urban uses for a price. The act also created a restoration fund financed by charges on water users (including hydrological power users) to help achieve habitat restoration and the purchase of water for wildlife needs. The end result is that wildlife needs are now placed on more equitable footing with other water users.

Tradeable non-point pollution permits -- Policy makers can also encourage the reduction of water pollution through tradeable pollution permits. These permits grant flexibility and control to individual water users in making business decisions. First, the total level of allowable pollution for a sub-basin is determined based on water quality standards. Second, individual allocations of the total maximum pollution load are divided equitably among water districts or individual users, taking into account various needs. Permit holders are allowed to trade (buy and sell) portions of their allocations to other districts or water users. Thus the resource users themselves determine the most appropriate measures for achieving that objective. In certain cases, it may be more cost-effective to buy additional emission permits than to reduce pollution emissions. Since there is a cap on the total amount of allowable pollution, this means that pollution emissions will be reduced elsewhere. Two caveats of such a system are: 1) it will only work in those countries that are able to monitor and enforce pollution control efforts; and 2) somehow, permits need to be allocated in such a way as to compensate for the unequal environmental effects caused by pollution discharges upstream relative to charges downstream. Pollution emissions upstream result in a greater pollution load for a longer stretch of river.

and economically convincing arguments can be made that exotic species must be introduced into a particular aquatic system, wherever possible, the species introduced should be one that already lives in the drainage area of the lake. *Aquaculturalists should adopt the precautionary principle, and assume that any introduced aquaculture stock will eventually escape into the wild.*

It is difficult to eradicate species, once introduced. However, the introduction of exotics can be <u>controlled</u> by: assessing all water engineering projects for their potential impact upon the spread of exotic aquatic species; signing international agreements banning the introduction of exotic species in aquatic areas shared with another country without express approval; ensuring that no introductions are undertaken without analysis of the impact of such introductions in other areas as well as studies of the life history of the candidate species in its native range; and attempting through research and legislation to reduce the number of species being transferred to new countries and drainage basins via ballast water.

D. Involve the Community

"It is becoming obvious that the key to protecting a cherished landscape lies within the communities that call it home."

IUCN (1993)

1. Integrated Conservation and Development Projects

Integrated conservation and development projects (abbreviated as ICDP or ICAD) are a popular approach for conservationists today. ICDPs attempt to protect biodiversity by using some component of the biodiversity to benefit local people, thereby generating local support. This is done either by developing income-generating activities within a protected area or adjacent to a protected area to reduce pressure on the protected area. The specific objectives of ICDPs are to: "1) develop and ensure environmental protection and management of an area over the long term; and 2) produce an improvement in the quality of life of the local population that is noticeable to them and compatible with conservation of the resource base" (Ack, 1991).

Certainly, conservation efforts are more easily accepted if local people perceive that they benefit. ICDPs, however, are not appropriate projects everywhere or for everyone. They are challenging and time-consuming. Some sites may warrant different conservation measures, ranging from nation-wide efforts (e.g., effecting economic or natural resource policy or legislative changes which can have a large impact in a short period of time) to site-specific efforts (e.g., working with church groups or traditional leaders to protect an area for spiritual or recreational purposes or to encourage behavioral change in resource exploitation). In sum, the conservationist should consider ICDPs as one tool in their toolbox. Perhaps the most useful benefit of a small-scale project such as an ICDP is two-fold: 1) to establish local credibility of the agent of change; and 2) as a model for regional or national efforts. In sum, thoughtful consideration needs to be given to ensure that ICDPs are established where they are most likely to succeed.

Kremen et al. (1994) reviewed 36 ICDPs. Only five demonstratively contributed to wildlife conservation to date. Alpert (1996) details why some African terrestrial ICDPs succeeded (in community development) while others failed. All of the five ICDPs he reviewed received income from tourism or hunting. Those that succeeded had governmental support, were easily accessible by tourists, had active community involvement, and had compatible local traditions. Conservation benefits included a reported reduction in illegal hunting and improvement in local attitudes towards conservation. Tourism revenues generated community benefits at two sites, "where the government had a nationally mandated financial policy to collect revenues, and a local administrative structure to disperse them" (Alpert, 1996).

Although ICDPs can be the most appropriate conservation approach at a given site, too often, little thought goes into addressing their economic, ecological, and social pitfalls. The pitfalls largely come about because of the following underlying problems (Shumway, 1993): 1) the *different agendas* that each stakeholder -- the conservation group and the landowners -- bring to the table; 2) the *unstated (and unproven) assumptions* upon which ICDPs are often based; 3) the *inexperience of environmental groups in development*, resulting in project failure; and 4) the *broader economic and sectoral policy issues that drive resource exploitation*. These pitfalls are discussed in some detail in hopes that the lessons derived here will aid in the design of more successful projects.

The Unstated Assumptions: ICDP projects are often based on implicit assumptions, which, if wrong, have serious implications for the long-term ecological soundness of the project. In any ICDP, <u>assumptions should be explicitly stated up front</u>; they then can be tested in the relevant cultural context and monitored to determine their validity over time.

The assumption that "producers will limit their production to a certain level, therefore using fewer resources when they intensify production" (Brown and Wyckoff-Baird, 1992). Buried in this assumption is a second: *that people will be perpetually content with the small amount of cash provided by such enterprises and not seek to maximize income.* In developed countries, the underlying, rarely questioned assumption is that economic growth must continue. Although some cultures may value time more than money, one cannot automatically assume that other peoples have different values!

In this consumer age, empowering communities may actually result in increased overexploitation. The IUCN World Congress Newsletter (IUCN, 1996) notes, "If successful in helping local people gain greater management rights, is it reasonable to expect them to use the resources sustainably when the full power of our globalizing economy and culture rewards so richly those who use resources unsustainably?" How much income is necessary to satisfy project beneficiaries and to change their resource use? We don't know. It has been suggested, however, that the "net revenue must meet or exceed the income generated from existing destructive practices" (Brown and Wyckoff-Baird, 1992).

The assumption that "resource users share conservationists' perceptions that resources are scarce and ...use should be reduced or limited." (Brown and Wyckoff-Baird, 1992).

If resource users do not have first-hand knowledge of the impacts of overexploitation, they are likely to be unconcerned about the prospect of future problems. It can be difficult to envision the consequences of one's development choice in an area that is still pristine; the area's beauty is simply taken for granted. One member of a Papua New Guinea NGO told me that he didn't even think about environmental problems until he saw the degraded environments in the United States! Yet more than 85% of marine conservationists believed that an understanding of the importance of renewable resources is essential if coastal residents are to change their destructive development practices (Wilcox, 1994).

The assumption that conservation is largely consistent with local peoples' priorities -- or, conversely, that by enabling local residents to better manage their resources for the benefit of current and future generations, conservation will result. Conservationists often have very different priorities than their intended beneficiaries. Their primary interest may be in conserving or restoring a natural area. The villager's interest may be along the same lines, or they may see the conservationist's offer of help as a convenient way of receiving immediate desired benefits, such as the building of churches, schools, and access roads, healthcare, income-generation and receiving assistance with crops. The interests of the two groups may increasingly diverge if the effort is profitable. The only way to resolve this conflict over the long term is through education and the development of a foundation of trust.

The assumption that biodiversity conservation is inherently compatible with development. "Unambiguously successful and convincing examples where local people's development needs have been effectively reconciled with biodiversity conservation remain difficult to find....Simply to assume that people will be more inclined to conserve local biodiversity if their living standards improve, or that there are always methods to improve local incomes without depleting biodiversity is, at best, naive" (Miller et al., 1995). *A related assumption is that it is in the interests of all social groups for resource use to be sustainable.* This is frequently not so (Robinson, 1993). The task for ICDP practitioners is to determine the circumstances which make biodiversity conservation and sustainable economic development compatible, and to adopt precautionary measures to ensure that they remain compatible.

The assumption that a project-based approach will conserve biodiversity over the long term. Threats to biodiversity are often caused by broader economic, social, and legal problems over which rural communities have little influence. "Even under the best of conditions, projects focusing on areas of high ecological value and targeting local populations can play only a modest role in mitigating the powerful forces causing environmental degradation" (Miller et al., 1995, after Barber et al., 1994; Alpert, 1996). Hence, ICDP projects need to be considered in conjunction with larger-scale economic and sectoral policy changes and education efforts.

The challenge (and promise) of ICDPs is that they need to ensure ecological, economic and social viability in order to be sustainable.

1. Ensuring Ecological Viability: Since a primary goal of an ICDP project is conservation, it is critical to ensure that the enterprise is ecologically sound. Yet, few ICDP projects have been able to demonstrate that biodiversity has been conserved while income is gained (Miller et al., 1995). To ensure ecological viability, a project must undertake baseline studies (to determine initial numbers, distribution, growth rate, etc.), and then monitor the enterprise's effect on the harvested resource, on ecologically associated species[2], and on the habitat. Monitoring does not have to be onerous. However, precautionary mechanisms may need to be set in place in advance of profits to ward against overdevelopment.

Ensuring Economic Viability: ICDPs either try to: "1) develop income-generating activities that are perceived to be more environmentally sustainable; 2) improve existing methods of natural resource exploitation to increase production in a sustainable manner; or 3) promote incentives for conservation as part of a contractual agreement" (Brown and Wyckoff-Baird, 1992). Generally, the income-generating activities are largely targeted for the export market. The hoped-for increased cash is seen as an incentive to local people to conserve their natural resources and to forego alternative destructive uses.

Much greater thought needs to go into addressing the economic viability of an enterprise from the beginning, for if it proves to be unprofitable, all credibility at the local level is lost. Let us examine each of these approaches in turn.

The Development of New Income-Generating Activities

The economic viability of enterprises should be one of the criteria for determining where a given ICDP site is selected. Developing profitable enterprises is not easy.

[2] Robinson (1993) comments that one has to consider "cascading ecological effects that alter ecological communities over time."

For example, not all sites can successfully establish ecotourism, since some are too expensive or time-consuming to reach, and some do not have the attractions or facilities to compete with other sites (Shumway, 1993; Alpert, 1996). Alpert (1996) reviewed three ICDPs in Africa that attempted ecotourism. Only one generated enough revenue to aid community development. Of the other two sites, one had too few tourists to benefit the community, and the other received just enough tourism revenue to cover the cost of managing the visitors and maintaining the facilities. Similarly, not all sites can sell products for the export market since some are too remote from markets and the transportation costs are too high.

Too often, income-generating activities are designed based on untested assumptions about the social situation and people's behavioral motivations. For example, planners designing integrated conservation and development projects optimistically talk about switching fishermen to aquaculture. This is not just an economic change; to some fishers, this completely changes their way of life and how they define who they are. The fishers themselves must be interested in making such a change.

The development of new income-generating activities should not focus exclusively on the export markets. The domestic market is equally important. Why? First, by focusing exclusively on the export market, it is likely that much of the business advice will come from outside consultants, since local residents often lack management skills and business experience. This effectively limits local feeling of participation, a critical component of a successful development project. Second, the domestic market can also enable one to easily test the market for a certain product before expanding to a more risky export market. Since export markets won't succeed unless there is a regular supply of such goods, it makes sense to develop a domestic market for the product first. In this way, the number of individual producers increases to the point that they can provide the regular supply needed by manufacturers. Furthermore, the domestic market can support small firms where larger firms cannot survive. Finally, the working style of domestic businesses is often better suited to local needs because they are generally managed in a way that is sensitive to the local culture (Hailey, 1987). In those cultures where familial sharing is expected and saving money not a tradition, domestic businesses can more readily accommodate both needs.

The Improvement of Existing Natural Resource Practices to Increase Production and Minimize Degradation

In practice, this is very difficult for ICDPs to achieve. Unless a company or individual businessman is resident in a community, they have no incentive to change their behavior unless the government develops policies or the enforcement capacity to require them to do so. It is simply cheaper to "mine" the resource and move on than to exploit it rationally. Even businessmen resident in a community would need to be convinced that they could make the same amount of money in the same amount of time if they converted to more environmentally friendly practices. Although we could prove this for the long-term for many practices, it is extremely difficult to prove in the short, since the proposed practice will generally reduce resource use over the short-term. Even in cases where alternative methods can be shown to generate the same revenue, force of habit and pressure from middlemen may cause users to resume the old practice. This was the situation with cyanide fishing in the Philippines (Coral Forest, pers. comm). Perhaps the only way companies or businessmen outside a given area would be willing to change their practices without policy or regulatory changes is if a market exists that is willing to pay a higher price for a resource proven to be managed sustainably (as is being tried for timber by the Forestry Stewardship Council, for seafood by the Marine Stewardship Council, and for aquarium fish by the Marine Aquarium Fish Council, for the U.S. market), or if they held long-term tenurial rights to the resource. There may be slightly more leverage for resident businessmen in a tightly knit community if the community can pressure the entrepreneur to act responsibly.

Monetary or Social Incentives for Conservation

A number of ICDPs have provided up-front subsidies or social benefits in return for villagers pledging to conserve an area over the long-term. Unless developed carefully and sensitively, however, this approach is not likely to be sustainable. Experience with rural development has shown that people may develop dependency or even resentment if things are given to them or done for them. The only way to mitigate against this is to ensure full reciprocity. If money is given in an ICDP project, it is best to provide the money in the form of a loan, not a grant. Also, any monetary or social incentive should be directly tied to conservation so that local residents recognize the conservation benefits of their actions.

Ensuring Social Viability: Conservationists should examine in great detail the social sustainability of their effort as well as the social changes that it may bring. Sensitivity to group dynamics is important. Who spoke up in the initial meetings, and who did not? In some societies, women may be reluctant to voice opinions in the company of men. Yet their acceptance may be critical to the project, and their ideas critical for project design. Even holding separate meetings for women may not work right away, as they could be interrogated by men when they return home (Byers, 1996). The only answer is to develop trust among the women. Also, who is going to benefit from economic gain, and who is not? How will the enterprise affect the status of women or their management of time? If an aquaculture project is planned, might it result in additional burdens on women's time? If an ecotourism project is planned, what mechanisms will be put into place to ensure that cultural integrity and pride stay intact? What are culturally appropriate methods of addressing conflict?

ICDP practitioners need to consider the cohesiveness of the group that will undertake an income-generating effort and the social longevity of the project. Discussions with local counterparts to determine how profits are to be distributed equitably need to take place before profits come in. Otherwise mistrust sets in that can sabotage a project. In addition, local counterparts need to be convinced of the necessity of putting money back into a business which can be difficult in areas with a tradition of sharing with relatives and little tradition of saving.

Development Inexperience: *"Despite much rhetoric to the contrary, most biodiversity conservation projects have treated local people as passive beneficiaries of project activities and have failed to involve them in the process of change and their own development. As a result, targets have often no stake in or commitment to activities being promoted."*

Miller et al., 1995

Fundamentally, one needs to change social and individual human behavior to effect conservation. Unfortunately, numerous integrated conservation and development efforts are begun by biologists or environmentalists, neither of which have experience in effecting social or behavioral change. Scientists are also taught to value results, not process. Yet process is of utmost importance in effecting human change. Many a brilliant management plan has been doomed to failure because communities didn't feel that they were fully involved.

ICDP practitioners need to learn from rural development lessons, both failures and successes, of the past. They need to be ever cognizant that most rural development projects have failed, at least from the standpoint of sustainability, and make efforts to reduce likely causes of failure (Reid et al.,1985; Miller et al., 1995). In addition, they need to appreciate that changing human behavior is hard and apply principles used in behavioral modification. Perhaps the most important development lesson learned in development over the last 20 years is that projects fail if projected beneficiaries are not equitably involved in all phases of a project, including information-gathering, design, decision-making, implementation, and evaluation (Brown and Wyckoff-Baird, 1992).

In designing an ICDP, " ...it is important to ask what local people are participating in, who is participating, how they get to participate and... how local participation is expected to contribute to the sustainable use of biodiversity" (Miller et al., 1995). Participation must be more than rhetorical. It means more than the occasional gathering of local people into workshops directed by the outside organization; it means more than conducting surveys to find out local groups' needs and wants; and it means more than providing socio-economic benefits to people. It means that the projected beneficiaries are treated as real partners. Otherwise the project ceases as soon as consultants go home.

As the Biodiversity Support Program has noted (1993), ICDPs have generally adopted two out of three participatory approaches: mobilization (rarely sustainable), whereby the project is designed by outsiders, and locals are "mobilized" to "endorse, collaborate with, and adopt a plan;" and community development (possibly sustainable if it addresses an important community need), whereby locals are periodically brought together with surveys or meetings to provide input. In the latter case, "groups may be involved in design and maintenance of specific initiatives," yet "decisions are still in the hands of the external agent." The most effective effort, however, is an empowerment strategy, whereby the community " initiates the learning process; defines their own goals; assesses options; and decides on responsibility for action." Here, the community is in control and thoroughly included in the project. They are also more motivated. Very few of the over 50 ICDPs studied to date have this level of involvement (West and Brechin, 1991; Wells et al, 1992; Little, 1994.) The box below demonstrates, however, that this can be done!

> Communities can initiate, run, and finance ICDPs entirely by themselves. Examples include: 1) a community-based ecotourism project in Capirona, Ecuador (Brandon, 1995), and 2) a village income-generating project in Papua New Guinea (Degemba and Tetaki, 1993). In the latter case, each villager had to pay $50 or its equivalent in resources to be part of the project.

Development experience may be even more critical for aquatic ICDPs due to the complexity of problems, greater scale required for management, and sensitivity to land use decisions, and yet there are even fewer practitioners or projects in this area. For example, Wilcox (1994) found just 30 marine projects worldwide that have an ICDP component.

Another lesson learned is that the successful development of such projects takes considerable time and patience - something which development projects often do not take into account. It may take up to ten years to ensure thorough participation in project development and implementation. However, conversely, for such projects to succeed in the face of large-scale threats and to overcome distrust, "the project has to produce visible and positive results (to the people) in a relatively short period of time." (Ack, 1991). The challenge is to produce some tangible benefits immediately for credibility while pursuing the more lengthy process of ensuring equitable participation.

The length of time required to ensure sustainability of an ICDP project over the long term means that conservationists need to critically assess when they are worthwhile. If the threat at a particular site is urgent and severe (i.e., the habitat may well be gone within the next five to ten years), policy, legislative and regulatory efforts may be best. Otherwise it is a race against time.

Ten Recommendations For ICDPs

1. **Site selection is critical for the viability of the project**. Both biological importance and socio-economic criteria should be a critical basis for ICDP site selection. Ensure that the site has easy accessibility to markets (roads, airports, etc.), making products or tourism competitive. With regard to social viability, the ideal is to select a site where: 1) the community is motivated and has already initiated a conservation effort and 2) the local government is interested. Don't try to force an ICDP project where the community is not interested. Think about who is most likely to benefit from a given business.
2. **Mobilize an integrated team** across sectoral and disciplinary boundaries of community members, conservationists, entrepreneurs, and sociologists/anthropologists via local or international NGOs, universities, and government. Ideally, incorporate local research questions and interests into the design of the initial assessments, and make this information accessible.
3. **Clearly define project objectives at the beginning and explicitly identify underlying hypotheses.** We urgently need better understanding of ICDP project design and management, replicability, sustainability, and effectiveness over the next few years (Miller et al., 1995). Projects should be designed in such a way as to generate lessons learned.

   Monitoring is essential, particularly for biodiversity. This builds increased interest and familiarity with the project and has the added advantage that people can see the results of the intervention. If visiting or in-country scientists are used, foster more give and take between scientists and local residents, incorporating local research questions into the scientists' work. Graduate students should be encouraged to undertake research projects at existing ICDPs. The community should feel as if they are getting some benefit from the studies! Both ecological and socioeconomic baseline studies should be conducted at the beginning to know the project has made a difference. Methods and indicators should be developed by an ecologist, while the monitoring itself is best accomplished in

Data gathering and analysis techniques generally applicable to the social assessment or participatory inquiry linked to biodiversity conservation projects.

Collection of secondary information.
Key informant interviews.
Direct observations of processes and behaviors.
Participant observations of processes and behaviors.
Diagramming.
Community mapping.
Production/livelihood diagramming.
Gender analysis tools.
Socioeconomic surveys.
Community information and consensus-building techniques.
Project design techniques for needs assessment and identification of risks.

Methods of participatory rural appraisal. ***World Bank, 1994. From Heywood, 1995, © United Nations Environment Programme.***

conjunction with, or entirely by the community (see pages 85-88). (Other solutions such as hiring contractors or visiting scientists do not seem to provide a long-term solution.) Biodiversity monitoring should include: 1) monitoring species directly impacted by the economic activity (by comparing species diversity and abundance in unmanaged areas, managed buffer zones, and core protected areas over time), and 2) monitoring overall ecosystem health with indicator species (not directly impacted) over space and time (Kremen et al., 1994). Indicator species should comprise several different functional groups, as various species may be impacted differently.

4. **Ensure local participation in all aspects of the project, including planning and day-to-day management.** Work towards a true partnership. Ideally, the community should initiate the project. At a minimum, be willing to let the community seize the project even if this means deviating from the original plan. Accept that local residents may have different ideas about how the project should operate. Foster a self-help mentality by requiring local residents to give of themselves in terms of time, money, or materials.

   A variety of methods have now been developed to assist in participatory inquiry, including **participatory rural appraisal** (Figure 45). Generally, the methods use a group inquiry process to obtain multiple perspectives from a diverse group of stakeholders, working together to identify both resource problems and possible solutions. According to Miller et al. (1995), "participatory rural appraisal is a collective term for a growing list of approaches based on interactive learning, shared knowledge, and a flexible yet structured analysis." Participatory inquiry methods should be used to obtain the wealth of environmental knowledge already present in the community during the planning stages of an ICDP.

5. **Use a longer time frame to measure success.** Ten years is not unreasonable for an aquatic ICDP. Dialogue, negotiation, conflict resolution, and capacity-building take time (IUCN, 1996, Alpert, 1996).

6. **Start small. Biodiversity conservation can be most easily achieved through income-generating projects if such projects directly address local peoples' environmental concerns.** To achieve conservation over the long term, Africans, like people everywhere, must perceive that conservation efforts serve their economic and socio-cultural interests and priorities (Brown and Wyckoff-Baird, 1992). By focusing on their concerns right from the start, one generates trust and helps to build a framework for broader understanding of the importance of conservation of other species. For example, people may be worried about the loss of an important aquatic species, providing the opportunity to embark on a restocking program and to increase awareness of the interdependence of species and ecosystems. Or the women in a village may be worried about water quality, providing an opportunity to simultaneously improve human health and aquatic habitat (Figure 49). In this way, people can most clearly see and appreciate the link between a healthy environment, biodiversity conservation, and sound development. More comprehensive biodiversity efforts can be undertaken later. One way to link environmental concerns with broader socio-economic ones is to join forces with rural development or health NGOs at a specific site.

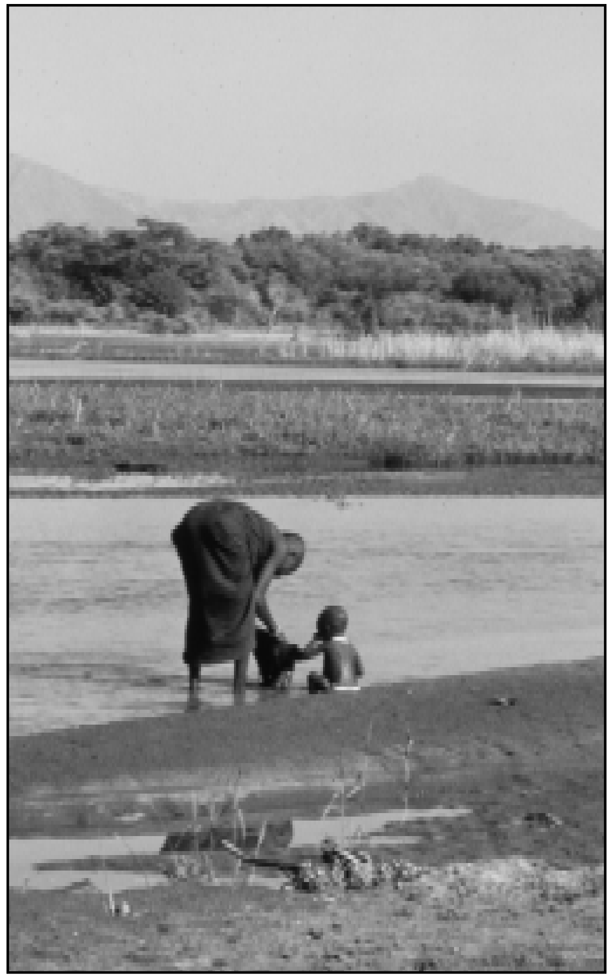

Figure 49. Biodiversity conservation should address local people's environmental concerns, such as women's concerns for water quality. World Resources Institute.

7. **Consider developing products for the domestic market**, for reasons stated earlier.[3]

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[3] Conservationists could also be innovative and encourage bartering between groups for certain needed items instead of creating income-generating actitivities. Bartering is being tried today in local communities even in the United States, which has had a long-standing cash economy. In countries with a tradition of subsistence agriculture, there clearly is a precedent for such activities.

8. **Pursue economic activities (exclusive of tourism) in secondary areas surrounding pristine sites, rather than at the site itself.** Ensure that adequate regions of intact habitat are protected. Pristine, high biodiversity sites, by definition, have high numbers of species but for any given species, limited abundance. This means that to generate enough income from a particular business, one would have to enhance a particular species and in the process alter the area significantly, as admitted by one of the main practitioners of ICDPs, Cultural Survival. Development inevitably comes at some cost to biodiversity (Kremen et al., 1994). It is certainly preferable to alter the species composition of a secondary, degraded area than a pristine one. Furthermore, by initiating economic activity in a secondary area, this will minimize the damage if an ICDP project proves to be economically successful, and the assumption that people will be content with a small amount of cash does not hold.
9. **Undertake ICDP projects in conjunction with larger-scale economic and sectoral policy changes and public awareness efforts.**
10. **Most importantly, emphasize the moral and spiritual imperative of conservation in parallel with economic development.** Behavioral psychologists have found that while one can achieve short-term behavioral change with the use of positive or negative economic incentives, the change is not durable and often disappears if the incentive is removed. Hence, conservation efforts should not focus exclusively on the economic benefits to be gained from conservation. This strategy can only backfire. Even in countries like Kenya that receive considerable income from protecting their wildlife, people will readily give up conservation as soon as a business is identified that yields even more money from the land than the money from conservation -- such as oil, gold, or other resources (Tudge, 1991).

    It is important to keep in mind that the benefits derived from conservation do not need to be monetary; they can also include a perceived sense that the landowner or their children have a better quality of life. In developed and developing countries alike, many peoples derive non-monetary, non-extractive benefit from wildlife - including aesthetic, recreational, cultural, and spiritual value. These values are already present throughout Africa and need to be nurtured as well. For example, Alpert (1996) interviewed Namibians in the Kaokoveld who told him that it was important that children see wildlife and that they were just good to have around.

2. Community Management

While community-based conservation is an ancient approach, its effectiveness is now being appreciated worldwide. Community-based management or co-management (a partnership between different institutions or groups, such as communities and government) should be considered for both protected and non-protected areas under management (BSP, 1993). It can be a cheaper and more effective means of managing aquatic resources than management by government alone, and is particularly effective for resources held "in common" (see Becker and Ostrom, 1995, for a summary of design principles). Most marine conservation practitioners feel that expansion of the role of local communities is necessary for effective conservation because they have the most to gain or lose (Wilcox, 1994).

Both local and national government need to be supportive of this type of approach. Governments generally do not willingly give up their power and responsibility willingly, however. But governments have much to gain from co-management or even community management arrangements. In fact, in places where enforcement of regulations has been difficult due to a paucity of government personnel, this type of management may be the only way to provide enforcement capability.

The more skilled and knowledgeable the community is about its resources, the more likely it can work towards sustainability. Governments, NGOs, and academics can assist by developing community skills in ecological monitoring, participatory appraisals, conflict resolution, and economic development. Alternatively, donors can help establish long-term links between communities and interested, preferably local, scientists, sociologists, and economists.

A review of community management and co-management (Pinkerton, 1994) showed that success is more likely when:

1) control is devolved to the local level as much as possible, and such control is clearly defined in writing or with legislation. Rights, responsibilities, and tasks need to be agreed upon.
2) he community also needs to agree on current problems and possible solutions (Nauen 1996). This helps to generate enthusiasm and a sense of stewardship over the process;
3) there are transparent criteria for local involvement in management;
4) the group is able to exclude outsiders, creating a greater

Local communities around the Fumba peninsula of Zanzibar grew concerned about overfishing and destructive fishing practices. With the assistance of the Commission of Natural Resources-Fisheries and the Department of Environment, the communities formed a management committee, and created The Menai Bay Conservation Area in August, 1997. All 17 villages around the bay now participate, and an environmental committee has been established in each village (Intercoast Network, 1998).

sense of ownership and responsibility;

5) the community is able to effectively discipline its members; in other words, to make and enforce rules. Pinkerton (1994) notes that "the willingness of fishers to obey the rules appears to be related to their ability to monitor each other's activity to ensure that everyone else is obeying the rules also (Ostrom, 1990)." Rules should be flexible, taking into account the current pressures on important resources;
6) the community contributes costs in kind, such as labor or equipment; and
7) the community receives some economic benefit from management of the resource. At a minimum, revenue should offset the cost of local management activities. In the case of fishing, possible revenue raisers include fish sales, landing taxes, licensing fees, etc.

Community management has now been tried all over the world, including community-based management of coastal benthic resources in Chile (contact: Juan Carlos Castilla at jcastille@genes.bio.puc.cl) and community-based management of coral reefs in the Philippines (contact Elmer Ferrer).

3. Bio-regional, or Ecosystem, Management

"Ecosystem management acknowledges that people are integral, interacting parts of nature."

Keystone Center Report, 1996

In the past, environmental management units often were arbitrarily drawn, with no relation to ecological boundaries or to local residents' cultural or political identity (Slocombe, 1993). This made it difficult, if not impossible, to effectively manage the ecosystem and also inhibited a sense of community. A recently developed approach, bio-regional management (also called ecosystem management), attempts to manage resources at the appropriate biological and cultural scale. The Keystone Center has defined bioregional management as "a collaborative process that strives to reconcile the promotion of economic opportunities and livable communities with the conservation of ecological integrity and biodiversity" (IUCN, 1996). In a sense, this management combines the principles of integrated conservation and development projects on a landscape scale, and is much like integrated coastal management in scope. Bioregional management is holistic, acknowledging the interrelationship of man and nature and considering humans and their activities as part of the ecosystem. It is also adaptive and flexible. Namibia is currently using this approach, along with community management in planning biodiversity conservation (Namibia, 1992, cited in BSP, 1993).

The impetus for starting a bioregional management process can originate from public agencies or communities themselves. The appropriate scale will depend on the conservation goal, as well as on practical social boundaries - in other words, how local people define home. Some aquatic conservation goals are large enough in scope that they will require transboundary cooperation.

Process is critical. Briefly, facilitated scoping sessions can help catalyze the process and generate social acceptance. The process must begin with the basic needs of the people. Working backward from desired future scenarios, stakeholders can develop a shared vision of the future. It is best to begin with a fairly easy issue of concern to most people in the area; over time, thornier issues can be tackled (Miller et al., 1995).

Main characteristics of a bioregional management approach include:

1. **Large regions --** regions must be large enough to include the habitats and processes required to make the flora and fauna sustainable over time.
2. **A matrix of diverse production and conservation systems ---** including protected areas representative of

The South African Council for Scientific and Industrial Research (SCIR) is proposing to assist Kenya in developing an integrated environmental management program for the Tana river delta, estuary, and marine system. Part of the goal will be transfer of South African experience in this area to Kenyan personnel (Raal and Barwell, 1995).

the area's biodiversity and corridors to allow migration and adaptation to global climate change, "nested within a matrix of mixed land uses and ownership patterns" (Miller et al., 1995). Restoration might be undertaken in degraded habitats.

3. **Full involvement of stakeholders.**

4. **Methods** include:

- Geographic Information System technology (GIS) which can help residents to see the ecological connections among their region and plan for the future;
- multidisciplinary approaches;
- use of both scientific and local knowledge in developing strategies;
- incorporating community and stakeholder values in design and implementation (Slocombe, 1993); and
- long-term monitoring.

4. Community Monitoring

The indigenous knowledge of local residents can be invaluable for monitoring and management. Local volunteers can help to inventory biological resources and monitor both harvest and habitat. They can help observe faunal or floral distribution, abundance, and changes such as the disappearance of a common species or the establishment of an exotic species (BSP, 1993). Recently, East African coastal scientists at the IOMAC International Scientific Workshop in Marine Scientific Cooperation recommended that local information on resource distribution be obtained through indigenous mapping and field surveys (Obura et al., 1995).

Local monitoring can be undertaken by itself or in conjunction with governmental, academic, or nongovernmental monitoring. <u>Combining</u> indigenous knowledge and skills with modern monitoring methods has a number of advantages. 1) It can help to deter overfishing. Fishers' knowledge can provide a useful early warning of overexploitation. Monitoring can also help local residents acquire increased knowledge of their resources and become more aware of the limits to such resources; 2) It can create a real sense of ownership and empowerment; 3) It promotes respect for the knowledge each side brings to the table. 4) Finally, parallel testing for a period of time may help convince government officials of the reliability of data collected by citizens; it also can highlight potential problems in volunteer methods or manuals used, facilitating improvement.

Monitoring should focus on easily identified and measured indicators that are most sensitive to environmentally induced change (UNEP, 1994). For freshwater systems, aquatic insects, molluscs, amphibians, and fishes can be used as indicators of ecosystem health and diversity (Stiassny, 1997; EDF, 1994). A rapid census of certain pollution-sensitive orders of **aquatic insects** is an easy method for testing water quality in rivers and streams (EDF, 1994). South Africa recently developed a simple water quality bioassay for rivers using invertebrates; the technique may be modified for other countries by substituting local invertebrate species (Chutter, 1994). In addition, G.P. Ganda and T. Oberdorff are working to develop a freshwater Index of Biotic Integrity suitable for Africa (also see Hughes and Oberdorff, 1998). The technique can help monitor water quality and fish conservation. The technique involves obtaining baseline data from undisturbed freshwater habitats and developing an index of the overall health of a fish assemblage (Reid, 1994). **The shells of bivalve molluscs** can be an easy means of monitoring changes in sediment pollution levels over time; the chemical composition of the new layers reflect changes in water chemistry (EDF, 1994). **Amphibians** are a very sensitive indicator for both air and water borne pollutants, as amphibian eggs lack a protective coating and are laid near or by water's edge (Species, 1997). Breeding populations of amphibians are also a good indicator for climate change, because climatic factors strongly influence the onset, duration, and strength of mating.

The U.S. EPA has developed simple manuals for the volunteer monitoring of estuaries, lakes, and streams (EPA, 1993), and, together with Adopt a Beach and King County, Washington, USA, have developed a manual for the volunteer monitoring of wetlands (Miller et al., 1996). (Contact Alice Mayio, USEPA, ph: 202-260-7018; email: mayio.alice@epamail.epa.gov.) The Volunteer Monitor is a U.S. newsletter dedicated to providing practical advice for volunteer monitoring of aquatic areas, along with community outreach ideas. The newsletter, as well as EPA materials can be accessed via the EPA's web site (http://www.epa.gov/owow/volunteer/vm_index.html).

For coral reefs, simple low-cost monitoring methods for estimating coral cover, and determining the location and abundance of select species are described in the ASEAN-Australian Marine Science Project's Survey Manual for Tropical Marine Resources (English et al., 1994). **This book also covers monitoring methods for mangroves, soft-bottomed communities, seagrass communities, and coastal fisheries.** A training course based on the book has been developed by IOC-UNEP-SPREP (1994). A methodology manual to track the impact of global climate change on coral reefs has been published by UNEP/AIMS (1993), as part of the Global Ocean Observing System (GOOS).

Figure 50. The Big Eye Emperor, Monotaxis grandoculis. *Because emperor fishes are particularly vulnerable to overfishing, they are useful for monitoring fishing pressure. New England Aquarium, 1998. Photo credit: Paul Erickson.*

Basically, observers note the extent of live coral cover, number of different types of corals, damage to corals, siltation, and location and abundance of certain species. Techniques for estimating coral cover include: manta tow surveys (involving a snorkeler towed behind a boat); line intercept transects, permanent quadrat methods, and photo transects (e.g., Nowlis et al., 1997). English et al. (1994) review the advantages and disadvantages of each method.

Following a basic biological survey of the area, replicate samples of reefs, randomly distributed throughout the area, should be tracked over time. Replicate fished and unfished reefs should be compared. Comparisons between fished and unfished reefs should be closely matched for oceanographic conditions and habitat quality.

A visual census of coral reef fish, used in conjunction with a line intercept transect, can provide baseline data for zoning, management, and monitoring. If coral cover can't be estimated directly, **butterfly fishes** (in the family Chaetodontidae) are useful indicators of the health and extent of corals because they are partial or obligate coral predators. Note that butterfly fish numbers are only good indicators where they are not exploited for the aquarium trade. The number of **large predatory fish** (snappers, groupers, and emperors) and **large shellfish** (giant clams and trochus) is a good indicator of fishing pressure. The following reef fishes are particularly vulnerable to overfishing, and are useful species for monitoring: **groupers** (home-ranging predators), **parrot fishes** (site-attached herbivores, important in the ecology of the reef), and **emperor fishes** (Figure 50).

Other useful references for coral reef monitoring include South Pacific Commission's Coral Reef Monitoring Handbook (UNEP, 1984), as well as a report by Nash in a recent ICLARM newsletter (Nash, 1989). A recent publication available from the University of Rhode Island, U.S., titled International Year of the Reef: Selected Guidelines, Handbooks and 'Tools' for Coral Reef Management (URI, 1996) provides a list of other useful references on monitoring, as well as protected area planning, coral reef education, and coastal zone management. The organization REEF (Reef Environmental Education Foundation) and The Nature Conservancy train volunteer recreational divers to assist in a Reef Fish Survey project. The Nature Conservancy's Coral Watch program uses volunteer divers to assess coral coverage and health. Contact REEF at 305-451-0312. ICLARM in the Philippines offers a community-based ICZM training course through the UN's TRAIN-SEA-COAST programme (R. South, personal communication).

5. The Importance of Public Awareness

Public awareness efforts can be used to: 1) increase recognition of the finite limits to resources and of the importance of sound resource management, 2) foster community support for behavioral change; and 3) develop or nurture concern for biodiversity as an intrinsic value. **Contrary to popular belief and most environmental education efforts, however, just providing knowledge does not necessarily change people's behavior.** Humans are flexible in some behaviors; other behaviors, however, are likely to be more intractable. If the problem is directly attributable to lack of information, educational efforts can be effective. For example, local people living near a relatively intact coastal or freshwater environment may not be aware of factors that could damage their environment. A simple project supporting their travel to degraded coastal or aquatic areas would allow them to see first-hand the consequences of ill-conceived development action. Such a project was invaluable in influencing foresters in the South Pacific to support more sustainable forestry (L.Newell, personal communication). Similarly, working to ensure that both decision-makers and the public have a basic understanding of the water cycle may help them become more conscious of the limits of the resource. Decision-makers also need to become aware of the value and importance of wetlands (including mangroves), and the immediate and long-term consequences of exploitation; this may influence their economic analysis of development options in wetland areas. However, if people know that the behavior causes environmental damage, but do it anyway, other motivating factors are at play. For example, awareness is not helpful in addressing resource problems due to greed (Krumpe and Ham, 1997).

Environmental educators have learned a lot from behavioral psychology and social marketing in recent years. Many factors influence human behavior towards the environment, including knowledge, attitudes, values, sociocultural factors, gender, social norms, skills, economics, time, options, laws, and habit. Krumpe and Ham (1997) identify three types of beliefs that influence human behavior towards the environment, based on the work by Fishbein and Ajzen (1975) and Ajzen (1991): behavioral beliefs (i.e., why a person does a particular practice); normative beliefs (i.e., how social norms influence their behavior--originating from peers, family, priests, local leaders, etc.); and control beliefs (i.e., how much a person thinks he/she has control over the practice). Each or all of these beliefs can be targeted for change or replacement in an education campaign. How knowledge is presented also plays a role in whether people will change behavior, again underscoring the importance of process: if presented as a mutual learning experience between the conservation team and the community, knowledge will be more readily received than if presented unidirectionally as a lecture.

Hungerford and Volk (1990) found that three main factors seem to contribute to behavioral change toward the environment: 1) entry-level factors which include environmental sensitivity, awareness, and ecological knowledge; 2) ownership factors which include personal knowledge and investment in environmental issues; and 3) empowerment factors which give people the sense that they have the power and skill to act in ways to resolve environmental issues. There are various ways to tap into a sense of ownership, such as using a flagship species to create pride among local communities and children, as successfully practiced by P. Butler of RARE in the Caribbean. P.H. Forestell of the Pacific Marine Mammal Association (Forestell, 1997) attempts to influence behavior during whale-watching tours. During the tour, he encourages tourists to actively participate in a small environmental clean-up effort. He also invites participants to jot down on a postcard three environmentally beneficial activities that they will do within the next six months. Six months later, he returns the postcard to the participants. According to the participants, receiving a postcard written by them is a very powerful motivator for doing the promised activities!

ASSESS THE SITUATION
What? Who? Where? When? Trends?

↓

IDENTIFY CRITICAL BEHAVIOR
AFFECTING THE RESOURCE

↓

UNDERSTAND THE KEY FACTORS
THAT INFLUENCE SUCH BEHAVIOR
What are the relevant motivating factors?

Figure 51. Steps in identifying the key human behaviors implicated in a particular threat (modified from Byers, 1996, p.24).

Conservation projects can be more successful if practitioners learn the basic methods and tools of **social assessment** (see Byers, 1996 for review and references), or ideally, incorporate social scientists as part of their team. A social assessment at the beginning of a project can help to identify those specific behaviors with the largest positive or negative impact on the environment or resource of interest, as well as the motivating factors underlying these behaviors (Figure 51). This can help to focus the conservation dollars in areas likely to have the greatest impact. Behaviors can then be prioritized on the basis of how feasible it is to change them. Information about how common a behavior is gives clues into how feasible it may be to change it. If everyone does a negative behavior, it probably will be difficult to change. Similarly, if no one does a particular sustainable practice, it may be difficult to introduce (Graeef, Elder, and Booth, 1993). Byers (1996) argues that one should also identify sustainable practices already in use that can be promoted or enhanced.

It is important to keep in mind that within a given community, there is likely to be a diversity of motivating behaviors. **Since communities (and individuals within a community) are not homogenous, no single strategy for influencing behavior is likely to be sufficient.** Conservationists may need to simultaneously address different factors influencing behavior, including economic, psychological, and sociocultural motivations (e.g., religion, cultural taboos). In communities where the church is a strong motivating factor, enlisting the support of church leaders can be invaluable in altering behavior and attitudes towards the environment.

E. Support Research: Address Gaps in Our Scientific Knowledge that Are Important for Aquatic Conservation

Study the ecological impact of variations in the timing and volume of artificial flood releases at a variety of African dams. This will aid modeling of options in the development of river basins.

> Rhodes University, South Africa has developed a computer-based expert system enabling managers to see the effect of various developmental options on the conservation status of a river (O'Keefe and Davies, 1991, cited in Davies and Day, 1998). The program incorporates river size, pollution levels, numbers of dams, catchment land use, types and numbers of species, and erosion.

Develop models for wetland utilization that both conserve wetlands and contribute to sustainable development (IUCN, 1990b).

Improve decision-making methodologies for wetland, river basin, and coastal zone planners. Identify activities which are possible in or around different aquatic ecosystems, and determine the appropriate scale for such activities that are compatible with maintaining ecosystem services. Help create a support system of scientists and environmental economists to assist with developing alternative development options. One important area to improve is environmental modeling, particularly models that incorporate the environmental impacts of socioeconomic factors, including a growing population. While ideally the indirect and direct benefits of the entire ecosystem would be estimated, in practice, it may be more feasible to estimate the economic cost associated with change or loss of habitat or resources following proposed developmental conversion.

Support studies assessing the effect of size of marine reserves on adjacent fisheries productivity, and on maintaining biodiversity within the reserve. We need a better understanding of what works in marine reserve design. Any experimentation must include adequate controls, such as baseline surveys and the monitoring of catch per unit effort in replicate sites before and after reserve establishment. In particular, it is important to understand whether reserves provide larval and/or adult spillover, and over what spatial range this might occur. We also urgently need a better understanding of: the duration of egg and larval stages of coral reef fishes, the frequency and consequence of density dependence on larval habitat selection and adult relocation, the temporal and spatial scale of a species' home range, and what physical features are barriers to fish movement (Kramer and Chapman, 1998; Sladek Nowlis and Roberts, 1998, in press).

Support research on the development of sustainable aquaculture systems for indigenous freshwater or marine resources. Well-designed mariculture or aquaculture may benefit overexploited wild stocks, by reducing pressure on this resource. Polyculture uses several trophic levels to boost nutrient recycling, such as combining mollusc and seaweed culture; and fish-rice culture (Littlewood and Marsbe, 1990). Reid et al. (1985) report that shrimp mariculture can be undertaken in the lowland areas behind coastal wetlands. It does not have to destroy threatened aquatic ecosystems such as mangroves. The FAO recently convened a technical consultative group that agreed there should be no further loss of fragile ecosystems as a result of shrimp aquaculture (Clay, 1998). A number of groups are currently trying to devise best practice guidelines for more sustainable shrimp culture, including: the industry-based Global Aquaculture Alliance, the NGO-based Industrial Shrimp Action Network, the FAO, and the Holmenkollen group (Clay, 1998).

Support aquatic restoration studies to assess: 1) the extent of which degraded environments and communities can be restored; and 2) the length of time needed for recovery (NRC, 1995). The World Bank (1996) proposes restoration of West African mangrove forests, in part to mitigate coastal erosion and in part to mitigate coastal effects of sea level rise caused by global climate change.

Support studies examining the impact of sedimentation on various coral communities. We don't know which types and species of coral can withstand sedimentation; what soil types, topography, and land use exacerbate sedimentation; and what oceanographic processes (e.g., flow rate or level of tidal mixing) mitigate the effects. This knowledge would improve the predictive abilities of environmental assessment during a coastal development planning process (Sladek-Nowlis, pers. comm.). For example, McClanahan and Obura (1997) examined the impacts of sedimentation on corals near Malindi, Kenya, and found no effect on coral diversity or coral cover. The authors note, however, that sedimentation rates around Malindi are low compared to what is usually considered a high sediment condition, and that the area has high tidal flux, factors which may have contributed to the reduced impact of sedimentation. Reefs stressed by another anthropogenic factor such as fishing seem to be more affected by sedimentation than reefs impacted by only a single stressor (McClanahan and Obura, 1997).

Support small-scale experiments in East Africa to assess the impact of removing sea urchins from heavily overfished, unprotected areas (McClanahan et al., 1996). Sea urchins appear to outcompete herbivorous fish. In overfished areas, their numbers increase due to fishing of their predators. Sea urchin reduction can help restore numbers of parrotfish, scavengers, and wrasses in highly degraded, unprotected sites. According to the authors, such an approach, however, is not recommended for lightly to moderately fished areas.

Some basic research is needed as well.

- **Train and support African aquatic taxonomists or parataxonomists.** Our knowledge of both marine and freshwater species is weak. A number of species have not been classified (McAllister, 1995). A hierarchical ecological classification system is also needed for both marine and freshwater African habitats. This is an important step in ensuring representative African aquatic systems are conserved.
- **Undertake regional surveys**. The open nature of LMEs means that a regional approach is necessary. Marine scientists at the IOMAC International Scientific Workshop in Marine Scientific Cooperation in the Indian Ocean recommended regional cooperation in two types of aerial surveys: 1) large fauna and habitat surveys to identify the distribution and abundance of threatened species, particularly marine mammals and sea turtles; and 2) coastal mapping surveys to create a baseline, monitor changes, and to identify critical biological areas (Obura et al., 1995). They also recommended research to identify the population structure of migratory marine species.
- **Support the development of national and regional marine and freshwater databases**, starting with existing data from the literature and museum collections.

F. Mimic Natural Disturbance Regimes: Maintain or Restore Natural Hydrological Cycles

"Reconciling humanity's growing demands on freshwater systems with the protection of their vital life-support function ranks among the most critical challenges in the decades ahead. It will require, most fundamentally, a new ethic of sharing water - both with each other and with nature as well."

Postel, 1996

The importance of natural disturbances such as fires, tree falls, floods, etc. in maintaining biodiversity has now become clear. Aquatic organisms and their associated terrestrial counterparts are exquisitely adapted to, and dependent on, natural hydrological processes (Figure 52). Riverine, estuarine, mangrove, and floodplain ecosystems and their associated species depend critically on maintaining natural hydrological cycles including both regular flows and seasonal flooding. Many riverine fishes, for example, undergo seasonal spawning migrations with the inundation of floodplains (Cooper, 1996), while deep-rooted riparian plants depend on cycles of flooding and

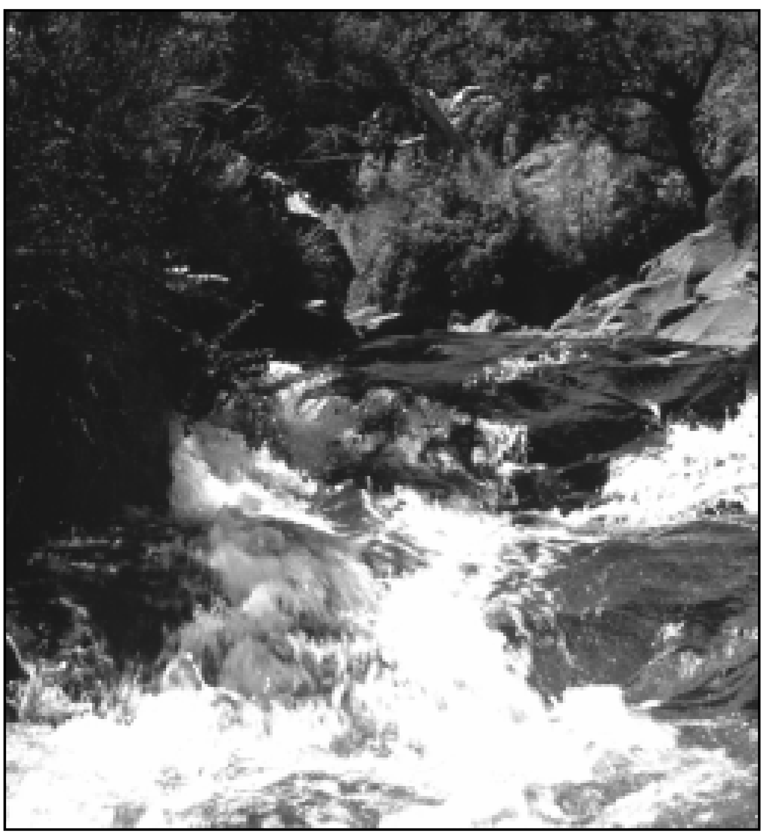


Figure 52. Maintaining natural hydrological cycles is critically important for aquatic ecosystems, from stream to sea. Photo credit: Dennis Zemba.

drought (EDF, 1994). Similarly, riverine food webs can be maintained by flooding (Wootton et al., 1996). The quality of aquatic habitats also depends on natural hydrological cycles, including both high and low flows. Flooding-induced movement of the river bed and its range of sediments, from fine sands to boulders, maintains gravel beds for spawning fish and generates transient gravel bars that provide habitat. If the river bed is not moved by floods, however, fine particles fill in and degrade invertebrate habitat, and destroy the quality of the spawning habitat (Barinaga, 1996). The elimination of the seasonal high flows, loss of sediment, and daily fluctuations due to hydropower generation on the Green River, Colorado, USA, reduced the connectivity of the river and its flood plain and decreased the productivity and food web stability in the shallow near-shore portions (Tyus and Karp, 1991).

Natural hydrological processes do not have to be completely altered with dam construction. Both biodiversity and productivity can be maintained while generating hydropower through controlled releases-- in effect making rivers smaller versions of their natural state. Controlled releases also balance equity concerns between those who benefit from hydropower (the urban population) and those who stand to lose (rural populations), reducing the potential for conflict (Scudder, 1991). Although the concept of controlled flood releases is not new, having been practiced in China for thousands of years (Scudder, 1994), the concept has gained recent attention. Both scientists and managers have become aware of the necessity of water movement in maintaining the health of riverine and other aquatic ecosystems, and the human populations that depend on them. The United States government now recognizes the damage that extensive damming has done to its western rivers, which have seen a decline of fish abundance and endangerment of several species of commercially important fish. In 1992, the U.S. Congress passed legislation requiring that a certain portion of water from the Central Valley Irrigation Project in California be dedicated to maintaining fish and wildlife habitat. Similar legislation is being developed in South Africa (Davies and Day, 1998). (See box, right.) The restoration of natural hydrological processes is now being tested in the restoration of the Trinity River in California by the U.S. Fish and Wildlife Service (Barinaga, 1996), and in the upper Colorado River Basin (Luecke, 1994). In Africa, controlled flooding has been tried on the Kafue River, Zambia (Scudder and Acreman, 1996); the Phongolo River in Natal, South Africa; the Senegal River (Adams, 1996); and the Logone River downstream of Maja Dam, Cameroon (Wesseling et al., 1996). The Itezhitezhi dam along the Kafue River, Zambia was the first African dam designed to release and artificial flood (Scudder and Acreman, 1996). Unfortunately, the dam does not allow sufficient water release and has not been able to restore wetland productivity. Scudder and Acreman blame a river basin development process that ignored downstream impacts and neglected to fully involve all water users. The authors advocate better integrated river basin planning and monitoring to enable adjustment of releases, thereby maximizing the environmental impact.

Both existing dams and future dams can be modified to better mimic the natural state so that humans, animals, and plants benefit. At a minimum, the operational management of existing dams can be changed to simulate certain levels of flood. Davies and Day (1998) suggest that between 20-40% of a river's original flow should be maintained in order to maintain normal habitats and ecological processes. Although such an effort may not replicate the more extreme 20-50 year floods, particularly in the movement of sediment, it should still provide considerable biodiversity and fisheries benefits. New dams can be constructed to operate with a multipurpose goal. If dams must be built, they should be positioned in tributaries or, less ideal, in the mainstem, upstream of major tributaries. This helps to maintain sediment and spawning habitat downstream.

While this approach is a win-win situation, policy makers may be reluctant to adopt such an approach until the biological and economic benefits of controlled releases to fisheries and agriculture are demonstrated. A few studies have done so. A twelve-year study of the Trinity river in California, U.S., showed that periodic flooding over

> South Africa used a broad consultative process involving tens of thousands of people to develop principles for its new Water Law (Davies and Day, 1998). As articulated in the White Paper on Water Law (Feb., 1997), the principles include a "water-reserve" that ensures water for both basic human and ecological needs must be met. The reserve will be required to maintain the biological integrity of the country's rivers. South African limnologists and water managers are currently preparing guidelines on the quality and quantity of the reserve needed for ecological functioning. Another principle recognizes that water exploitation must be sustainable over the long term. The legislation based upon these principles has been taken up by Parliament (Day, pers. comm.).

several days combined with removal of invading vegetation created improved and preferred habitats for fish (Barinaga, 1996). An analysis of the Hadejia-Jama area floodplain in northern Nigeria showed that the economic gain from agriculture, fishing, and fuelwood collection was greater than that from proposed development upstream (Aylward and Barbier, 1992). A recent four-year study of the Manantali Dam along the Senegal River showed that it made economic sense to use only 80% of the available hydropower while releasing 20% of the water in a simulated flood; the monetary loss of the hydropower would be more than compensated by the monetary gain in biodiversity, fisheries, and traditional agricultural production (Scudder, 1996). In contrast, lack of flooding would reduce the productivity of the critical dry season floodplain pasture by an estimated 70% and greatly reduce fish stocks.

Figure 53. Few African wetlands, mangroves, coral reefs, lakes, or rivers are currently under protection. Photo credit: Dennis Zemba.

New technologies, policies, and management strategies are needed to maintain or restore the health of riverine systems, which depend on the natural spatial and temporal variability of flow (Species, 1997). Creative efforts need to be applied to future dam design such that sediments can bypass reservoirs, thus providing organic sediment to downstream areas and prolonging the life of the reservoir in terms of water storage capacity (Pernetta and Elder, 1993). Multiple institutions need to be involved so that river basin development considers a variety of users in its design including the habitat needs of aquatic wildlife, and so that land and water management are better integrated (Scudder, 1994; EDF, 1994). To optimize tradeoff between hydropower generation and downstream fisheries, agriculture, and other wildlife, the timing and volume of releases needs to be examined, as there are limits to the amount of water that can be diverted. The timing and volume needs to be tailored for each site, because each river has unique seasonal flow patterns, different stakeholders, and different levels of biological importance. Achieving harmonious use between various water-users is not easy, however, and one needs to be sensitive to the potential for conflict. Even very small-scale hydrological management can upset the balance established over time among different users, as shown in the Hadejia-Nguru Wetland conservation project (Thomas, 1996).

G. Establish Critical Aquatic Reserves

Many more aquatic areas could and should be protected. Few wetlands, mangroves, coral reefs, lakes, or rivers are currently under protection, even in part, and even in countries which have devoted considerable area to terrestrial reserves (Figure 53). Some African countries have marine protected areas, but many are protected on paper only.

To be successful over the long term, though, an aquatic reserve <u>cannot</u> be established in isolation of other conservation efforts, including land use planning, coastal zone management, and policy changes. If these problems are not addressed, the conservation benefits of a reserve will be short-lived. But a reserve may provide a useful start in directing attention and concern to aquatic wildlife. For example, Australia's Great Barrier Reef Marine Park has generated much attention and public interest. Yet even here, the managing institutions have not regulated land decisions, although The Great Barrier Reef Marine Park Act gives them the authority to do so (Salm, 1989)! Land management efforts are currently being attempted for the Florida Keys Marine Sanctuary, USA.

Detailed guidelines for establishing coastal and marine protected areas, including coral reefs, estuaries, mangroves, and coastal wetlands can be found in Salm (1989), Bohnsack (1990), Kelleher and Kenchington (1991), Roberts (1994), Agardy (1994b) and Gubbay (1995). A series of modules for staff training in the management of marine protected areas is available from UNEP (1994). I have been unable to find similar reviews for freshwater conservation. Obviously, such guidelines need to be considered in light of what will work best for a particular country.

1. People Must be Part of the Process

The establishment of aquatic reserves should be predicated on the understanding that people, like wildlife, are part of the landscape. History shows that putting fences around protected areas and excluding local residents has led to a mistrust of government officials and hostility to conservation efforts (Brown, 1996). In such a system, African park officials have focused on enforcing park rules, rather than listening to local people. Breaking the barriers of mistrust takes time and sensitivity. Some uses may be incompatible for the same space, such as fishing and tourism. McClanahan and Obura (1995) have shown that heavily fished sites have reduced abundance and diversity of both corals and fishes, and suggest small protected areas for tourists. However, if certain areas are to exclude certain types of use, this needs to be worked out with local residents.

A possible model for reserves originates from Papua New Guinea, where the government respects the land rights of customary landowners. Whether this model might be applicable to any given country in Africa depends on the country's laws on aquatic areas and resources. Are these areas and resources considered common property, personal property, or property of the state? If considered state property, is it possible to grant some tenurial rights to local residents? Papua New Guinea's Fauna (Protection and Control) Act of 1978 is designed to protect animals (Owen and Marat, 1993). Under the Act, communities can request the establishment of a Wildlife Management Area. The community benefits by obtaining government assistance in management. Consultation with customary landowners is required before the government approves a Wildlife Management Area and before a management plan is established. The management committee reflects the interests of customary landowners within the area, along with local government officials. By 1993, over 90 communities had requested the Department of Environment and Conservation to establish Wildlife Management Areas in their areas.

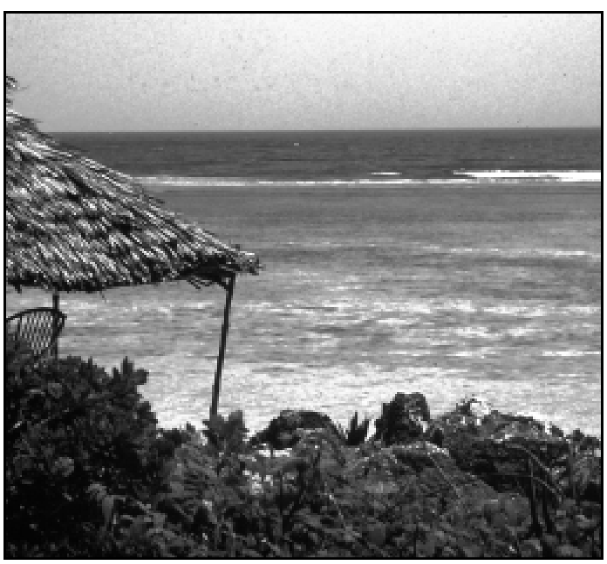


Figure 54. Marine reserves can generate income through environmentally-sensitive tourism. Photo credit: Dennis Zemba.

2. Benefits of Aquatic Reserves to Conservation and Fisheries

Reserves generate innumerable benefits to both conservation and fisheries as summarized in Table 8 (Sobel, 1996). **Benefits to conservation:** Marine reserves provide areas of undisturbed habitat; maintain aquatic species diversity; possibly increase community stability (Alcala and Russ, 1990) and can generate more income revenue than fishing (Figure 54). Figure 55 shows the increase in species diversity in Kenyan marine protected areas (McClanahan and Obura, 1996). Roughly 50% of the species found in the protected areas were not found on the adjacent fished reefs. Figure 56 shows that Kenyan marine parks provide 2 1/2 times more income than fisheries on a per area basis (McClanahan and Obura, 1996). Reserves may also be used to help restore degraded habitat, although this effect has been less well documented. The establishment of the Mombasa Marine National Park led to a reduction in algal substrate and large increases in hard coral cover (400% in six years), due to restrictions on destructive fishing practices, a resurgence of herbivorous fish and a concomitant decline of competing sea urchins (McClanahan and Obura, 1996).

Benefits to fishermen: Aquatic reserves can provide both practical and ecological benefits to fisheries management, especially in multi-species fisheries where other management techniques clearly have not worked (Bohnsack, 1990; for reviews, see Dugan and Davis, 1993b; Roberts and Polunin, 1991; Roberts, 1994; Polunin and Roberts, 1993). Reserves may be particularly helpful for coral reef fisheries, where fish are often slow-growing, long-lived, and have delayed maturity, and where food webs are complex (Buxton,1993). Reserves can be especially important for such valuable but vulnerable predatory species as groupers (serranids), snappers (lutjanids), jacks (carangids), and porgies (lethrinids) (Salm, 1989).

Practical: Reserves simplify enforcement, since it is easier to restrict access than to control catch size or inspect gear; they reduce data collection requirements, and they are easily understood by the public. If other management efforts are being applied in the same area, reserves provide an additional insurance against management failure.

Even though numerous studies have demonstrated benefit to fisheries, fishermen can still be hostile to what they perceive as restricted access to fishing. They may feel that even a small conservation project will result in the government taking away their rights to the resource (McClanahan et al., 1997). The only way to address this is to work towards mutual understanding, fully engaging

Table 9. Marine Reserve Benefits Statement

Based on global experience, this statement was developed by 25 international experts at a CMC/CMRC Marine Reserve Workshop in the Bahamas, 26 to 30 September, 1995. The following benefits can reasonably be expected with an appropriate system of marine no-take reserves accompanied by other management measures. For some benefits, the degree of benefit will be variable for individual species and dependent on both their life histories and reserve design.

Protect Ecosystem Structure, Function, and Integrity

- keep biodiversity intact at all levels
- protect food web
- safeguard ecological processes
- maintain trophic structure
- protect natural population structure
- retain keystone species
- sustain species presence and abundance
- prevent loss of vulnerable species
- preserve natural community composition
- eliminate second order impacts
- maximize system resilience to stresses
- avert cascading effect
- maintain physical structure of habitat
- preclude threshold effects
- preclude fishing gear impacts
- avoid incidental damage
- retain natural behaviors and interactions
- maintain high quality feeding areas

Improve Fishery Yields

- Protect spawning stocks
- increase spawning stock biomass
- raise population fecundity
- enhance reproductive capacity
- increase spawning density
- provide undisturbed spawning sites
- ensure viable spawning conditions
- improve spawning habitat
- boost egg and larvae production
- provide export of eggs and larvae
- enhance recruitment
- supply spill-over of adults and juveniles
- reduce chances of recruitment over-fishing
- decrease over-fishing in vulnerable species
- mitigate adverse genetic impacts of fishing
- reduce inadvertent and bycatch mortality
- protect diversity of fishing opportunities
- maintain sport trophy fisheries
- simplify enforcement and compliance
- help reduce conflicts among users
- provide information from unfished populations necessary for proper management of exploited stocks
- improve management and increase efficiency with limited resources and information
- insure against stock collapse due to management failures and inadequacies and speed recovery
- increase understanding and acceptance of management
- facilitate stakeholder and user involvement in management

Expand Knowledge and Understanding of Marine Systems

- foster understanding of natural systems
- provide experimental sites for natural areas
- permit knowledge continuity of unaltered sites
- retain memory of natural systems
- enable study of relatively intact ecosystems
- allow study of natural behaviors
- provide long term monitoring areas
- reduce risks to long term experiments
- offer foci for study
- enhance synergy from cumulative studies
- allow research, monitoring, data- collection and learning that require natural sites
- provide controlled natural areas for assessing anthropogenic impacts, including fisheries

Enhance Non-Consumptive Opportunities

- enhance and diversify economic activities
- improve non-consumptive recreation
- improve piece-of-mind
- enhance aesthetic experiences
- increase wilderness opportunities
- promote spiritual connection
- foster sustainable employment opportunities
- diversify and stabilize economy
- enhance conservation appreciation
- create public awareness
- reduce room for irresponsible development
- foster constructive social activity
- encourage holistic approach to management
- provide otherwise unavailable educational opportunities

Reserves provide innumerable benefits to conservation and fisheries management. Reprinted courtesy of The Canadian Museum of Nature: Sobel, J. Marine reserves: necessary tools for biodiversity conservation? Global Biodiversity *6(1): 8-17. Copyright 1996, Canadian Museum of Nature, Ottawa, Canada.*

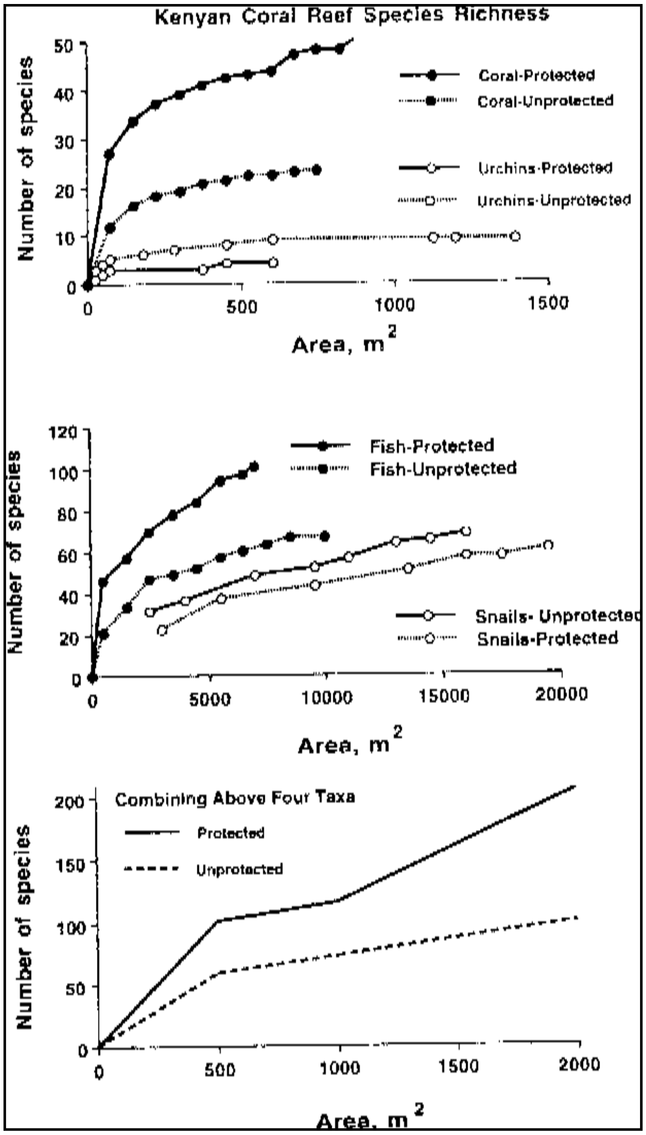


Figure 55. Increase in species diversity in Kenyan marine protected areas compared to unprotected areas. McClanahan and Obura, 1996. From East African Ecosystems and Their Conservation *by Tim McClanahan and Truman P. Young. Copyright © 1996, Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.*

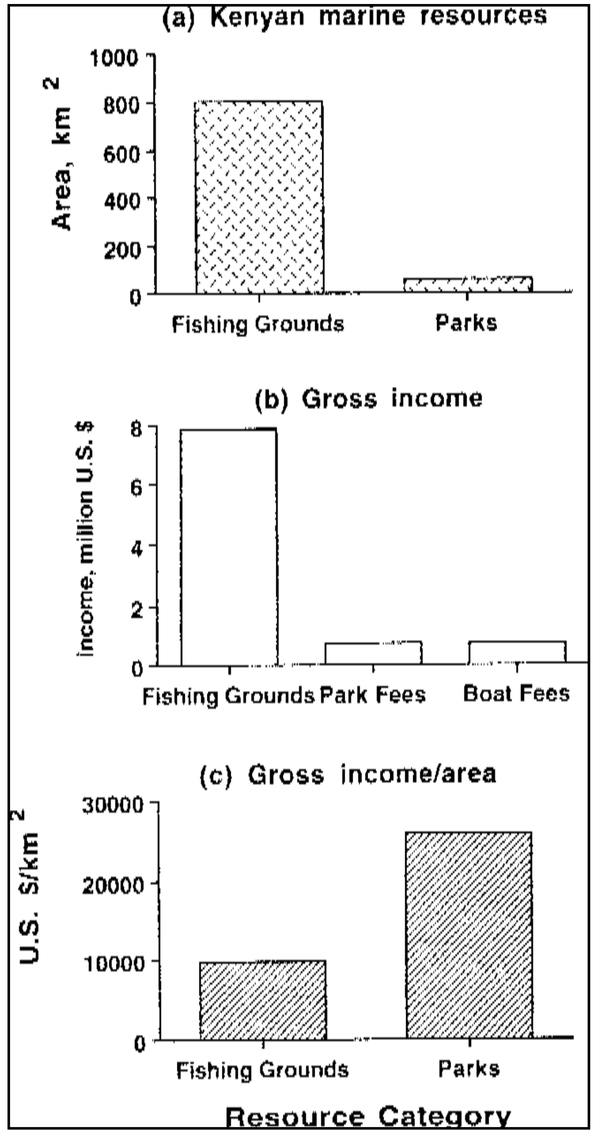


Figure 56. Comparison of income from fisheries and tourism to marine protected areas. McClanahan and Obura, 1996. From East African Ecosystems and Their Conservation *by Tim McClanahan and Truman P. Young. Copyright © 1996 by Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.*

fishermen as stakeholders in reserve planning, and ensuring equitable rules for all of the different users. Roberts (1994) recounts the process in St. Lucia, where nearly 20 marine reserves were established without the involvement of fishermen. The fishermen felt that the regulations picked on them exclusively, and did not comply with enforcement. The parks failed. In 1992, the fisheries department involved fishermen in the process, with the result that the reserves now had broad community support. In sum, fishers need to buy into the process.

While the establishment of a reserve <u>will</u> cause immediate short-term losses in fishing due to reduction in the size of the fishing area, in many cases, the losses will be minor (Sladek Nowlis and Roberts, 1998, in press). The impact will be worse in the first year or two. McClanahan and Kaunda-Arara (1996) studied fisheries yield next to a large, recently established Kenyan reserve which eliminated nearly 65% of the fishing area. The numbers of fishermen fishing also declined by the same amount, thus keeping fishing effort relatively constant. While increases in catch per unit effort occurred almost immediately, the <u>total</u> catch declined by 35% after two years. More recent unpublished measurements, however, indicate that the total catch now exceeds the original catch before reserve establishment (Sladek Nowlis, personal communication). The impact can be lessened by reserve design and mitigative management measures such as providing compensation to fishers in the early years, reducing the total number of fishermen through the development of alternative livelihoods, or phasing the reserve in over a period of years (although this latter measure can reduce long-term gain, Sladek Nowlis and Roberts, 1998, in press).

Ecological: The three most touted benefits are that reserves protect spawning stock biomass, provide larvae to adjacent areas, and provide adults to adjacent areas via emigration (i.e., a 'spillover effect'). Have these benefits been demonstrated?

Numerous studies have shown differences between reserves and adjacent fished areas, including 2-25 times <u>greater abundance</u> of targeted fish and some invertebrates, and 12-200% <u>increase in size</u> (and hence <u>increased reproductive output</u>) within the reserve (Alcala and Russ, 1990). Roberts (1994) reports that the increased abundance and size result in 80-600% higher egg production in protected populations. The benefits of increased abundance and size are very rapidly attained. For example, Saba Marine Park and Hol Chan Marine Reserve doubled their standing stock within a four year period (Polunin and Roberts, 1993). Only a few studies, however, compared the reserve area before and after closure to fishing, leaving the other studies open to criticism that the reserve and fished areas themselves differed substantially in some environmental characteristics such as quality of habitat, or current flow. Bennett and Attwood (1991) compared catch per unit effort before and after the establishment of a marine reserve in South Africa, and showed general stock recovery as a result of the reserve. Note that even studies comparing the same area before and after closure of part following reserve establishment can be confounded by changes in fishing effort following a reserve, and/or change in gear types allowed in remaining fishing grounds (Sladek Nowlis, pers. comm.).

Several studies have shown that while increases in size of protected individuals is likely to occur for most species, increases in abundance and diversity may not occur for all taxa or species (McClanahan, 1994; Buxton and Smale 1989; Russ and Alcala, 1989; and Cole 1993). This can occur for a number of reasons, including differences in fish behavior (such as differences in catchability and mobility); differences in growth rate, differences in stock-recruitment relationships (Polunin and Roberts, 1993); and how fishing pressure impacts a predator-prey relationship (Roberts and Polunin, 1993).

A few empirical studies (largely tag-recapture studies) have examined whether emigration from adults, or "spillover" occurs (Russ and Alcala, 1996; Buxton and Allen, 1989; Attwood and Bennett, 1994; Holland et al., 1993; Holland, 1996; for review, see Roberts and Polunin, 1991). The overall conclusion from these studies is that some movement does occur <u>to nearby areas</u>, generally within a range of few hundred meters to less than two km. However, species differ in their willingness to relocate (Kramer and Chapman, 1998). Attwood and Bennett (1994) found a few tagged individual galjoen 1000 km away from a S. African reserve! Davies (1995) surveyed the distribution of a serranid between and within five coral reefs along the Australian Great Barrier Reef, and found that less than 1% of the population moved between reefs, but there was considerable movement within reefs. Buxton and Allen (1989) found no movement out of the South African Tsitsikamma Coastal National Park of two sparid species even after 500 days, but acknowledged that the reserve may have been too large to facilitate spillover. A few studies directly demonstrated increased fishing yields. Alcala and Russ (1990) showed that the fishing yield was 50% higher in areas adjacent to a reserve protecting 25% of the reef, in contrast to an overall decline in fishing yield when the protection was lifted. McClanahan and Kaunda-Arara (1996) compared catches per fisher at two locations differing by their proximity to the establishment of a Kenyan marine reserve, and showed increased catch per fisher next to the reserve, suggesting spillover.

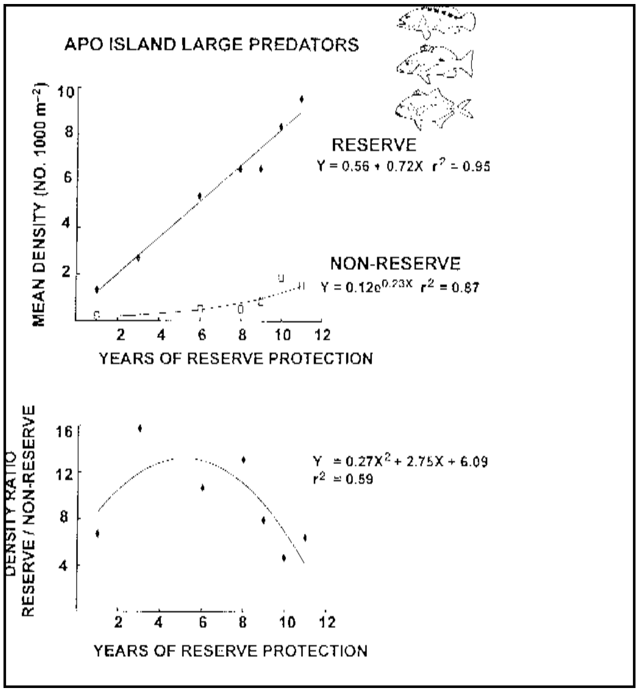


Figure 57. Adult 'spill-over' effects of reserves to adjacent fisheries. The top figure shows the change in density of large predatory fish as a function of time in protected and fished areas in the Philippines; the bottom shows that it took five years to maximally increase fish density in the reserve. From Russ and Alcala, 1996. © Inter-Research.

Adult spillover benefits may take some years to develop, particularly if pressures to relocate are "density dependent", meaning that adults disperse to less densely populated areas as density increases. As measured by catch rate, benefits were detected five to eight years after reserve establishment (Yamasaki and Kuwahara, 1990; Russ and Alcala, 1996). (See Figure 57) Our scientific knowledge is incomplete, though; we simply don't know how frequent density-dependent relocation is in adult fish. Modeling studies by Polachek (1990) and DeMartini (1993) suggest that adult spillover can increase catches slightly, with the effect greatest when fisheries are heavily overexploited.

To date, there have been no empirical studies directly showing spillover of larvae to adjacent areas (Sobel, personal communication), although this is to be expected. Modeling studies by Sladek Nowlis and Roberts (1998, in press) indicate that a higher total catch should be achieved following the establishment of a reserve despite a smaller fishing area. The model assumes density-dependence of larval settlement. The authors argue that slow-moving or sessile species, and those with high site specificity are likely to fit their assumptions. Just as with adults, however, we cannot generalize to whether larvae are positively or negatively attracted by conspecifics. Sweatman (1983, 1988) has shown that some species preferentially settle around conspecifics, and some are influenced by other species (e.g., prey, predators, or competitors) (Reed and Dobson, 1993, Jordan et al., 1997, Kramer et al., 1997).

Reserves may provide other benefits as well. Bohnsack (1996) suggested that marine fishery reserves could boost population stability by dampening natural variability, making fisheries more stable and easier to manage. The model by Sladek Nowlis and Roberts supports Bohnsack's hypotheses, but no field work has empirically shown this to be true. Such a result is very important, as it could boost the ability of fishers to predict their future income.

Reserves also protect intraspecific genetic diversity, at risk due to selective fishing pressure on certain phenotypes (e.g., large size, fast growth). Finally, reserves preserve natural population age structure, sex ratios, and community complexity. Selective fishing pressure is often exerted on the larger (and hence older) fishes, which can affect sex ratios of those species in which sex change is size-dependent (Shumway, 1999). Buxton (1993) showed differences in the sex ratio of protected versus unprotected fish in South Africa.

3. Differences Between Terrestrestrial and Aquatic Conservation

While the science of aquatic reserve design generally lags behind that of the terrestrial, it is clear that terrestrial models should not be blindly followed. Terrestrial and aquatic conservation have different approaches and different biological realities. For example, many terrestrial reserves use island biogeographic theory to determine size and shape. While island biogeographic theory may be useful for highly restricted (i.e., stenotopic) lacustrine species, it is not sufficient in a marine setting because of the tendency of some marine organisms to disperse their larvae more broadly through pelagic dispersal. Terrestrial models have often focused on structural protection (e.g., putting fences around reserves), been species-oriented, and used a hot-spot approach, although the situation is changing (see Soulé and Simberloff, 1986; Pickett et al., 1996). It should be clear that none of these approaches will provide effective aquatic conservation over the long term. Due to the fluidity of the medium and the link with other ecosystems, simply putting a fence around an aquatic area is insufficient; indirect degradation can occur due to global warming, point source pollution, or poor watershed or coastal zone management (Agardy, 1994b). Aquatic conservationists have recognized the need to protect important ecological processes such as productivity and links in nutrient cycling, in addition to species endemism and/or species numbers (Agardy, 1994a). For example, freshwater input and mixing are important contributors to marine productivity and diversity (Agardy, 1994b). Terrestrial and aquatic reserves also differ relative to property rights: aquatic areas are often considered either state property or common property.

Regarding approach: Terrestrial and aquatic reserves differ in management practices (Weru, 1995). While some terrestrial protected areas are strict no-take reserves, no-take aquatic reserves are rare. McClanahan (1990) and Sobel (1996) have argued forcefully for the need for no-take reserves, in part because of their utility in being control areas to compare with other areas disturbed by human stresses and in part to their role in conserving top-level predators that are impacted by overfishing. Generally, however, aquatic reserves are zoned for multiple use. Reserves can encompass core and buffer areas, or different multiple use areas with compatible uses allowed in one space, and incompatible uses separated. Kelleher and Kenchington (1991) provide some guidance on management of multi-use marine reserves.

Regarding biology: Terrestrial and aquatic ecosystems differ in dynamics, scales, patchiness, integration with other ecosystems, life history characteristics, and diversity. Unlike terrestrial ecosystems, often defined by geographic boundaries, it is difficult to detect ecosystem boundaries in the ocean, with the exception of coral reefs. Marine primary producers, unlike terrestrial ones, can be small and mobile, facilitating transfer of nutrients between sites (NRC, 1995, UNEP, 1994). Marine systems are more dynamic and nonlinear than terrestrial ones. Food webs can be more complex. Marine biogeographic zones also change more quickly in time than terrestrial ones because marine organisms respond more quickly to changes in temperature and currents (Kelleher and Kenchington, 1991). Due to pelagic larval dispersal and the necessity for different habitats at different points in the life cycle, marine systems are "leakier", more connected, and operate on larger scales than terrestrial ones. Marine ecosystems can include hundreds of km. At the same time, due to considerable environmental variability at a local level (both in time and space), aquatic systems are more patchy in terms of food resources and habitat. Large marine predators and grazers also have a greater "range of life-history characteristics" than terrestrial ones, including diverse reproductive strategies (NRC, 1995). Finally, aquatic systems differ in having much more diverse higher taxa. The marine world has thirteen unique animal phyla, in comparison to one unique phylum on land. Thus species diversity measurements alone are not adequate for ecologically assessing the importance of a site.

4. Where Should a Reserve be Located?

Both ecological and social factors should be considered in determining the location of a reserve. (See Chapter 6). The selection of criteria depends on the reserve's stated purpose. For example, if considered as a tourist attraction, overall aesthetic value, public safety, and accessibility may take precedence over population abundance of particular species (Salm, 1989). One important point to highlight is that we need to better protect productive areas, not just species-rich ones. We need to protect species, their support systems (e.g., nutrient inputs), and their critical habitats.

One advantage of establishing an aquatic reserve relative to a terrestrial one is the fact that boundary delineation does not need to be costly or permanent. In principle, aquatic reserves can be flexible, migrating in time, or even space (Figure 58). For example, a reserve could protect a given site seasonally during spawning aggregations. Beets and Friedlander (1999) have shown that this type of protection was sufficient to bring the red hind back from the brink of overexploitation. Or a reserve could be established temporarily to boost the size of the standing stock, resulting in increased fecundity. Recent modeling efforts by Guenette (cited in Sladek Nowlis and Roberts, 1998, in press) suggest that reserves can benefit even highly mobile species through enhanced population fecundity gained from temporary protection. Migrations in space might be considered for an overfished area, to alleviate the concern of local fishers that an area might be permanently closed, or to protect migratory species. (Migrations in space, however, may have additional hurdles due to political considerations.)

Recommendations for specific sites for African marine reserves are provided by Wells and Bleakley (1995) and Gaudian et al. (1995), and are summarized on pages 42-45. As a whole, the continent currently has very few marine protected areas. Those that exist were largely selected for tourism considerations only (Salm, 1996). The reserves are also small and often not managed. Countries that need to be surveyed to identify priority sites include: Eritrea, Cameroon and Gabon. Surveys can be simply undertaken with satellite imagery, aerial photography, and a limited ground survey.

5. Considerations of Size and Shape

Failure to consider the right size and shape of a marine reserve can lead to degradation of a protected area, inability to protect the species within it, and failure to achieve management goals. Weru (1995) notes that the boundaries of many of Kenya's marine parks were drawn

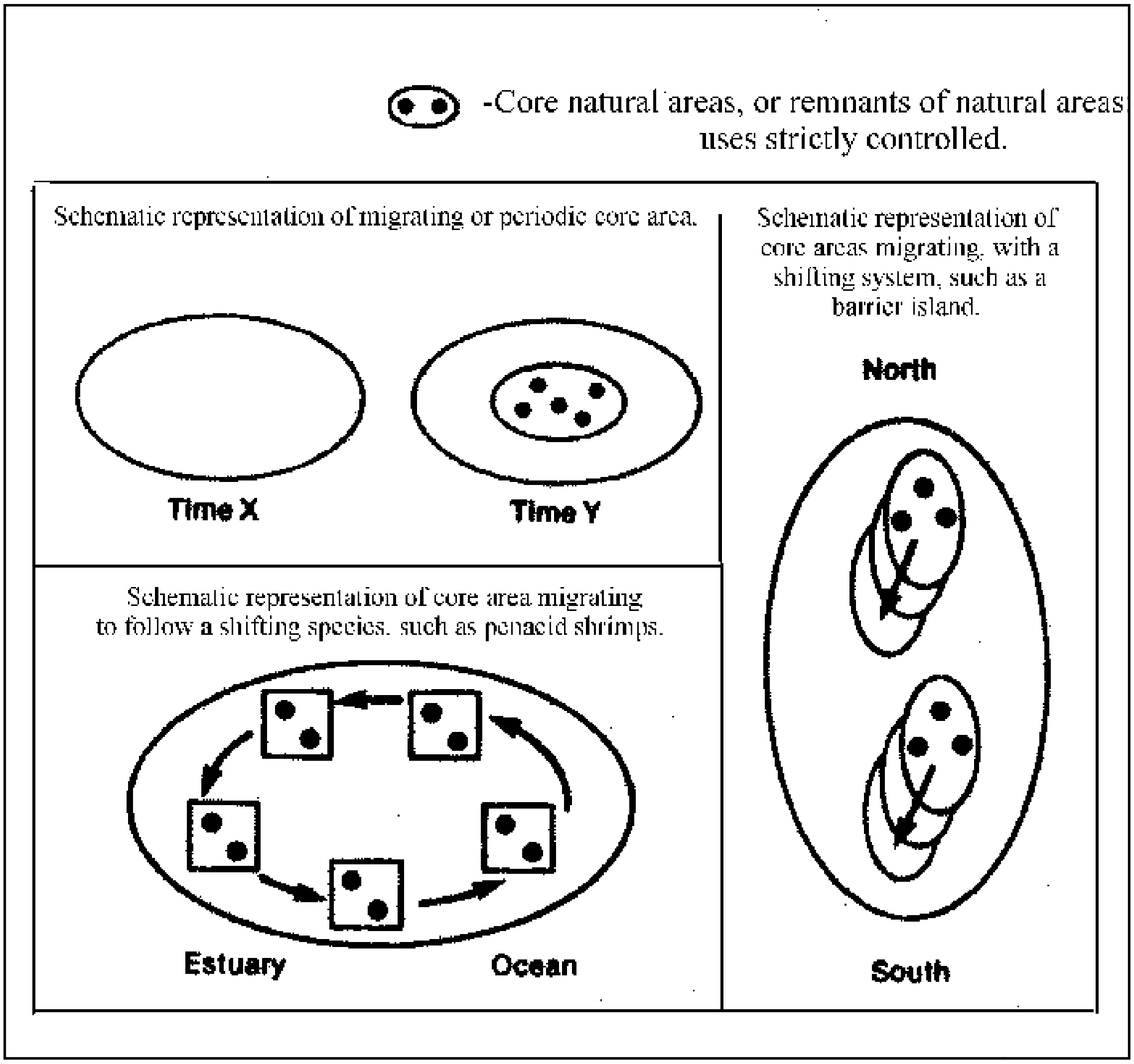


Figure 58. Aquatic reserves can be flexible, migrating in time or space. From Salm, 1989. © IUCN.

without an understanding of the local coastal ecology. Conservation planners should not be daunted. If oceanography, habitat quality, species life histories, and socioeconomic considerations are taken into account, conservation can be achieved with a well-designed mixture of small reserves, coupled with sound management of the other areas (Kelleher and Kenchington, 1991; Dugan and Davis, 1993b).

Size and shape considerations include two issues: 1) the total extent of an area protected relative to the surrounding managed area; and 2) the size and shape of the reserve itself. The second issue, size and shape of the reserve itself, depends on the goals. Is the reserve for conservation, fishing benefits, or both? If it is for fishing, is the goal to generate maximum long-term benefits, or are there pressures to obtain short-term benefits as well?

In all cases, one needs to consider the following in reserve design:

Which neighboring habitats are functionally interconnected. Aquatic ecosystems often incorporate a cluster of habitats that need to be managed as a functional unit (Salm, 1989). For example, coral reef communities depend on adjacent reef flats and/or reef sediments and sea grass beds for their supply of fixed, usable nitrogen, which is essential for photosynthesis. The nitrogen is obtained from algal fragments from the reef flat, from fishes feeding on the reef flat, and from bacteria in the reef sediments and sea grass beds. Mud and sand flats are the habitat of some molluscs, and the feeding grounds of shrimp, crabs, and shorebirds. Fish and invertebrates utilize different habitats at different stages of their life cycle. Larval and juvenile fish predominate in seagrass beds, salt marshes, mangroves, and estuaries (Salm, 1989). Salm argues that the most successful way to protect these latter communities is to protect "all habitat types along a salinity gradient", thereby ensuring that all life stages are protected. Salm notes that species generally move to low salinity areas as young, gaining protection from predators unable to tolerate low salinity conditions. As fish mature, they generally move to more saline waters. Finally, a number of fish have daily feeding migrations to particular sites, which can be hundreds of meters away from their resting sites (e.g., Holland et al., 1993).

<u>Which areas are larval sources; which are larval sinks</u> (i.e., areas where larvae settle). Current patterns can aid in regional efforts at conservation, by informing design of a network of reserves. Larvae tend to stay in the water column from days to two months, with population abundance showing a relationship to current patterns (Dight, 1994). Areas which receive little larval replenishment from the outside will be dependent on the success of local management, while areas which receive ample larval input will be less affected.

What are the general rules? Reefs with larvae that broadly disperse to other reefs should be selected as high priority areas for regional conservation, since they can help maintain populations and fisheries elsewhere. However, these reefs will be less likely to provide local benefits. Other sites should also be chosen to provide local benefits. If a reserve is designed to benefit an adjacent fishery, the reserve should be "upstream" of the fishery area, to facilitate larval export. Note that the population distribution estimated from current patterns is likely to be an upper bound, however, as larval behavior can influence settlement, reducing geographic extent.

As a *first* step in identifying sources and sinks, one can use simple oceanographic measures to assess surface currents, such as floats or dyes. These measures should be taken at various times of the year to attempt to address such considerations as seasonal, tidal, and turbulent flow. Roberts (1997b) mapped surface current patterns over a one to two month duration to identify potential ecological connections between areas in the Caribbean. He showed an order of magnitude variation among sites in the extent of larval supply and the extent of larval export. He also showed connectivity in the range of less than 150 km among sites.

<u>Diversity of reef sizes:</u> Recruitment may be maximally enhanced for a number of reef species by preserving an area with a variety of reef sizes, with more small than medium than large (Schroeder, 1989; also see Sobel, 1994). Salm (1980b) found that some coral species occur only on reefs larger than a certain minimum size. With respect to fish (which are notoriously variable across species), such a <u>mixed size design</u> takes into account more species and more life stages (Schroeder, 1989). Depending on the species, environmental and social variables important for fish habitat selection include the physical and chemical characteristics of the water, characteristics of the substrate; and the presence or absence of conspecifics or other species (Kramer et al., 1997). The recruitment of some fish (e.g., wrasses) also appears to depend on a minimum reef size (Schroeder, 1989).

<u>Diversity of habitats</u>. Protecting a variety of habitats may help to protect significant populations of a variety of species (McClanahan, 1994). Reefs with the greatest diversity of shape, slope, depths, and rugosity (surface irregularities) are likely to have the greatest variety of organisms (Sale, 1989). On coral reefs, two important environmental factors for settlement include depth and substrate type, of which there are many (e.g., ledges, crevices, reef faces, etc.) (Luckhurst and Luckhurst, 1978). Community structure and species dominance also may vary depending on the habitat. Here, too, population variation is important: species widely distributed at one site may not be distributed at others (Williams, 1991). Fishelson et al. (1987) showed that the behavior of the surgeonfish *Acanthurus nigrofuscus* differed dramatically between two sites less than 2 kilometers apart! At one site, feeding migrations occurred to an area 400 meters away, whereas no feeding migrations occurred at the other.

In <u>freshwater systems</u>, conservationists need to take a more dynamic view of population distribution, considering how it may change in space over time (Cohen, 1995). In considering the size of the protected area, one should consider the patchiness of the distribution of a freshwater species, and how long-lasting or ephemeral the occupation of any given patch is: can one be certain that patches adjacent to the current range of a species are not important in its distribution? Paleontological studies from Lake Tanganyika have shown that a given species distribution can change dramatically over time and that current unoccupied areas may become important "stepping stones" for recolonization. Herschler et al. (1990) have demonstrated a similar patchiness in riverine molluscs. Given increasing habitat fragmentation/degradation and environmental variability, conservation efforts in lakes and rivers need to take such metapopulation considerations into account (Fryer, 1995; Herschler et al., 1990; Cohen, 1995). Cohen (1995) argues that where feasible (i.e.., depending on sediment and fossil conditions), freshwater conservationists should consider the use of paleobiological data to determine the historical habitat range and variability in distribution of individual species.

<u>The behavior and life history characteristics of target species</u>. While behavior is often neglected in marine reserve

design, it plays an important role. Information on recruitment and settlement, habitat preferences for spawning, resting, and feeding, territorial and home ranges, and degree of site fidelity is all important in optimizing design (Kramer and Chapman, 1999; Rakitin and Kramer, 1996; Shumway, 1999). In particular, one needs to consider the home range and movement patterns of the species of interest (Kramer and Chapman, 1999). Home range is the area in which an animal can be found 95-99% of the time. Home range may comprise two separate areas, connected by a narrow corridor used in feeding migrations, as occurs for grunts (Haemulidae) (Burke, 1995). Unless both habitats are protected, these species may be the most vulnerable to fishing pressures. Other species may forage at distant sites or migrate diurnally or seasonally, where they may be harvested. In addition, one needs to know the home range of the species during its different life history stages (Fogarty, 1995).

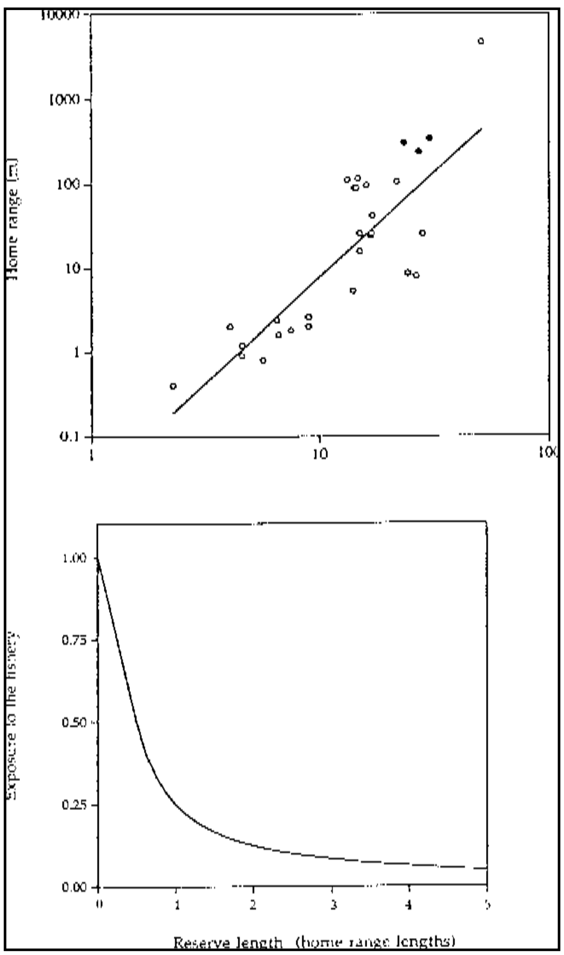


Figure 59. Home range is an important consideration in determining reserve size. Top: Empirically, home range (y) increases with a 2.5 power of body length (x axis). Bottom: Modeling studies suggest that if one wants to limit fishing mortality to less than 10% of the nonreserve situation, reserve size should be <u>*over*</u> *2.5 times home length. From Kramer and Chapman, 1999. Reprinted with kind permission from Kluwer Academic Publishers.*

If one wants to completely protect a population, the reserve should be larger than the size of the home range. How much larger? Modeling studies by Kramer and Chapman (1999) suggest that reserve length must be at least 2.5 times home range length if one wants to limit fishing mortality to roughly 10% of the nonreserve situation and 12.5 times if one wants to limit exposure to 2% (Figure 59). If the 10% figure is desired, a 20 centimeter fish would have a home range of about 45 meters, and the reserve would need to be 100 meters long. This is somewhat of a simplification, as it ignores the fact that different reproductive strategies influence the size of the home range.

The mobility and site attachment behavior of species affect whether or not spillover occurs, and whether or not the density and mean size of a population will increase inside a reserve. Rakitin and Kramer (1996) suggest that the species most likely to benefit from reserve establishment are those that are the most "catchable", i.e., vulnerable to fishing, such as heavily- fished large predatory species with small home ranges, those that are the most site-attached, and those that are the least mobile. Kramer and Chapman (1999) suggest that the benefits of adult spillover will be obtained primarily from species with an "intermediate" tendency to relocate. Those that relocate too readily will not achieve protection from the reserve; those that do not relocate at all will not provide adult spillover.

<u>The orientation of the reserve relative to existing currents and natural boundaries</u>. The shape of home ranges can depend on available habitat. Some fish species will not cross sand flats to relocate to other reefs, even under conditions of high population density, and even though the same species will make extensive movements within continuous reefs (Warner and Hoffman, 1980, Chapman, 1997). Thus if the goal is adult spillover to benefit fisheries, the reserve boundary should cross contiguous habitat.

<u>Socio-economic considerations,</u> including community support, institutional capability, enforcement and compliance, long- and short-term economic impacts, cost of establishment, urgency of action, and political realities (Dugan and Davis, 1993). Ideally, a reserve would be established where there is community and fisher support. If some citizens express reluctance towards a reserve, it may be best to start out with smaller and few reserves. In this way, community members can see the benefits of a reserve for themselves. At the same time, they become more aware of the time required to recover from overfishing or

Figure 60. Determination of reserve size and shape may need to be an iterative process based on local fishing yields and pressure. Ghana fishing industry, World Bank, 1993. Photo credit: Curt Carnemark.

habitat damage. After support is established, local citizens may be more accepting of expansion of the protected area, *if evidence is provided of the ecological necessity of doing so, and they derive local benefits from a reserve.* A small reserve with high levels of community support and active management is far preferable and cheaper to protect than a large paper reserve with hostile residents!

How might urgency of action influence size? If, say, a relatively sedentary species is heavily overexploited, a small reserve will buy some time at least. Later, a more integrative management, policy and regulatory approach would need to be taken. How might political reality influence size and shape? If policy or regulatory changes are impossible to achieve, then pursuing a larger reserve, encompassing a watershed, may help to protect ecosystem processes in the absence of policy changes.

If a reserve is established for conservation purposes alone, most scientists might intuitively believe that the larger, the better. Salm (1989) suggests that the minimum size is that size necessary to ensure that all coral species within the area are represented. In the Chagos Archipelago, Indonesia, Salm found that a minimum of 300 ha was necessary to ensure that all species were represented in each reef type. However, McClanahan (1994) has argued that given high local genetic diversity and ease of dispersal, some of the arguments for large areas do not apply to coral reefs. Furthermore, endangered sedentary species may require only a small protected area, assuming other threats such as pollution, sedimentation, etc. are either not an issue or are subsequently addressed. One also needs to consider the ratio of edge to area (minimizing the edge to reduce adult spillover) and orientation of the reserve relative to existing currents (to ensure larval settlement in the area).

If a reserve is established to benefit fisheries alone, then one needs to consider the following:

The extent of the area protected, relative to the total amount open for exploitation: A balance must be struck. If too much of a fishing area is protected, the benefits of the reserve are countered by a loss in fishing yield. Optimal reserve design depends on the level of fishing pressure, species assemblage patterns, the life history characteristics of the species of interest, the population growth rate, the mobility of adults, and characteristics of larval settlement (Sladek Nowlis and Roberts, 1998, in press; Kramer and Chapman, 1999; Auster, 1994).

Determination of size and shape may need to be an iterative process based on local fish yields and fishing pressure (Figure 60). Fisheries reserves need to be flexible, with managers responsive to the feedback obtained from monitoring. Regulations, size and shape can all be adjusted as new information on the success or failure of a reserve is obtained (Auster, 1994). A recent modeling study suggests that the size of the reserve needs to be matched to fishing intensity, increasing in size with increasing fishing pressure (Sladek Nowlis and Roberts, 1998, in press). Other modeling studies and some empirical evidence suggest that benefits to fishing are realized when at least 20% of an area is protected (Roberts, 1994; Russ and Alcala, 1996). Reserves may need to be larger, however, for species vulnerable to fishing before they reach sexual maturity. Very large reserves (e.g., 75-80% of total area) are only necessary for replenishing extremely over-fished populations, all else being equal (Sladek Nowlis and Roberts, 1998, in press). Again, the amount required for protection can depend on the behavior of the species of interest. Yamasaki and Kuwahara (1990) showed benefits to snow crab fisheries after just 2% of the fishing ground was protected!

The ratio of edge to area: I would recommend trying to maximize larval spillover and provide at least some level of adult spillover for fishing reserves. Boehlert (1996) reports that the majority of coral reef fishes and invertebrates disperse widely as larvae and narrowly as adults. A recent modeling study also suggests that the greatest benefit may be larval dispersal (Sladek Nowlis and Roberts, 1998, in press), but this has yet to be shown empirically. If one wants to optimize adult spillover, a balance must be reached between too much spillover, which could limit reproductive capacity, while too little will make fishers less likely to support a reserve.

Importance of Land Protection Within a Watershed

One of the major tributaries of the Tennessee River, U.S., maintained its biodiversity because of watershed protection. While other tributaries lost numerous mollusk species following the generation of dams on the Tennessee, with mussel densities declining by 50-75%, the mussel densities in the Duck River increased over 100%. This occurred despite the completion of one of two dams on the Duck River. What was the reason for the success? Over 15 years ago, the government purchased large portions of the watershed (16,000 acres) including one-quarter of a mile on either side of riparian land. As a result, the river was unaffected by pollution from nutrients, pesticides, and salt. This result indicates the intimate link between the health of species in aquatic environments and land use in the watershed. It is clear that policy-makers should make every effort to maintain riparian vegetation in a sufficiently-sized buffer strip along rivers and streams (Bean, 1994). The U.S. EPA has distilled the Top 10 Watershed Lessons Learned, along with case-studies in a 1997 document. Contact: http://www.epa.gov/owow/lessons.

The edge should be long relative to area in order to facilitate the exchange of both larvae and animals from the reserve to adjacent areas. One way to facilitate the exchange of both larvae and adults is to create small reserves within an unprotected (but preferably managed) area (Roberts, 1994); large reserves are likely to leak more slowly. Roberts (1994) suggests that the minimum viable size is a reserve of one to three kilometers^2. While the Saba Marine Park in Belize was only 0.9 km^2, it showed a doubling of standing stock after a four-year period. McClanahan and Kaunda-Arara (1996) suggest a reserve size of less than six kilometers^2.

6. Total Catchment Management

In locating a reserve, one needs to take into account the ecological links between marine, fresh, and terrestrial ecosystems. Management should consider important elements within an entire catchment (i.e., the entire area, from mountains to ocean, that is drained by a single river system, Davies and Day, 1998), noting the location of the watersheds, rivers, streams, estuaries, and lagoons (Salm, 1989). At a minimum, one should consider upcurrent sources of municipal, agricultural, or industrial pollutants, nutrients, or sediments in placement. Data from Sladek-Nowlis et al. (1996) suggests that corals sited a few kilometers from rivers will be reasonably protected from sedimentation. For a lacustrine reserve, Cohen et al. (1993) recommend siting protected areas adjacent to rivers with small drainage basins or to erosion-resistant rocky areas. Coulter and Mubamba (1993) recommend extending lacustrine reserve boundaries to protect some pelagic lacustrine species from overfishing.

H. Develop Sustainable Fisheries

Within limits, the interest of managing exploited fish stocks for maximum sustainable yield and the conservation of biodiversity are mutually compatible, not conflicting. In many countries, however, fisheries managers now need to change their focus from maximizing yield to restoring stock (Figure 61). Both fisheries departments and conservation departments have an interest in halting overfishing, preventing pollution of waters, and protecting critical habitats. **It is at this juncture where efforts should be focused.**

Adopt a precautionary approach in fisheries and other coastal resource management. As Ludwig et al. (1993) note, "Effective policies must take uncertainty into account. We must consider a variety of plausible hypotheses about the world; consider a variety of possible strategies; favor actions that are robust to uncertainties; hedge; favor actions that are informative; probe and experiment; monitor results; update assessments and modify policy accordingly; and favor actions that are reversible."

Because uncertainty affects all elements of the fishery system in varying degrees, some degree of precaution is required at all levels: in planning, management, research, technology development and transfer, policies, fish capture and processing, stock enhancement, and aquaculture (FAO, 1995a). An important place to start is to incorporate into national legislation the currently voluntary FAO Code for Responsible Fisheries (McAllister, 1995).

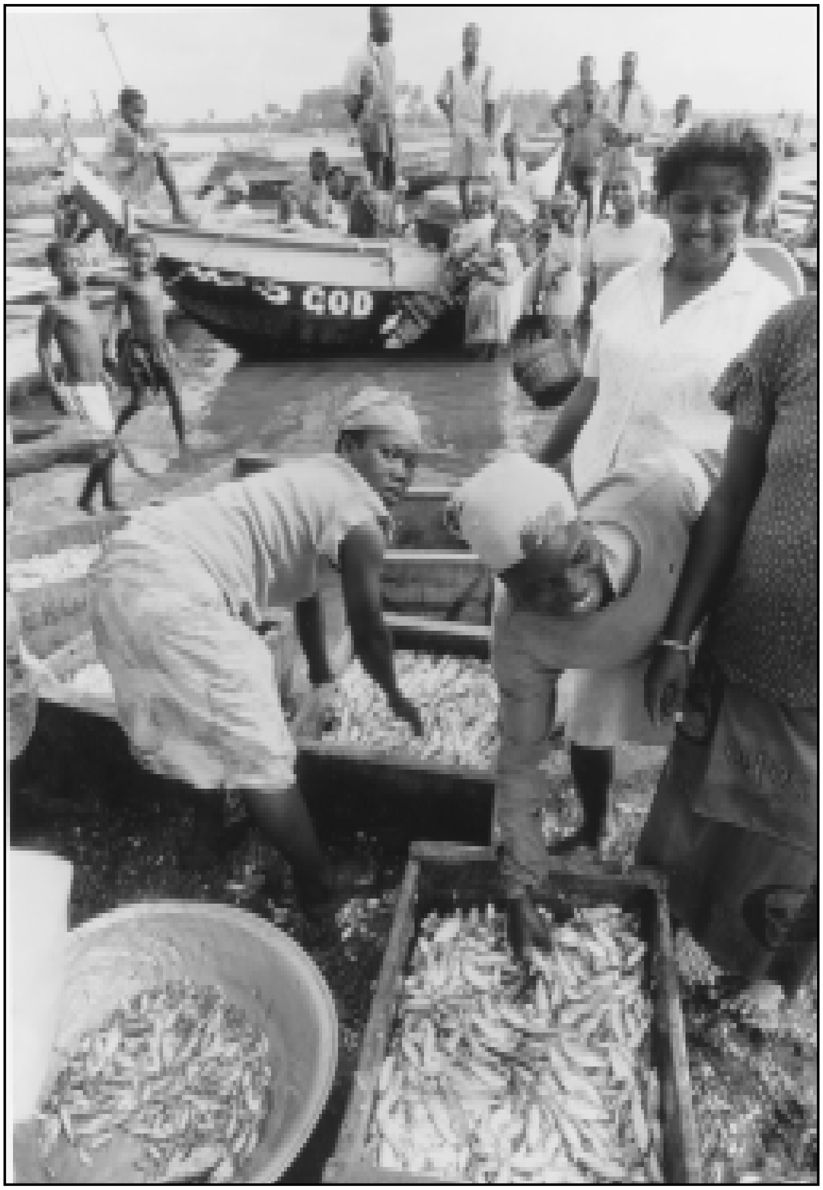


Figure 61. In many countries, fisheries managers need to change their focus from maximizing yield to the restoration of stock. World Bank, 1993. Photo credit: Curt Carnemark.

The following is a brief description of precautionary guidelines. (See FAO, 1995a, for more detail):

1) <u>Take into account the combined stresses of fishing and environment on fisheries resources</u> (Garcia, 1995). Estimates of sustainable catch levels should be conservative enough to account for both scientific uncertainty and natural variability (Fujita et al., 1994). Management action should be automatically enacted when early warning signs of overfishing are found, such as: changes in species composition; reduction in spatial distribution of the stock; and shifts in the age structure of spawners to younger fish (FAO, 1995a). Ancillary impacts should be examined as well, including <u>degradation of fish habitat</u> and effects on birds, mammals, and other species (FAO, 1995a).

2) <u>Take steps to prevent overcapitalization, both in vessels and in processing.</u> When there is a good year class, use the recruits to increase stock levels rather than total harvest. Do not provide subsidies or tax incentives to maintain fishing capacity. Remove excessive fishing capacity from the fishery (FAO, 1995a). Finally, take advances of fisheries technology into account. Even if fishing effort remains constant, increased technological efficiency could result in overfishing.

A new fishery should be limited enough such that irreversible risk is likely. Right from the start, management should prevent excessive investment in processing and build in flexibility so that it is feasible to phase vessels out of the fleet if necessary. Management objectives should be set below maximal sustainable yield, until more detail is available regarding population demographics, total population estimates, and the effect on fish habitat.

Underlying principles of the precautionary approach are: 1) that action should be taken even in the absence of scientific certainty if there are risks of serious or irreversible damage (Kirkwood and Smith, 1995); and 2) that the regulatory burden of proof should be shifted onto those seeking to profit from the resource to demonstrate there will be little or no environmental impact (M'Gonigle et al., 1994, cited in Hilborn and Peterman, 1995). Such an approach is more likely to be accepted if management action is automatically enacted when the stock or change in the environment reaches some pre-defined critical level (Garcia, 1995).

Enhance collaboration and cooperation between fisheries departments and departments of wildlife and conservation. Fisheries departments need to become more aware that aquatic reserves can be a useful component of efforts to halt overfishing. Similarly, conservation managers need to realize the importance of interacting with fisheries managers. Perhaps this can be facilitated by funding short-term secondment, or “swaps,” of personnel between organizations.

Incorporate aquatic reserves as part of a fisheries management strategy (See pages 92-102 for more detail on reserves)**.** Such an approach is particularly important in multi-species fisheries. Kenchington states that “marine parks and reserves assist fisheries management by providing replenishment areas or refuges for breeding stocks, by providing research sites for fisheries scientists, by providing alternative sources of income for the expanding fishing community, and by resolving resource conflicts with non-fishing users” (Kenchington, as cited in Samoilys, 1988b).

Encourage governments to work *with* local fishers to design culturally appropriate fisheries regulations (Figure 62). Too often, fisheries regulations devised by fisheries departments in conjunction with donor consultants are doomed to failure, being socially and culturally inappropriate. An example is restricting the number of fishing licenses in a community which believes in the equitable sharing of resources. In this particular example, a more appropriate regulation would be to ban fishing on particular days, since such a regulation would apply to all.

Fishermen are most likely to comply with regulations when they are confident others are doing the same. In the case of artisanal fisheries, managers could focus on preserving biological processes (e.g., habitat, spawning, etc.) rather than the number of fish caught. Why? The biological processes affecting the various life stages are more regular and predictable than stock level, making it easier to regulate the “how, when, and where of fishing.” Examples include limiting the season of fishing, restricting fishing of certain spawning grounds, etc. This method has traditionally been used successfully in over thirty artisanal fisheries worldwide (Wilson et al., 1994). Such management only works, however, if locals have recognized rights to the resource or territory (Wilson et al., 1994). McGoodwin argues for this type of management at local levels in concert with an overall national limit on exploitation rates (Fogarty, 1995).

Other management strategies can be applied to a combined artisanal-industrial fishery where fish are considered a common resource. In this case, overfishing occurs because fishermen are afraid that if they don’t catch the fish, others will. Managers could consider creating rights to the resource with some type of quota system that provides transferable rights to a portion of the catch: either individual transferable quotas (ITQs) or community development quotas (CDQs). Essentially, a biologically conservative ceiling is put on total catch each season. ITQs are given to individual fishing vessels. It is important to note that ITQs require a well-developed institutional infrastructure to ensure adequate monitoring (Fujita and Zevos, 1996). As such, they may only be appropriate for some countries. Further, a valid criticism of ITQ systems is that they are likely to exacerbate highgrading (the discarding of small or lower grade fish of the same species) if there are substantial price differences (Fujita and Zevos, 1996). Highgrading negatively impacts the gene pool. This problem may be alleviated with community development quotas which spread fishing effort out geographically. CDQs are components of the total allowable catch that are allocated to eligible communities (Fujita and Zevos, 1996). In both cases, shares can be used, leased, or sold.

Figure 62. Fisheries regulations should be developed in conjunction with, and in full compliance of relevant local communities. Ghana fishing industry, World Bank, 1993. Photo credit: Curt Carnemark.

These types of quotas have been shown to reduce overcapitalization and increase profitability (Muse and Schelle, 1989; Muse, 1991, cited in Fujita et al., 1994). Since fishermen know how many fish they can catch, they have no incentive to overinvest. “Leaving fish in the sea for conservation purposes finally makes economic sense to an individual fisherman” (Fujita et al., 1996). However, it is important to note that such methods directly address only some of the issues causing overcapitalization. They do not address subsidies or tax incentives that are independent of fishing effort (EDF, 1994).

The resurrection of traditional management practices was recently successfully and voluntarily applied by a number of villages in Vanuatu, an island in the South Pacific, even in areas where they had not been practiced for a lifetime (Johannes, 1994; also see http://www.solutions-site.org for this case study).

Fishermen need to feel that the allocation is fair. Quota programs can be sensitively designed so that they maintain a diverse fishing industry and do not result in undesirable social changes. The initial allocation formula should not place too much weight or be exclusively based on catch size (Fujita et al., 1996). To prevent excessive consolidation of the fishing vessels, quota shares can be allocated according to distinct vessel categories. In addition, guidelines can establish that no single holder may own more than a few percent of the total allowable catch (Fujita et al., 1996). Other possible allocation approaches include formulas based on equal shares, catch capacity, catch history, clean fishing practices, or a combination thereof (Fujita et al., 1994).

Wherever possible, work with governments and traditional authorities to determine the extent to which traditional conservation practices could be reestablished, or strengthened and reinforced by laws. Traditional management practices (such as size restriction, taboos on certain methods and periods of collection, or taboos on species) can be reestablished or strengthened in countries known to have had them in the past. While the original intent of some of the customs may not have been conservation, the potential conservation impact of such practices can be considerable. In Ghana, certain rivers and streams were considered sacred and adjacent forests were also protected. In West Africa, some coastal lagoons were considered sacred, and some species considered taboo; even today, tabooed species remain protected while other species in the same area are overexploited (Ntiamoa-Baidu, 1991, cited in BSP, 1993). Currently in the Inner Niger Delta, Mali, “water keepers” have water rights, based on patrilineal lineage. The right can be transferred, however, by paying a fee.

In the Philippines, the national government has devolved jurisdiction over inshore marine areas to local governments and given preferential rights to organized artisanal fishermen (Heywood, 1995). Similarly, a pilot coastal zone planning project in Guinea-Bissau gives preferential boat (“pirog”) quotas to local fishers (IUCN, 1996).

One caveat is that not all traditional practices continue to be effective in protecting biological diversity. McClanahan et al. (1997) examined traditional fisheries management at a site in southern Kenya, and found that it was currently unable to conserve fisheries resources. The authors noted, however, that while most of the traditional rules were fully observed 30 years ago, today, the younger generation did not follow the rules, for a variety of reasons. A second caveat is that governments may need to be convinced of the value of traditional management. Government may fear that traditional management will conflict with national policies (McClanahan et al., 1997).

To address the problem of management capacity, governments should consider devolving control to community-based management or co-management (i.e., joint management by a community and government). See pages 83-84 for further detail. The advantage of co-management is that fisheries departments can provide technical advice if needed - particularly if government officials are afraid that citizens may not have the expertise to manage. Even in the case of community management, fisheries departments can always reserve the right to intervene if they believe conservation and wise stewardship is not being practiced. Regardless of whether management is undertaken by governments or communities, managers need assistance in developing capacity for effective enforcement.

Work to reduce dynamiting and poisoning in East African reef fisheries. The International Marinelife Alliance in the Philippines teaches cyanide fishermen non-chemical, non-destructive fishing techniques. WWF is working to reduce dynamite fishing on Mafia Island, Tanzania, while IUCN is working with local activists in the Tanga region.

Work with fishers for the aquarium trade to ensure they are collecting the fish sustainably. Consider the possibility of ecolabelling to help develop a sustainable trade in aquarium fish or other fish products, much as has been tried with forestry products. Ecolabelled fish can be sold at a higher price, providing an economic incentive for sustainable collecting. A consortium of organizations recently established the Marine Aquarium Fish Council to help certify and develop market incentives for an ecologically sustainable aquarium

Figure 63. Overexploitation can be addressed through practices such as encouraging fisherman to diversify their choice of fish. Ghana markets, World Bank, 1993. Photo credit: Curt Carnemark.

trade. Contact Paul Holthus, Executive Director, for more information (email: paul.holthus@aquariumcouncil.org; web: http://www.aquariumcouncil.org.)

Help reduce bycatch, waste and overexploitation by:

- **encouraging the development of artisanal fisheries using selective gear**, rather than the development of large-scale commercial fisheries.
- **encouraging fishermen to diversify their choice of fish, and assisting with the marketing of diverse species.** When exploitation is spread throughout an ecosystem, less damage is done with respect to species distribution or the abundance of any given species (Figure 63). The diversification of fisheries also provides increased numbers of jobs, as it tends to result in a wider diversity of capture and processing methods. Finally, diversification can reduce the problem of bycatch; and
- **improving methods of fish handling and preservation through training at technical workshops.** Developing local preservation and processing methods reduces waste, adds value, and increases local employment. The University of Rhode Island College of Resource Development (USA) has recently developed a method that keeps fish fresh for up to 14 days without refrigeration.

Encourage integrated aquaculture, which offers opportunities for efficient use of water. Water can be collected from rainfall runoff and stored in ponds. The stored water can be used not only for fish production (either aquaculture or cage culture) but also for livestock, irrigation, and domestic uses. The integration of aquaculture with animal husbandry offers efficient recycling of wastes. The integration with agriculture offers benefits in terms of maximal utilization of labor and land. ICLARM is supporting studies in Malawi on the development of integrated vegetable-fish and rice-fish farming systems. The fish eat insects and molluscs that would otherwise damage the rice and the fish's excrement fertilizes the rice (Pullin, 1997).

Traditional aquaculture methods should also be supported wherever possible, using species indigenous to the area. The heaviest fish yields (up to 100 times normal yield) without artificial feeding are those of the traditional "acadja" fish parks in West African coastal lagoons. In this system, shallow aquatic areas are planted with bamboo stakes. The stakes attract fish by increasing the surface area for growth of periphyton, the food for tilapia and other fishes (Lowe-McConnell, 1987b; World Bank, 1994).

Where overfishing is a problem, support the development of alternative livelihoods for fishers. Possibilities include assisting with artificial reef programs, tourism, or aquaculture. Such an approach, however, must be sensitively developed in conjunction with the fishers themselves, to find out what they might be interested in pursuing. It is not a simple matter to transform a fisherman into a "fish farmer." Fishermen often define themselves in terms of the sea. Further, the socio-economic feasibility of alternatives needs to be rigorously examined.

Chapter 7.
Case Studies for the Conservation and Sustainable Development of Africa's Aquatic Biodiversity: Why, Where, and How?

A number of important aquatic habitats in Africa, such as the African Great Lakes, would benefit from immediate conservation action. Each of these lakes contain more endemic fish species than any other lake in the world. Photo credit: Caroly Shumway

This chapter shows how some of the recommendations provided in Chapter 6 might be specifically applied to 14 important aquatic areas in Africa that would benefit from immediate conservation action. As should be evident from Chapter 4, these are clearly not the only important aquatic areas. The areas and recommendations have been chosen and developed using the criteria described on pages 67-69 in a qualitative manner, and following consultation with both international and African experts. Some globally or regionally important areas are not described due to the already extensive conservation effort at the sites, or to current lack of conservation feasibility. Most of the areas have previously attracted some attention.

This section provides suggestions for what can be done. Interested groups should obviously consult closely with local and international experts from a range of institutions before embarking on any project. The areas described below include a range of scales, ranging from local to transnational. **Many would benefit from integrated, multiple-use management efforts, with technical and financial assistance to small-scale community-initiated or supported pilot projects within them.** Where appropriate, these are described. Some are listed to highlight a particular country's commitment to aquatic conservation (e.g., Uganda's wetlands), and do not reflect a coherent management unit. The justification for each site is provided in the section following.

Areas 1, 2, and 3: The African Great Lakes

Category: Lakes

Biological and scientific importance: Each of the African great lakes contains more endemic fish species than any other lake in the world, and more species than the entire freshwater fish fauna in Europe (Fryer, 1972a). Most of these fishes are cichlids. All of the lakes have two subfamilies of cichlids: haplochromines and tilapiines (important in aquaculture). Lake Tanganyika also harbors the subfamily Lamprologinae, which are substratum-spawning cichlids, also found in the Zaire River, from which many of the lakes' fishes are derived (Kaufman, 1991b). Many cichlids have a very limited distribution (i.e., are stenotopic). Some species in Lake Malawi, for example, are confined to small rocky outcrops, with a total distribution of no more than 3000 m^2 (Ribbink, 1991).

Cichlids have developed complex feeding and reproductive behaviors including nest building, territorial, courtship, spawning, and parental behaviors, and an array of physiological adaptations. Some fish, for example, are mouth-brooders while others lay eggs in rock crevices. Some are monogamous pair-breeders, while others have a complicated social structure, including juvenile helpers. Some species form large leks, with the males producing species-specific courtship bowers (Stauffer et al., 1995). At least ten different bower forms have been identified (McKaye, 1991). Almost every type of food available is utilized, including such "bizarre" diets as eating scales, parasites, and even the eggs of other fish! A number of cichlids can even individually change the shape of their teeth and skulls in response to dietary changes (Greenwood, 1965; Liem and Kaufman, 1982; Meyer, 1990; Witte et al., 1990).

Because of the explosive and unique species radiation within each lake, the lakes are tremendously important scientifically. They are even more important than the Galapagos as a laboratory to study evolutionary processes — particularly to study the ecological and behavioral changes that occur with the evolution of new species. These lakes have been characterized as "one of the evolutionary wonders of the world." The lakes could help us understand the evolution of behavior, of food chains, of physiology, and even of our brains.

Some would argue that given the similarity in the lake's three faunas, it would be better to focus limited conservation resources on those lakes which still have relatively intact faunas. However, the uniqueness of the fauna in the lakes and the fact that they evolved largely independently argues for conservation of all three. The independence of the evolution offers the chance of a replicated evolutionary experiment; the loss of one lake would greatly weaken the strength of evolutionary hypothesis-testing (Kaufman, 1991b). Furthermore, the types of diversity expressed within the lake are different and worth conserving (Table 10). Lake Victoria, for example, has the lowest phyletic diversity, but has high functional (i.e., trophic) diversity, and an extraordinary species diversity given the lake's age. Lake Malawi has the highest species diversity. Lake Tanganyika has the highest phyletic diversity, form diversity, and the greatest diversity in reproductive behavior. The chance to understand the reasons for such differences in species diversity is unparalleled.

Also, the fact that the lakes are some of the oldest and deepest lakes in the world make them important sources of geological information. Unlike seabed sediments, the Rift Valley sediments are so laminated that they may be able to provide information about annual, if not seasonal, variations in temperature to as far back as 5-10 million years. The lakes also are part of a global tectonic rift system, of which little is known. Finally, the lakes provide important records of human activity over time, with some sites providing records of the earliest known human activities (Cromie, 1982)

Table 10. Physical and biological characteristics of the major East African Lakes

	Victoria	Tanganyika	Malawi	Albert	Turkana	Edward	George	Kivu	Kyoga
Physical									
Size	68800	32900	22490	6410	4250	2250	270	....	....
Max Depth(m)	100	1435	706	53	73	112	3	>500	....
Altitude (m)	1134	773	474	619	380	912	916	1460	1033
Mean Latitude	10S	70S	120S	1.50N	3.50N	0	0	20S	1.50N
Conductivaty	96	610	210	735	3300	925	200	1240	....
Salinity %(g/l)	0.093	0.530	0.192	0.597	2.482	0.789	0.139	1.115	....
pH range	7.1-8.5	8.0-9.0	8.2-8.9	8.9-9.5	9.5-9.7	8.8-9.1	8.5-9.8	9.1-9.5	....
Biological									
Endemic Cichlids	400+	170+	500+	Few	Few	60+	60+	Few	
Trophic Diversity	High	Med	High	Low	Low	High	High	Low	High
Reproductive Divversity	Low	High	Low	Low	Low	Low	Low	Low	Low
Phyletic Diversity	Low	High	Med	Low	Low	Low	Low	Low	Low

Physical and biological characteristics of the major East African Lakes (biological refers to chichlid radiations only). From Kaufman et al., 1996. From East African Ecosystems and Their Conservation *by Tim McClanahan and Truman P. Young. Copyright © 1996, Oxford University Press, Inc. Used by permission of Oxford University Press, Inc.*

Developmental importance: Socioeconomically, the lakes are valuable as sources of water, for fisheries (both for income and food, with the people around the lake dependent on the fish for protein), recreation, transport, and as potential sites of oil. The lakes' magnificent scenery, clear water, and diverse fish fauna affords considerable potential for tourism. The colorful cichlids are also valuable in the aquarium trade, and are especially popular in Europe.

Threats: The lakes' cichlids are particularly vulnerable to human disturbance because of their reduced distribution, relatively small population size, low fecundity, and poor dispersal capabilities. Specific threats are detailed in sections following. Anthropogenic threats are exacerbated by the lack of regional coordination and collaboration among the riparian nations bordering the lakes in developing and managing the lakes' resources. In addition, there is inadequate scientific knowledge of the fisheries' resources, reluctance to apply available scientific knowledge by fisheries agencies, and an increase in demand for fish (Twongo, 1993).

One major threat is pollution. The total inflow of all three of the great lakes, relative to volume, is very small, making turnover time very long (ranging from 150 years to 1700 years for Lakes Victoria and Malawi, respectively). In comparison, the most polluted of North American lakes — Lake Erie — has a turnover time of three years. This means that pollution could easily cause an irreversible disaster of inconceivable magnitude and "a crime on a scale such as perhaps yet to be perpetrated against Nature. The moral is obvious: while prevention is always better than cure, it is here essential as no cure may be available" (Fryer, 1972a). Oil spills, for example, could destroy all of the other uses of the lake, including drinking water, tourism potential, and fisheries. To date, oil exploration has been carried out in all three lakes by nine major U.S. oil companies.

Justification: The lakes are the planet's only tropical great lakes and have a much richer fauna than their cousins in North America and Russia (Lake Baikal). "From a scientific standpoint, it may well be argued that their faunas are at least as important as the great mammalian faunas of the adjacent terrestrial environments" (Fryer, 1984). Stuart and Adams (1990) considered conservation of these lakes to be one of the highest priorities for biodiversity conservation in Africa.

What could be done:

Specific recommendations for each lake are provided below. In all cases, the riparian nations should be encouraged and supported in efforts to develop regional management plans for each lake, and to boost capacity for regional coordination. Countries should be encouraged to require EIAs on any future development plans around the lake.

1. Lake Victoria (abuts Uganda, Kenya, Tanzania)

Category: Lakes

Biological importance: The cichlids in this largest of the African lakes are renowned for their rapid rate of monophyletic speciation (i.e., descended from a single stock). Speciation apparently occurred less than 225,000 years ago, with a major burst occuring 12,000 years ago, a geological instant (Meyer et al., 1991; Johnson et al., 1996; Kaufman et al., 1997). The cichlids have extraordinary behavioral diversity and high phenotypic plasticity. The Lake Victoria region is also rich in butterflies, mammals, and birds. 505 passerine bird species are found here, 15 of which are endemic.

Development importance: Lake Victoria's fisheries provide protein for the eight million people living along the lake's shores (Figure 64). The fisheries comprise 25% of the total inland fisheries in Africa, supporting over 100,000 artisanal fishermen and yielding a catch worth $90 million, largely due to the Nile perch. The lake's catchment provides a livelihood to 1/3 of the populations of Uganda, Kenya, and Tanzania, combined (GEF, 1996).

Threats: Threats to the lake are many and varied. These include introduced species (Nile perch and Tilapia); overfishing; anoxia; rapid population expansion around the lake, which already has a much higher population per area than any other African lake; the spread of water hyacinth (*Eichhornia crassipes*); increasing deforestation and resulting sedimentation; pesticide runoff; eutrophication (primarily from increases in phosphate); and loss of papyrus refuges. See case study (Annex) for further detail.

Justification:

"The value of conservation efforts, even in badly damaged ecosystems, should not be doubted. Anything is better than waiting 20 millenia for a new fauna....to evolve."
Kaufman, 1992

A project on Lake Victoria is urgent because of the rapid loss of biodiversity as well as the economic dependence of the local people on fishing. The biodiversity of the lake is immediately threatened not just by the Nile perch but also by increasing anoxia. The lake has already undergone the greatest mass extinction of modern times. Nearly all of the deepwater species and roughly half of the species from waters less than 20 m deep are now extinct. The anoxia also threatens the perch since it is very sensitive to O_2 levels < 5 ppm.

Although some people would write Lake Victoria off, we still have a chance to conserve at least some of the several hundred haplochromine species remaining in the lake (Seehausen, 1996). Evidence from other lakes indicates that certain haplochromines are able to survive in the presence of the Nile perch; Lake Tanganyika, for example, has four endemic Lates species yet the diversity of its cichlids is still maintained (Kaufman, 1992). At least ten percent of the nearshore fauna in Lake Victoria

Figure 64. Lake Victoria's fisheries provide protein for eight million people and support over 100,000 articanal fishermen. Photo credit: Les Kaufman.

appear to persist sympatrically with the perch. In addition, many native species are still found in the deep gulf, sandy areas, peripheral ponds, satellite lakes, papyrus refuges, and mid-lake environments (Kaufman et al., 1997). It would be useful to better understand why some cichlids can live with the perch and others can't, and which ones might survive with some assistance.

It is a race against time to improve food security for the people and conserve biological diversity before pressures mount for additional introductions (Figure 65A). The perch has already been largely fished out in Kenya. Five out of 18 fish processing plants in Kenya have closed, while another six are on the verge of doing so (Inter-Press Service, 1995). Kenyan fishermen are already requesting the introduction of another fish like the Nile perch (Dr. Okemwa, pers. comm.). People have also proposed introducing small plankton-eating herrings into the lake.

The socio-economic implications of a perch crash would be devastating. However, if we accept the strong likelihood of a crash in the perch population in the not too distant future, we can begin to prepare for it now. We can attempt to develop alternative sources of income before it is too late. Harris (1993) speculates that the considerable investment in industrial processing creates unceasing pressure to maintain the present level of fishing effort and effectively precludes reduction in fishing. As all three commercial stocks become overfished, more and more immature fish will be taken, exacerbating the likelihood of a fisheries crash.

Efforts to rehabilitate this lake will provide a useful model for other lake conservation efforts. As Kaufman (1992) states, "conservationists scan the scars of civilization for those places where the odds and the payoff for biological salvage and reconstruction are the greatest... On water, it is without question Lake Victoria."

<u>Related conservation and management projects:</u> Conservation efforts could not be more timely. The lake provides a marvelous opportunity to conserve biodiversity at the same time as maintaining food production. The GEF has recently implemented a new $35 million dollar (with another $35 million from IDA) "Lake Victoria Environmental Management Project" which will work to establish regional collaboration and management (GEF, 1996). This 5 year, multi-country GEF project will work to improve lake management lake-wide, as well as address specific environmental threats in 14 pilot zones. The project will work to: control water hyacinth; reduce and monitor industrial and municipal pollution and sedimentation; boost institutional capacity; promote regional management; harmonize and enhance fisheries policies and their enforcement; restore several threatened and endangered species of fish through aquaculture; map the aquatic biodiversity; educate people on its importance; propose ways to sustainably utilize the resources of the lake; analyze the socioeconomic conditions around the lake; study the possibility of levying a fine on the fishing industry for management and conservation; and promote afforestation. This is an impressive and comprehensive list.

The EU is undertaking stock assessment, primarily focusing on commercial species, and management strategies of fishing communities. The McArthur Foundation is funding studies on the socio-economic impacts of change in the lake's fisheries. The International Development Research Center is analyzing artisanal fishing; and the University of Zurich, along with the GEF, is examining sustainable management of the ecotones.

<u>What could be done</u>: Interested parties should take as active a role as possible in the GEF project to ensure that it conserves biological diversity. Given the enormity and immediacy of the lake's problems, assistance should be comprehensive in scope <u>and complement or support the proposed GEF project</u>. Promising aspects of the project include the facts that it was developed by the three lacustrine countries themselves, that communities were involved in preparation of the project and that community

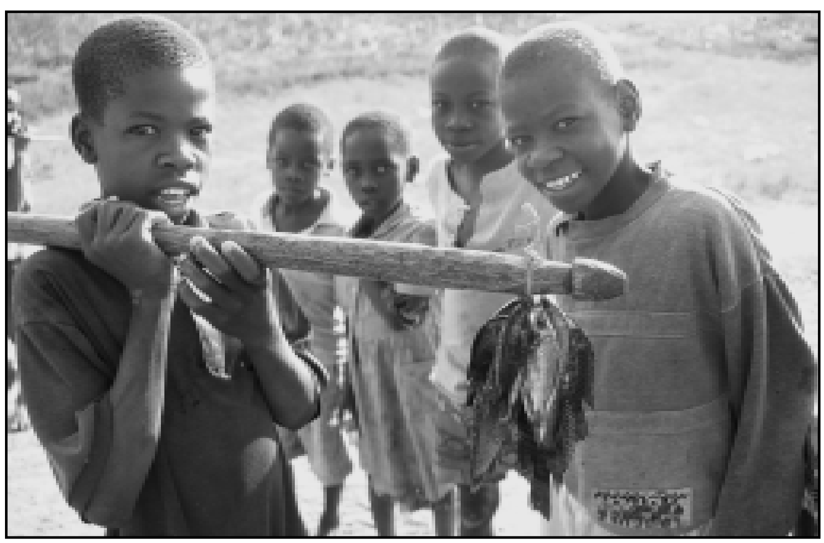


Figure 65A. It is a race against time to imrpove the food security for the people surrounding Lake Victoria and conserve its remaining biological diversity. The New England Aquarium, 1998. Photo credit: Alexander Goldowsky.

participation is woven throughout the project. Interested organizations could assist in implementing projects in the proposed pilot zones earlier than the proposed schedule, or expand pilot zones to additional sites, taking care not to overwhelm the implementation capacity of a given institution or country.

Many of the following suggestions originate from the recommendations from the 1992 Jinja conference (Table 11).

National and international NGOs should get involved. The GEF document notes the importance of involving NGOs and local communities in the project, and specifically provides for community micro-projects and community involvement in research. In particular, NGOs should make an effort to play a role in the biodiversity conservation subcomponent, currently implemented solely by the Fisheries Research Institutes. At least one local NGO is involved: this is the group OSIENALA, or Friends of Lake Victoria. Comprised of Kenyan professors, researchers, and community leaders, the group is working to protect local fishers' interests, encourage aquaculture, and educating local communities about the advantages of fish farming (People and the Planet, 1997).

Provide assistance, in collaboration with the GEF and the Lake Victoria Research and Conservation Program, to develop "fish parks", or aquatic reserves. The GEF project mentions that closed sanctuaries important for fish breeding, nurseries, and juvenile feeding will be established in pilot zones in Kenya and Uganda, and have already been established in Tanzania. The document is unclear, however, whether these areas will focus on commercially important fishes or not. An initial survey could be supported to identify areas of importance to the lake's biodiversity, keeping in mind that to successfully set up parks requires a better understanding of the Nile perch's distribution patterns as an adult and as larval young. Recent studies suggest, however, that the perch does not tolerate hypoxia as well as a number of the haplochromines, implying that possible "perch refuges" would be the satellite lakes and ponds separated from Lake Victoria by papyrus swamps (which are low in oxygen), or low oxygen sites themselves. Kaufman et al. (1996) suggest other refugia, including: 1) structural sites such as shallow rocky shores. Such parks could either be within the lake itself or within adjacent peripheral lakes and ponds; and 2) riverine refugia.

Within the lake itself, experimental management sites also could be set up, varying such factors as the size of the reserve, whether or not the perch predator is excluded or reduced, etc. Experimental management sites could yield important scientific information as well, since those sites that excluded the perch would enable one to separate out the impact of anoxia and eutrophication on the cichlids from the impact of the perch.

Richard Ogutu-Ohwayo of UFFRO (Ogutu-Ohwayo, 1993a) recommends that Lakes Kayanja, Kayugi, and Manywa be designated conservation areas for *O. esculentus*, *O. variabilis*, haplochromines and other native species which were previously abundant in Lake Victoria. Kaufman suggests the Sesse Islands in the middle of the lake as a good place to explore the establishment of an aquatic reserve, since the villagers are interested in a model conservation project. Ecotourism to this site also could be developed (Kaufman, 1993).

Support development of conflict resolution methods that can be rapidly used by the three countries. While all of the countries support regional cooperation in principle and in their NEAPs, the stalemate over water hyacinth control indicates that developing a rapid mechanism for conflict resolution could be invaluable for joint management efforts.

Enhance collaboration and cooperation between fisheries departments and departments of wildlife and conservation. Fisheries departments often have a mandate to maximize the yield from fishing which may conflict with conservation goals. Thus, a strengthened regional fisheries organization may, but doesn't need to be, at odds with conservation efforts. Collaboration and cooperation are essential. An advocate for conservation should be present in any decision-making about the lake's future.

Develop economic alternatives to fishing to buffer the economic impact of a Nile perch crash. Again, this would be an opportune project for NGOs.

Work with governments to set up effective EIA procedures. The NEAP's of the riparian countries highlight the importance of establishing environmental impact assessment procedures, but they are still not in place (GEF, 1996).

2. Lake Tanganyika (abuts Burundi, Rwanda, Zaire, Zambia, Tanzania)

Category: Lakes

Biological importance: Lake Tanganyika contains over 1200 species of flora and fauna, of which at least 500 are endemic (Coulter, 1991). The lake has the highest biological diversity of all of the three great lakes (considering all species: fishes, invertebrates, etc.), and is particularly important for its phyletic diversity of cichlids. (Figure 65). According to Coulter and Mubamba, there are 6 pelagic fish species, 80 benthic, and 207 littoral, of which 170 are cichlids (Kaufman, 1991a). Other wildlife include molluscs, crustaceans, crocodiles, hippos, and a variety of birds. The food webs in this ancient lake are incredibly complex.

Developmental importance: The lake is important for fishing, transport, and as a source of freshwater, being the largest single reservoir in Africa. 86,000 tons of fish were caught in 1986. Commercial fishing takes place only in Burundi and Zambia, with artisanal fishing elsewhere. According to Coulter and Mubamba (1993), maintaining fish species diversity should benefit fishing productivity and provide economic gain. The pelagic fishes normally comprise a hierarchy of predators which can help to reduce catch oscillations. The lake also supports an aquarium fish export industry.

Table 11. Summarized Recommendations from the 1992 Jinja Conference on People, Fisheries, Biodiversity, and the Future of Lake Victoria

General
- Support development of a Lake Victoria Fisheries Commission
- Study the feasibility of a tax on export for conservation, management, and monitoring of the fisheries

Limnology and Environment
- Develop an ecosystem model
- Develop the ability to forecast when O2 levels will fall low enough to endanger fish stocks and where
- Determine the effects of chemical changes in the lake on fish stocks
- Quantify energy transport through the two major trophic pathways, grazing and detritus
- Research and manage wetland and forest habitat, with special attention to the water hyacinth

Fish Biology
- Need for stock assessment (size, abundance, spatial and temporal distribution)
- Study food web interactions and their effect on eutrophication
- Establish refuges (fish parks)
- Involve fishermen in the planning and implementation of conservation efforts
- Explore the conservation and development potential of aquaculture
- Require careful biological, social, and economic study before further introductions

Policy, Management, and Socioeconomics
- Need for water quality controls in land use management
- There is a need to balance export interests and local needs
- Study factors that impede local participation in fisheries management
- Study ways to more effectively implement fishing regulations
- Develop programs to assist groups likely to suffer from crash
- Conduct economic assessment of the value of the native fauna
- Study nutrition levels around lake to determine the impact of the export market
- Need to integrate fisheries management with biological conservation
- Any proposal for fisheries development should be subjected to a detailed social and environmental impact assessment

From Kaufman, Ochumba, and Ogutu-Ohwayo, 1992.

Related conservation and management projects: In 1995, the UNDP/GEF project on “Pollution control and other measures to protect the biodiversity of Lake Tanganyika” started. The project intends to: establish a regional management plan for pollution control, conservation, and management of the lake; establish mechanisms for regional coordination, including a legal framework; provide environmental eduction and training; and develop strategies for conservation of biodiversity. The Jane Goodall Institute is currently funding a project to reduce deforestation.

Threats:

Overfishing, particularly with beach seines (Natural Resources Institute, 1997). The seines catch all species and sizes indiscriminately and destroy valuable bottom habitat. Nursery grounds and substrate spawners are particularly susceptible. Ten years of overfishing has decimated the numbers of pelagic clupeids.

Excess sedimentation due to deforestation. Forests are burned for either grazing or subsistence agriculture. Nearly 100% of the northern part of the basin (Zaire, Burundi) is deforested, while forty to sixty percent has been cleared in the central portion (Cohen et al., 1993). The sediment has already significantly modified the lake’s ecosystem, particularly in the northern basin. Deforestation has the greatest impact in areas with large drainage basins, such as the Burundi coast (already deforested), and much of the Zambian coast (Cohen et al., 1993). These authors have shown a statistically significant decline in species diversity in ostracods, and a similar trend in fish species with increasing sedimentation.

Pollution, primarily a problem in the north near Bujumbura, Burundi, the second most densely populated country in Africa. The population around Bujumbura is estimated to increase significantly over the next decade. Types of pollution include industrial (especially heavy metals), agricultural (both fertilizers and pesticides), and municipal discharges (Natural Resources Institute, 1997). The lake is particularly susceptible to pollution, since turnover time is hundreds of years (Lowe-McConnell, 1987b). Nine-tenths of the lake is permanently stratified and deoxygenated below 200 m (Cohen et al., in press). Because the entire water mass of the lake generally does not mix (i.e., the lake is meromictic), a point source of pollution travels through the oxygenated layer very quickly. Considerable amounts of pesticides, including DDT, have been found in important food fishes (Fryer, 1984).

These problems have led to a deterioration of water quality, a reduction in fish and mollusk population size and diversity, reduction of algal growth rates, and the disappearance of hippos, crocodiles, and water fowl, important wildlife attractions for tourists.

Justification: One of the world’s most important biological treasures, as detailed in the beginning overview section.

What could be done:

- Help to reduce deforestation around the lake’s basin and catchment area. Assist with the reforestation of surrounding slopes and the development of plans to reduce further erosion near the lake. Erosion is exacerbated by lack of suitable agricultural terracing practices, along with poor road building practices. The GEF project includes studies to look at sediment discharge and its consequences. The recommended actions would complement the GEF effort while directly addressing one of the most serious threats to the lake.

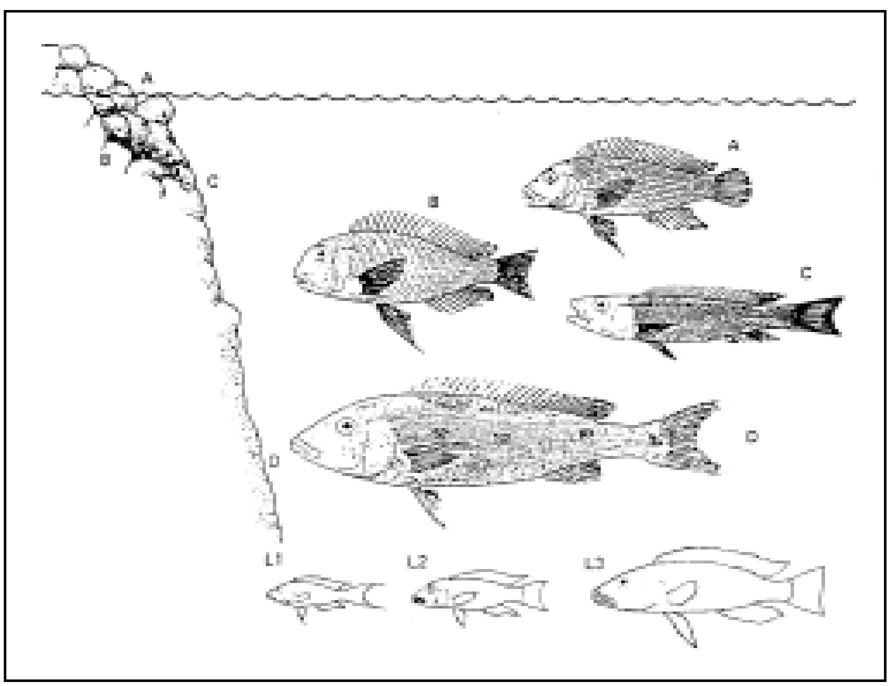


Figure 65. Diversity of Tanganyikan cichlids. From Lowe-McConnell, 1987b. Reprinted with the permission of Cambridge University Press.

- Provide technical assistance to establish pollution prevention measures in the industries in the Bujumbura area.

- Assist with government efforts to manage underwater sites incorporated into already established terrestrial parks by the basin (may be easiest administrative option), and establish other underwater sanctuaries elsewhere, particularly in the Democratic Republic of the Congo (Natural Resources Institute, 1997). Underwater reserves already exist on paper for Nsumbu National Park, Zambia, Rusizi National Park, Burundi, and Mahali National Park, Tanzania, but management efforts do not include the underwater fauna (Cohen, pers. comm.). In general, the parks suffer from poor enforcement, poaching, lack of park expertise, and uncontrolled human settlements within the parks. Reserves can have a large impact, as most of the cichlids are highly stenotopic (i.e., localized to a particular place), all of the pelagic and some benthic species have early inshore life stages (Coulter and Mubamba, 1993, but see Pendleton and van Breda, 1994); and they could help to reduce fishing pressure. Further, underwater reserves may be very attractive for tourists, as the clarity of the water afford a nature experience akin to visiting a coral reef. Note that the establishment of an underwater reserve alone, without protection of the surrounding catchment, is only a viable conservation strategy if the area has a small drainage basin or erosion-resistant sediment, reducing the potential impact of deforestation (Cohen et al., 1995). Conversely, underwater parks adjacent to large and/or easily eroded watersheds will need to protect the surrounding catchment. It must be kept in mind that broader pollution efforts will be necessary at the same time to prevent lakewide pollution that could undermine the benefits of parks.

  Cohen (1995) has paleological and biogeographic data from ostracods sugesting that these benthic fauna may be distributed in metapopulations. This means that their populations may be patchily distributed, interconnected genetically through sporadic dispersal events. Should this model be true for the cichlids too, it has profound implications for lacustrine conservation. If habitat destruction is localized, areas that have lost populations can be reestablished from surrounding patches. But, according to Cohen, " ...the elimination of intervening patches caused by broad habitat deterioration may lead to a cascading sequence of extinctions, both directly, through the loss of recolonization, and indirectly, by eliminating the very population structure that originally allowed the high alpha diversity among competitors to exist".

  Additional conservation sites to protect different outstanding habitat types could be added in the other surrounding nations. The Democratic Republic of the Congo (formerly Zaire) has several excellent potential sites for the establishment of terrestrial and aquatic reserves (Coulter and Mubamba, 1993). The reserves should try to address multiple use, accommodating existing human activities wherever possible. Habitats associated with the lake, such as marshes and lagoons, should also be looked at.

  Some of these sites should be considered as potential ecotourism sites, taking into consideration the lake's sensitivity to pollution. Nature reserves could support windsurfing, sailing, underwater nature trails, scuba/snorkelling, glass bottom boats, guides, guide books, and education displays. Lake holidays could be coordinated with other tourist attractions such as game viewing, as done in Kenya with its coast and safaris. Floating hotels (small vessels for tourist hire, now available on Lake Malawi) could be used to explore some of the most spectacular lake scenery inaccessible by land.

- Help to develop an integrated regional approach to conservation and management of the lake (Coulter and Mubamba, 1993). At the moment, no such framework exists, although the GEF project is trying to lay the framework.

3. Lake Malawi (abuts Tanzania, Malawi, Mozambique)

<u>Category:</u> Lakes

<u>Biological importance:</u> Lake Malawi, the 3rd deepest lake in the world after Baikal and Tanganyika and occupying 20% of Malawi, is the world's richest freshwater ecosystem. This ancient lake (1- 1.5 million years) contains more species of fish than any other lake and more than in all of North America, with at least 600 known species, and perhaps as many as 1000 from ten different families; 99% of which are endemic. Between 400-500 species are cichlids (Ribbink, 1988; Lowe-McConnell, 1993b). Lakeside animals include hippos, leopard, greater kudu, bushbuck, zebra, impala, grey duiker, baboon, vervet monkey, bush pig, some elephants, fish eagles, cormorants, crocodiles, and water monitor lizards (IUCN, 1987). The fish in Lake Malawi, particularly the 200 endemic rock-dwelling species called "mbuna" (Ribbink, 1991), are among the most spectacularly colored in the world and are popular with aquarium hobbyists. The cichlids possess considerable diversity in social and feeding behavior (Figure 66). Both the sandy shore cichlids as well as the pelagic cichlids known as utaka also appear to be highly diverse. Only a

small portion of the lake is now protected in Lake Malawi National Park, a UNESCO World Heritage Site.

Development importance: Eighty percent of the lake's population live in Malawi, the fourth most densely populated country in Africa (GEF, 1994). The lake's fisheries (primarily haplochromine cichlid) are of considerable nutritional importance to this country which has such widespread malnutrition. The 30,000 tons/year of fish provide roughly 70% of Malawi's protein — food for at least 5 1/2 million people. Fishing is also the major occupation. Fishing is of three types: 1) artisanal fishing, supporting 22,000 fishermen and providing most of the catch; 2) commercial trawling, and 3) fishing for the aquarium trade. The three most important food fishes are the haplochromines called utaka (some of which have a very restricted destribution), the cyprinid called usipa, and the three tilapiine species called chambo (which now make up 25% of the catch). The mbuna fetch high prices in the aquarium trade, particularly in Europe (Stauffer, pers. comm.). Rare mbuna (with only a few hundred fish in a population) can cost several hundred dollars.

The lake also provides a source of freshwater; is a tourist destination (with the Cape McClear area already one of the most popular holiday destinations in Malawi): and provides an important source of energy (with a hydroelectric facility on the outflow of the lake via the Shire River). The tilapiine cichlids in the lake offer possibilities for aquaculture.

Threats: *The main threats are overfishing,* particularly in the southern part, *and river catchment degradation.*

Overfishing of food fishes, both commercial and artisanal, *is the greatest threat to the lake's biodiversity* (Reinthal, 1993). The dramatic rise in Malawi's population and the use of commercial demersal trawling in the south part of the lake since 1968 have led to overfishing. Overall catch has declined since 1976. The decline in catch of the larger, more valuable species has led to the use of smaller and smaller meshed nets which has resulted in changes in the species composition of the exploited stock. *Dramatic changes have occurred in species composition (with over 20% of the species disappearing from the catch in just four years), size structure, and species distribution of monitored catches.* A bottom gill-net fishery in the south catches mostly *Labeo* spp., *Bagrus meridionalis*, and *Oreochromis*, in order of abundance. *Labeo* and *Bagrus* sp. have declined continuously from the 50's through the 70's (Coulter et al., 1986). The cichlid "utaka" is declining in number; as has the endemic cyprinid "mpasa" (GEF, 1994).

Traditional fishing is now largely opportunistic, with few obvious alternatives to their destructive practices. The most common fishing methods are gillnets, beach seine nets, chiromile nets, hooks, and traps. Tweddle (pers. comm.) thinks that trawling and the small mesh beach seines are doing the most damage. The trawl fisheries are heavily overexploited. The number of commercial trawlers in the south-east portion of the lake has quadrupled in the last five years (Reinthal, 1993). The Fisheries Department did trawling surveys in this area, and claim that

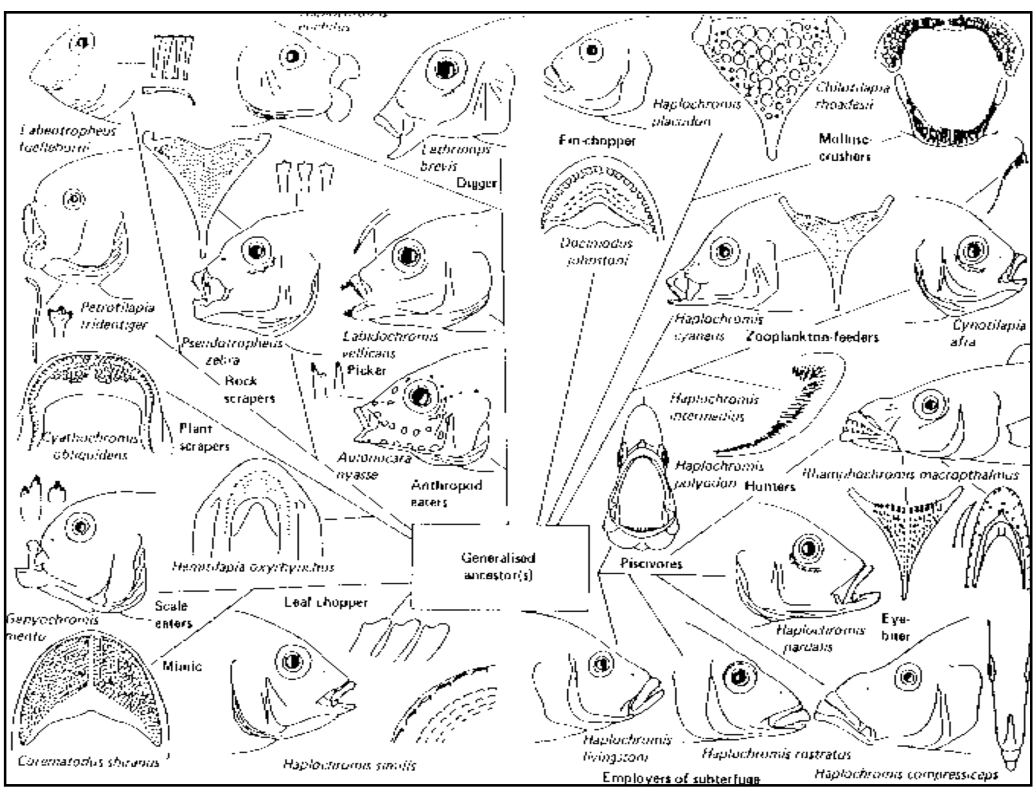


Figure 66. Examples of adaptive radiation in Lake Malawi's cichlids. From Lowe-McConnell, 1987b. Reprinted with the permission of Cambridge University Press.

some species have gone locally extinct. Tweddle thinks that a number of other species will go extinct in the next ten years as well. The trawl is pulled all day and catches fish of all sizes. Trawlers are supposed to use 38mm mesh, but smaller ones are being used. Tweddle (pers. comm.) has measured nets as small as 22mm.

Beach seining in spawning sites is a common practice. Unfortunately, this destroys fish habitats. Due to the rising cost of fuel, artisanal fishermen can't afford to use motorized boats to fish offshore, forcing them to fish closer to the shore. Artisanal fishermen use very small mesh beach seines with mosquito nets in the productive swampy areas. Only rich fishermen can, however, afford the fine mesh nets that catch everything.

The "mpasa" were formerly of great importance in the Lake Malawi fisheries, but have declined since the 1960's because of the loss of their spawning areas in the rivers and streams. They are now found primarily only on the Mozambique side. The Bua river, protected in part by the Nkhotakota Game Reserve, is the largest spawning ground of the commercially important cyprinid "mpasa" (*Opsaridium microlepsis*), or lake salmon. The Nkhotakota Game Reserve protects against siltation in the Bua River. Many other non-protected rivers, which used to be the fish's spawning grounds, no longer support the fish because of siltation, overfishing, and damming. Major threats to the long-term viability of the endemic anadromous cyprinid species include the poaching of migratory adults and the poisoning of the river when it is low in the dry season.

Uncontrolled fishing could destroy this valuable ecosystem. As long as food fishes remain, the mbuna are not threatened. Even the fishing villages inside the park mainly catch pelagic fishes. However, depletion of the existing food fishes will lead to increased overexploitation of the mbuna. Fishing regulations do exist, but the Fisheries Department has limited capacity for enforcement. The Fisheries Department is planning on imposing new fishing regulations on mesh size, with mesh sizes increased in small annual increments to mitigate their economic impact.

Pollution: Lake Malawi's outflow, like Lake Tanganyika's, is minute; complete turnover would take 1700 years (Fryer, 1972b). Fortunately, at the moment, the lake's waters are still almost pristine, and Lake Malawi has no large cities on the lakeshore. However, the potential for municipal, agricultural, and industrial pollution problems is serious since Malawi's population is rapidly expanding (the population in the southern end of the lake alone is expanding by 7%/year), land cultivation in the catchment area has doubled in less than a decade (as reported in Grigione, 1990), and there are strong pressures to increase the country's industrial capacity, particularly around Llilongwe. Villages do not currently have sewage treatment. The most devasting potential threat is from heavy metals, pesticides, and other toxic chemicals; the lake can recover from increased eutrophication but not from these substances. Most of the lakeshore is within agricultural growing areas. Pesticide use already occurs throughout Malawi, including the Lake Malawi region. Major agricultural projects are being developed along the lakeshore plain for crops such as sugar and rice, using irrigated water from the lake. Proposals have also been made to set up paper mills in the lake basin. One paper mill is already situated in the northern part of lake basin— the Vipia pulp mill. A future pollution threat is hotel effluent. Large-scale development, with mass tourism and the corresponding sewage problems, would be catastrophic.

Deforestation and corresponding soil erosion in the catchment areas of the lake, including illegal deforestation within the Lake Malawi National Park. Malawi's deforestation rate of 3.5% per year (or 150,000 ha) is the second highest rate in Africa. Soil erosion is caused by: deforestation; increasing cultivation of marginal or unsuitable land, including steep areas; shorter fallow periods; increased use of maize or other row crops; increased acreage of crops like tobacco which do not protect the soil; reduced intercropping and crop cover; and overgrazing.

Spread of water hyacinth. Although water hyacinth is not yet in the lake, it is already prominent throughout the Lower Shire, and will likely spread.

Justification: The lake's biological and developmental value warrant action while it is still relatively pristine.

Related conservation and management projects: There is a $5 million, 5 year GEF Lake Malawi/Nyasa Biodiversity Conservation Project being implemented by Malawi's Ministry of Forestry and Natural Resources (GEF, 1994). The project began in 1995. Its main objective is to assist the riparian states (primarily Malawi) in "creating the scientific, educational, and policy basis necessary for conserving the lake." The project has four components: research (biodiversity surveys, generation of a species identification manual, and water quality monitoring), national capacity building, environmental legislation, and protected areas management. Its primary output will be a biodiversity map and management plan for the lake including biodiversity hotspots, critical habitats, sites where pollution is the greatest threat, and a management plan for the park. The Wildlife Society of Malawi, a local

NGO, will assist the GEF project in conservation awareness-raising. CIDA will finance and assist with data collection in developing a Strategic Plan for the Nankumba Peninsula and Lake Malawi National Park. This latter component will emphasize community participation in the planning process and identify possible community roles in park and lake conservation.

The World Wildlife Fund and Peace Corps have previously been involved in awareness-raising efforts within Lake Malawi National Park; WWF is currently developing an integrated conservation and development program for Lake Malawi National Park. There is also a World Bank (IDA) Malawi Fisheries Development Project focusing on management of the fisheries stocks (including such actions as control of net mesh size, closed areas and seasons), and a JICA Aquaculture and Hatchery Project focusing on developing a research center and promoting small-scale aquaculture for two fisheries species, the "mpasa" and "ntchila" (GEF, 1994). Both Tanzania and Mozambique are in the process of developing national environmental action plans. Tanzania has identified the deterioration of freshwater and marine systems as one of 6 environmental areas requiring urgent attention (GEF, 1994).

<u>What could be done:</u> The activities proposed below complement the GEF effort.

- Assist with halting deforestation in the catchment areas and preventing further degradation of rivers and streams from soil erosion. Plant riparian buffers around the lake for protection. Encourage the extension of two terrestrial parks, Nyika and Nkhotakota, to include more of Lake Malawi's watershed, important for drinking water, agriculture, industrial use, and fisheries. Help to reforest Lake Malawi National Park which has been heavily deforested, particularly around Chembe village, Nankoma Island, Mumbo Island, and the Mwenya and Nkhudzi Hills.

- Encourage the establishment of environmental impact assessments (EIA) for any proposed industrial or tourism development in the catchment area. This is an urgent need, given recent proposals (currently on hold) to build large-scale hotel complexes within Lake Malawi National Park. Train personnel in EIA methods.

- Work with aquarium traders to ensure collection is sustainable. Although the mbuna are currently not under threat, it is important to set in place a system now that will ensure sustainability. One option would be to set up a certification system for interested traders. Traders willing to participate would need to prove through monitoring that their system is sustainable over the long term. Another option for conserving lake stocks is to support the breeding of mbuna in tanks for export, as is currently being done near Senga Bay (Lowe-McConnell, pers. comm.).

- Assist in the immediate protection of other areas around the lake. While a priority map of biodiverse sites will be developed by the GEF project within the next 5 years, (i.e., by 2001), we already know that certain sites are highly diverse. Reinthal (1993) recommends protecting rocky outcroppings along the Likoma and Chisumulu Islands (Mozambique) and Nkhata Bay (Malawi), areas important for cichlid diversity and endemicity. According to him, protection of cichlids in Nkhata Bay would protect the majority of the mbuna genera. The Malawian Department of National Parks and Wildlife would like to extend both the aquatic and terrestrial borders of Lake Malawi National Park, and should be supported in this effort. Currently, the park extends only 94 km2 on land, and the size of the water area of the park is only 700 ha, .04% of the total area (Grigione, 1990).

- Promote alternative income-generating activities to fishing both outside and within the park. Note: WWF is working on alternative income-generating activities inside the park. Seventy percent of the fish caught in Lake Malawi are caught in the southern end of the lake where the park is located. In collaboration with WWF and the Department of National Parks and Wildlife, work with interested communities to develop alternative development opportunities, including agroforestry, handicrafts, local guides, as well as others. WWF would like to encourage guides, snorkal rentals, guest houses (there are already 3 rest houses for tourists), and start a campground in Chembe village (located inside the park). A mechanism is in place to share park revenues with local residents; this revenue sharing will be tied into protection of the resources and community improvement once viable decision-making bodies are formed.

- Assist with the facilitation of a regional consultative group for the lake, a concept recommended by the UK/SADC pelagic fish project and endorsed by the GEF project.

- International and national researchers could volunteer their assistance in conducting <u>biodiversity surveys</u> around the lake, particularly along the Mozambique and Tanzanian lake shores and waters (Reinthal, 1993). Assistance should be coordinated with the GEF project and the IDA fisheries project. Apart from the mbuna, little is known about fish communities in the lake, species distribution, and breeding locations. Only the chambo has been studied in any depth. It is critical to determine which fish are caught with certain nets and which fishing techniques are competing with other ones. Currently, the species of fish caught by the commercial fisheries are almost totally unknown. Tweddle (pers. comm.) thinks that 300-500 species of fish are being caught commercially. Food fishes of concern include the zooplanktivorous haplochromines "utaka", "chambo", "usipa", the bottom-dwelling *Lethrinops* ("chisawasa"), and the predatory pelagic *Rhamphachromis* sp. ("inchini") (Tweddle, pers. comm.; Reinthal, 1993). Stock identification is critical for the utaka, of which at least 25 are known. It is also critical to determine their population distributions. Some appear to have a very narrow distribution, restricted to a single rocky outcrop. In addition, studies should be made of the important anadromous fishes to identify the number and location of rivers that need to be protected.

4. Madagascar's lakes and wetlands

Category: Lakes, wetlands

Biological importance: *Madagascar's lakes, streams, and wetlands harbor some of the most threatened endemic species in the country.* Of the country's 29 endemic freshwater fishes, half are threatened, as is the country's single endemic species of freshwater turtle, a large number of endemic crustaceans, and probably the 19 species of endemic freshwater molluscs as well. The lakes, streams, and estuaries contain very primitive cichlids that are as important evolutionarily as Madagascar's prosimians. Lac Alaotra, the largest lake, is an important swamp both to the local people and to two of the most endangered Madagacascar birds, the pochard and grebe. The lake is threatened by deforestation, massive erosion, and runoff. Madagascar's second largest lake is the floodplain Lac Kinkony, important for birds and the Madagascar bigheaded turtle. Lac Ihotry is an important site for water birds. Other lakes to be considered for protection include Itasy, Bemamba, Masamba, and Befotoka (Stuart and Adams, 1990).

Developmental importance: Madagascar's inland waters support 65% of Madagascar's fisheries (Brainerd et al., 1992).

Threats: Deforestation and its consequences, erosion and sedimentation; the introduction of exotic species (primarily tilapia for aquaculture); habitat alteration; pollution.

Justification: The aquatic wildlife in Madagascar is under severe threat.

What could be done: Initially target the most important lakes (Ihotry, Alaotra, Kinkony) and work to stop deforestation and pollution.

Additional wetland activities in this country could include funding surveys of the country's mangroves on the west coast to identify sites for protection. These mangroves are the largest and some of the most important stands in the Western Indian Ocean.

5. Okavango River wetland, Namibia

Category: Wetlands, rivers

Biological importance: The wetlands of northern Namibia are the country's most important, both for their biodiversity and for supporting human populations (Hines and Kolberg, 1996). The Okavango River wetland supports a rich diversity of wildlife and is of both international and national importance. The wetland provides habitat for 390 species of birds, including 18 threatened species, and 99 species of mammals, including hippos, elephant, zebras, impalas, and giraffe. The Okavango River contains the highest biological diversity of fishes of any of Namibia's rivers. The river harbors even more diversity of fishes than the Okavango Delta; of the 83 species and subspecies of fish found in the Okavango drainage system, 71 are found in Namibia and 32 in the Delta.

Developmental importance: The Okavango River is of critical importance to the Okavango Delta since it provides the Delta's main source of water. Any deterioration of the Okavango river's water quality or quantity, therefore, could threaten the Delta downstream. The river and its associated floodplains are of national importance for flood control, aquifer recharge, and maintenance of water quality. In addition, over 94,000 people living along the river (the densest rural population in Namibia) are dependent on the river's biological resources for survival. Fish are the main source of protein for three of the five tribes. Over 840,000 kg of fish are caught per year. Reeds are used for thatching, fencing, baskets and traps; and a number of wild fruits and animals are used for food and/or medicinal purposes.

Threats: The Okavango River is severely threatened by increasing population pressure and development. Threats include: habitat destruction and soil erosion caused by settlement and agriculture; the alteration of natural flood regimes; overexploitation; pesticides (DDT); and fertilizers. The local people have already deforested what used to be the country's most extensive riverine forest.

Justification: In addition to the site's biologic and development importance, including its importance to the Okavango Delta, efforts here could have tremendous impact. Few groups are currently working on environmental activities at this site. There also appears to be clear interest and commitment on the part of the government towards conservation in general, as reflected in the fact that commitment to sustainable development and protection of biodiversity is written into the National Constitution and the fact that Namibia has already protected over 13% of its land (Baker, 1996). Namibia is particularly committed to conserving its important wetlands.

What could be done:

1. Reduce the damage done by agriculture and deforestation. Encourage agroforestry to minimize erosion, and the use of biological control rather than pesticides.
2. Encourage the development of a multi-use management plan by the local communities. Begin with participatory rural appraisal. Sponsor workshops for the community where people have a chance to brainstorm about how to address some of the problems facing the river.

   Additional activities could include assisting with implementing the recently developed management plan for the East Caprivi wetlands. Help to increase the capacity for enforcement in Mamili and Mudum National Park to control poaching and overgrazing by cattle.

6. Uganda's wetlands

Category: Wetlands

Biological importance: Uganda is rich in water resources, with wetlands making up ten percent of the country's area. Important wetland areas include areas around Lakes George, Kyoga, and Victoria. Lake George is a Ramsar site that has diverse habitats, a rich birdlife, including the rare shoebill, and a highly productive fisheries. Swamps also occur in many other places, such as along the Nile Valley, around the lakes in the Albertine District, and in the Kabale District. Swamps and lake shores are protected in the Queen Elizabeth National Park (which abuts Lake George) and the Lake Mburo National Park. Both Queen Elizabeth National Park and Murchison Falls have large populations of hippos. Queen Elizabeth National Park also provides the livelihood for fishing communities living within its borders. The floodplains of Lake Victoria and Lake Kyoga are considered to be centers of endemism for Africa's freshwater wetlands (Stuart and Adams, 1990).

Developmental importance: Uganda's wetlands are nationally important for fisheries (especially Lakes George, Kyoga, and Victoria); as water resources for communities; and for papyrus husbandry.

Threats: Threats to wetlands include agricultural conversion, drainage, industrial pollution, and overharvesting of natural products. Numerous wetlands have been lost in the southwest to agricultural conversion; only a small percentage of the once extensive swamps now remain. Fortunately, the government has now banned large-scale drainage. Lake George is further threatened by mine tailings from the Kilimbe mines and papyrus burning for roofing. Only about two percent of wetlands are currently protected.

Justification: To support Uganda's admirable Wetlands Conservation and Management Programe which considers the integrated management of wetlands and its recently established Community Conservation Programe. The timing is good, as the World Bank is also supporting The Uganda Environmental Management Project, part of which is designed to boost instititutional capacity for environmental management as the national, district, and community levels, and part of which will be used to assist communities in addressing their own environmental problems (Environment Matters, Fall, 1996). Uganda's NEAP focuses, in part, on wetlands loss and declining fisheries (GEF, 1996).

What could be done:

1. Support the implementation of recommendations arising from the NEAP's taskforce on Wetlands, Water Resources, Fisheries, and Aquatic Biodiversity. These could include: policy development, institutional strengthening, and efforts to establish pilot integrated rural development projects for wetlands, including agricultural projects. Pilot projects could be supported through assistance to IUCN. IUCN recommends pilot projects in the Kigeze and Dojo areas.
2. Extend the boundaries of Queen Elizabeth National Park to include more of Lakes George and Edward. Protect the Lake Opeta floodplain to conserve its abundant birdlife.

7. Rufiji Delta/Mafia Island (Tanzania)

Category: Mangroves, coral reefs

Biological importance: The pristine stands of mangroves in the Rufiji Delta are the most extensive in the Indian Ocean. The delta also contains a variety of other wetland habitats including freshwater riverine wetlands, riverine forests, swamps, and floodplains. None of the areas are currently protected. The delta's proximity to the reefs and marine resources of Mafia Island further enhances this as an area for biodiversity conservation. Mafia Island is one of the richest and least disturbed coral reef sites in the Indian Ocean. Because of its isolation (100 km from Dar es Salaam), it has escaped the brunt of dynamiting which has devastated other Tanzanian reefs. Species diversity is high, with over 350 species of fish, 40 genera of coral (Gaudian et al., 1994). The site is a breeding area for an endangered turtle.

<u>Developmental importance:</u> The Rufiji Delta is an important fish breeding and spawning ground and an important prawn fishing site. The health of Mafia Islands reefs is dependent on the health of the Rufiji delta mangroves.

(Mafia Island) - Fishing is the main form of resource utilization by the islanders. The finfish and octopus fisheries are particularly important, but sea cucumbers and crayfish are caught as well. Shellfish are collected for the curio trade and seaweed are farmed. The local people are very supportive of assistance in sustainably managing their resources. The reef may be an important source of larvae for other reefs (Gaudian, 1994).

<u>Threats:</u> (Rufiji Delta) - Continued deforestation of upland areas as well of mangroves as within the delta; changes caused by the building of two dams on the Rufiji river (including increased coastal erosion, sedimentation, and reduced volume of freshwater); a commercial shrimp aquaculture project, and poaching from outsiders. Locals are well aware of the problems and are trying to stop outside poaching.

(Mafia Island) - dynamite fishing by outsiders from the mainland; overuse of seine nets; collection of shells and both live and dead corals (for lime production and building); and anchor damage.

<u>Justification:</u> This is a chance to assist in the conservation of two critical aquatic ecosystems and to assist Tanzania's initial efforts in aquatic conservation. Tanzania's NEAP focuses, in part on biodiversity conservation, along with freshwater and marine resource management (GEF, 1996). The country's National Environment Management Council has begun to design a national wetland conservation and management program (Adams, 1996). Additionally, the fact that this park will be established under the jurisdiction of the Fisheries Department means that *this affords a unique opportunity to strengthen the link between fisheries management and conservation*.

(Rufiji Delta) The country's National Environment Management Council Workshop in Nov., 1991, recommended that coastal mangroves be conserved. IUCN has also recommended that a reserve be established in the Delta.

(Mafia Island) There are now very few coral reefs on the E. African coastline that are in excellent condition. The loss of the unique ecosystem of the Western Indian Ocean mainland coral reefs is of global importance.

<u>What could be done:</u>

1. Assist with the establishment of a reserve on the Rufiji Delta, and support the development of a multi-use management plan for the Delta. IUCN has a research proposal for $1.5 million/3 years to develop a wetlands management plan for the Rufiji Delta. Dr. Semesi, at Univ. of Dar es Salaam, is studying the delta to develop a management plan. (Presumably both efforts are connected.) The country already has a pilot wetland management project at the site. NOTE: Ideally, the management plan would include both the Delta and Mafia Island. The judgement of IUCN should be followed here. IUCN is hoping to include Mafia in the management plan at a later date, but notes that it is in a different district.

2. Assist with the Government's/WWF's/IUCN's efforts to implement the multi-use master plan for management of the proposed marine park on Mafia Island. Tanzania recognizes the importance of a multi-use plan; the problem is funding. The proposed Mafia Island park will include at least one-third of the island, and will incorporate at least 34,000 of the island's 58,000 people. This will be the first marine park in Tanzania. The park will come under the jurisdiction of the Department of Fisheries; the park concept was actually conceived and created by this department. The country is now in the process of enacting legislation to create a marine park (The Marine Park and Reserves Act). WWF is working with responsible agencies and Mafia Islanders to: improve fishing management practices, while maintaining traditional fishing rights; reduce dynamite fishing by increased enforcement; develop environmentally friendly industries, including ecotourism, seaweed collection, and production of fibre from coconut husks; strengthen local participation in resource planning, and address institutional issues, such as legal prohibition of dynamite fishing in the park.

3. Promote tourism to the Rufiji Delta and Mafia Island as part of a safari package. Assist with development of tourist infrastructure on the Island, and possibly with the development of a raised boardwalk for tourists on

the Delta. At the moment, Mafia Island is currently difficult to reach because of limited air service and has little infrastructure for tourists.

8. Delta du Saloum - Gambia/Senegal

Category: Mangroves, rivers

Biological importance: The mangroves in the Saloum delta area, along the lower part of the Gambia River in the south, are extensive. They provide the nutrient base for many of the marine and estuarine organisms, making this part of the river the most productive fishing ground and an important fish spawning ground. The area is important for breeding waterbirds, including 1000 pairs of lesser and greater flamingoes and wintering waders. Manatees, humpbacked dolphins, olive riddley, green, and loggerhead turtles, and crocodiles are also found here. Some of the mangroves are protected in the Niumi/Sine Saloum National Park (Gambia) and in the Delta du Saloum National Park in Senegal.

Developmental importance: The Gambian coast supports one of the richest fisheries in West Africa. 16,000 artisanal fishermen depend on the river for its productive estuarine and coastal fisheries, yielding over 8100 metric tons of fish.

Threats: The Saloum delta area is threatened by agricultural conversion (extension of rice cultivation onto seasonally flooded areas), deforestation, the dam at Kereti, fires, overfishing, and the destruction of bird colonies. Intensive agriculture and the destruction of natural riverine wetlands have already caused increased erosion and siltation of the upper sections of the Gambia River, necessitating dredging operations in order to keep the river channel open.

Justification: These mangroves are important for two reasons: 1) their critical support to Gambia's rich fisheries; and 2) their importance to Palearctic birds. Conservation of this area was considered highest priority for Gambia by MacKinnon and MacKinnon (1986), IUCN (1987), and Stuart and Adams (1990).

What could be done:

1. Support environmental economic analyses to determine the value of these ecosystems, and the costs and benefits of agricultural conversion.
2. Develop a multi-use management plan for the area that attempts to reduce agricultural conversion and overfishing. Set aside mangrove areas as fish reserves to replenish overfished stocks. Perhaps encourage integrated fish/rice aquaculture in manmade ponds in a buffer zone outside of the mangroves.

   Additional activities could include protecting other mangrove areas and coastal wetlands.

9. Guinea-Bissau's mangroves

Justification: This country has the most extensive mangrove stands in Africa, but the mangroves are seriously threatened by agricultural conversion. Large areas have already been cleared.

What could be done: Work with the government to establish protection for the country's remaining coastal and estuarine mangroves. Support IUCN's Conservation and Sustainable Development Project in the Coastal Zone. If possible, protect mangroves in the coastal zone that are interdependent with the reefs bordering the Bijagos Archipelago. Support Guinea-Bissau's National Institute for Environmental Protection (INEP) in development of the Bijagos Biosphere Reserve.

Related conservation and management projects: The World Bank has a project to protect the coastal resources of the Bijagos Islands.

10. East Africa's Coral Reefs

Category: Coral Reefs

A. Madagascar's Reefs

Biological importance: Most of the country's southwest coast has significant coral reefs. These reefs are some of the last pristine reefs in the western Indian Ocean. None are currently protected. Important coral reefs include those in the southwest off Toliara and those in the northwest, including the sand cays of Nosy Foty, Nosy Anambo, Nosy Fasy, Nosy Faty, Nosy Faho, Nosy Langna, and the reefs of Nosy Be and Nosy Tanikely. 500 species of reef fish have been reported from Grand Recife and Toliara, along with a high diversity of other marine species, including molluscs characteristic of the Indo-Pacific (Gaudian et al., 1994). Dugongs are found on the northern and western coasts.

Developmental importance: The area is important for artisanal fisheries (Gaudian et al., 1994).

Threats: A current threat to coral reefs is sedimentation from excessive erosion. The coral reefs of the Tulear region were destroyed by pollution, overfishing, and mangrove destruction leading to erosion and sedimentation. Molluscs are threatened by overexploitation for food and shells. Crocodiles and sea turtles (green and hawksbill) are severely threatened by hunting.

Justification: Given the high profile of Madagascar's biodiversity worldwide and the correspondingly large number of international NGOs working in the country, this project (along with Project #4) should help to raise awareness among the conservation groups about the importance of conserving aquatic ecosystems. Further, this area affords an opportunity to highlight the links between terrestrial, marine, and freshwater ecosystems.

This project is also timely. The Government has recently become interested in the conservation and management of its reefs: the Government's National Environment Office's research component will include marine biodiversity as one of the three themes it will address over the next three years. In 1993, the marine research program, led by the National Center for Oceanographic Research, evaluated the degree of degradation of the Tulear reefs with the intent to create a national park as well as study methods for the protection and management of marine biodiversity. UNESCO/UNDP have also begun an effort to conserve coral reefs. *However, interested organizations should ensure there are committed individuals in Madagascar who want to make aquatic conservation a reality before embarking on such a project.*

What could be done:

1. Encourage the establishment of marine protected areas. According to Gaudian et al. (1994) the highest priority region is Grand Recif and the coastal zone of Toliara, with two sites recommended as marine protected areas: Passe Sud d'Ifoty and Nosy Be. IUCN also mentions Nosy Tanikely, and the sand cays of Nosy Foty, Nosy Anambo, and Nosy Fasy. *Encourage the protection of adjacent mangrove areas as well, since these are likely to be critical for the healthy maintenance of the reefs.* Extensive stands of mangroves (7 species) are found here.
2. Link reforestation, freshwater fish conservation, and coral reef parks.
3. Incorporate snorkeling or diving the reefs into an ecotourist package to Madagascar. Some of the profits from such an enterprise could go towards the maintenance of the reserves.

B. Other East African coral reefs

Salm (1996) recommends improved biogeographic classification and a more regional approach to conservation of East Africa's reefs. A number of small-scale coral reef conservation and development projects have relatively recently been established (e.g., Kenya's Coral Reef Conservation Project, supported by the Wildlife Conservation Society; co-management projects in the Tanga region of Tanzania, and some pilot community managed marine protected areas in Zanzibar, supported by the GEF). Such pilot efforts should be supported, and more developed to eventually establish an ecologically relevant network of sustainably managed and conserved areas throughout the East African reef system.

11. Inner Niger Delta, Mali

Category: Wetlands

Biological importance: *This is the most important wetland in West Africa.* The Inner Niger Delta's massive complex of floodplains and shallow lakes (covering 17,000 sq km) is critically important for migratory birds and fisheries. The area is a wintering ground for a large variety of Palearctic migrants, as well as birds which migrate inside Africa. Elephants migrate between the Diafa River floodplains and Burkina Faso. Manatees and warthogs are also found here. Stuart and Adams (1990) consider the delta to be one of the major centers of endemism for Africa's freshwater wetlands.

Developmental importance: One of the most important areas of human settlement in the Sahel (Webster, 1994).Over 550,000 Malians rely on the Inner Niger Delta for their survival. The Niger River, tributaries and associated floodplains support an important fisheries that provides most of the fish for Nigeria, Mali, and Niger and the livelihood of over 54,000 fishermen. Depending on the seaons, people use the delta for grazing for their livestock and for traditional agriculture adapted to the terrain, including floating rice and wild grains.

Threats: The ecosystem is in a serious state of decline as human population pressures, upstream dams (including the Selingue dam) and changing patterns of resource use have coincided with a long period of drought. Conflicting laws have led to the destruction of the flooded woodland forests. Two-thirds of the bird colonies have disappeared due to a combination of drought and deforestation (Webster, 1994).

What could be done: Provide assistance to help establish a multiple-use management program in the Inner Niger Delta, with reserves at a few important sites such as the Ramsar sites Lac Debo, Lac Horo and Seri. (Recommended by Stuart and Adams, 1990). These efforts would build upon the work already accomplished by IUCN's Inner Niger Delta Conservation and Development project (funded by the Federal Republic of Germany and more recently by AID/Mali), WWF-US, and the Biodiversity Support Program in the late 1980's. These NGOs have developed a sustainable use plan for the area, and helped to draft an agreement that returns control of natural resources to local and traditional managers. Support IUCN's testing of various types of integrated conservation and development wetland models, particularly at Lac Horo, a site which offers the potential for integrated management for both conservation and agricultural improvement. This site is important for wildlife and lies adjacent to an intensive and economically profitable agricultural project.

12. Lake Chad, Niger

Justification: One of the three most important West African sites for Palearctic migratory birds, as well as for fisheries.

What could be done: Survey wetland habitats in the area to identify potential areas for protection. Work with the Lake Chad Basin Commission (Nigeria/Niger /Cameroon/ Chad) to establish regional policies and the harmonization of national policies. A master plan for the lake has already been developed. Support regional coordination of national wetland policies and regulations; harmonization of water quality regulations; or regional fisheries management

13. Diawling/Djoudj wetlands, Mauritanic and Senegal

Category: Wetlands

Biological importance: The delta of the Senegal River, the second largest river in W. Africa, contains diverse habitats abundant wildlife. Mauritania's proposed Diawling Park in the delta is adjacent to the small, but important reserve, the Djoudj National Park in Senegal. The river is the country's hope for increased agricultural productivity through the Senegal River Basin Development Programme.

Threats: Population pressures and changes in the water level due to development pressures for the need for water in the Sahel. Two-thirds of the park has already lost its supply of freshwater from the Senegal river, causing increased salinity and large consequences for the park's ecology, due to the Diama dam and draining (Frazier, 1996). The development of rice fields along the border may lead to agricultural pollution.

Justification: Of international biological importance. Together, the Diawling/Djoudj site comprises one of the three most important West African sites for migratory Palearctic birds, particularly waterfowl.

What could be done: Support regional collaboration, planning, and management. Work with Senegal and/or Mauritania to develop water policies for the Senegal River that accomodate the water requirements for the Senegal Delta ecosystems. Currently, IUCN, the French, and the Dutch are working in this area.

Restore the natural hydrological cycle by imitating flooding through the sluice gates (Frazier, 1996). Currently, the sluice gates are not large enough. A component of the water policy should be to encourage water conservation, particularly among agricultural users. Help to reduce the level of pesticide use in the area through training and encouragement of biological control methods.

Assist with implementation of the management plan for Djoudj National Park in Senegal, developed by WWF and IUCN.

14. Bazaruto Archipelago, Mozambique

Biological importance: Of regional to global importance due to its diversity of coastal and marine habitats. A wide variety of habitats – coral reefs, seagrass beds, mangroves, rocky intertidal areas, and dune forest – supports large populations of threatened and endangered species such as turtles and marine mammals. The area is critical to the survival of dugong in East Africa.

Developmental importance: The area is a productive fishing ground, and is a prime tourism site in Mozambique.

Threats: Overfishing (particularly by fishermen coming from the mainland, rather than island-dwelling fishermen); destruction or degradation of terrestrial vegetation by goats, cultivation and fires; risk of inappropriate tourism development. The influx of people to the island during the war had big impacts. Although many of these people have now returned to the mainland, there are some enduring effects (e.g. the goat population is now greater than it was before the war). Problems are exacerbated by the fact that there are few economic alternatives for the islanders, and the fact that there are complex linkages to fishing communities on the mainland.

Justification: The World Bank is proposing a Marine and Coastal Biodiversity Management Project that will help implement the country's marine and coastal biodiversity strategy as defined within the National Forestry and Wildlife Program, including strengthening and extending existing marine protected areas, managing marine mammals and sea turtles, developing sustainable financing mechanisms, and improving legislation and regulation. This area is considered a regional priority by regional experts (Gaudian et al., 1994).

What is being done: Part of the archepelago (3 of the 5 islands) is gazetted as a national park. A proposal is being considered to extend the park to provide more meaningful ecological limits. The National Directorate of Forestry and Wildlife (responsible for park management), Worldwide Fund for Nature and Endangered Wildlife Trust have for several years been undertaking a project which aims to promote conservation of the archepelago through development of sustainable livelihoods for local people. The project is currently working with local people, hoteliers and other stakeholders to find economic alternatives to unsustainable or damaging practices, developing linkages between conservation and development. The park management plan is being updated; this process has included extensive stakeholder consultation, with negotiations on zoning and unsustainable activities. Early funding came from the EU and WWF; the project is currently funded by SWATCH and WWF.

What could be done: Assist WWF/Southern Africa Nature Foundation in developing and implementing a community-based multi-use management plan through consensus. This project will help boost benefits to local communities; support community-based environmental management and monitoring; and support sustainable technologies (WWF, 1998). WWF is also supporting the declaration of the Greater Bazaruto National Park in Mozambique.

Further work is needed with stakeholders, particularly fishermen on the mainland. Capacity building is required for various stakeholders. Greater dialogue is required between stakeholders, and further work is needed on investigating alternative economic activities that link conservation and development. Funding has been made available for an ecoregional approach for Bazaruto, looking at threats and opportunities beyond the national borders of Mozambique. This is particularly important in a marine environment.

Chapter 8. Conclusion

Aquatic ecosystems provide critical services for man and wildlife. They are important both to the flora and fauna living in the water as well as to those on land. In this age where biodiversity loss has become a global concern, aquatic life is too often forgotten. The aquatic biodiversity in Africa is one of the world's richest treasures, and equally importantly, is critical to African nations and peoples. We have the chance to conserve some of this wealth if action is taken now, and alternatives are provided. It is not too late.

Which path do we choose? This....

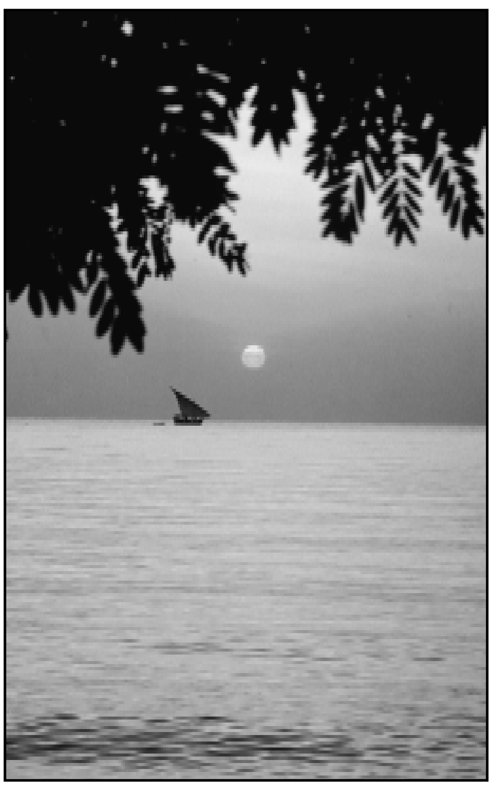
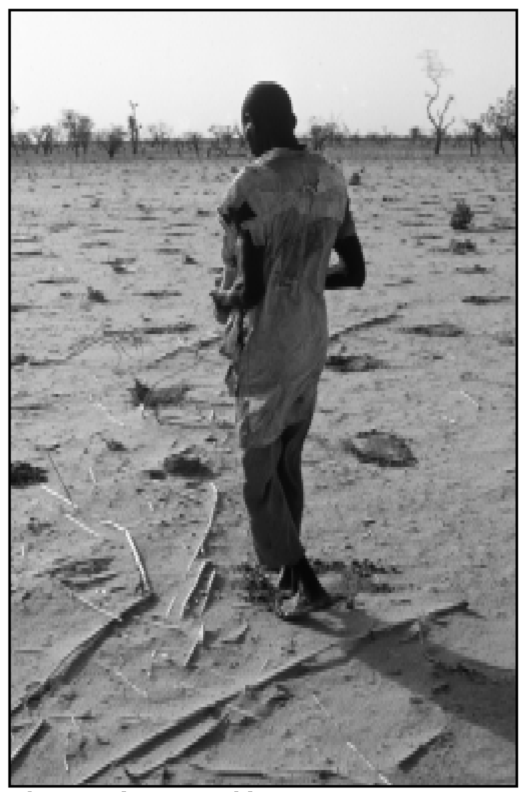


Photo credit: Caroly Shumway.

or this?



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Chapter 9.
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Chapter 10.
Annex

A. Regional Initiatives

Continent-wide

The **World Bank**'s Africa Region has adopted an Integrated Water Resource Management Strategy for sub-Saharan Africa which will help develop mechanisms for transboundary cooperation; assess freshwater resources, use patterns and environmental threats; and identify the potential for sustainable water resource management. The Bank has assisted in developing water management strategies in Tanzania, Kenya, and Zimbabwe, and fostered cooperation on water resource management among the SADCC countries (Environment Matters, Fall, 1996).

UNEP has the Regional Seas Program. Three Regional Conventions for Africa fall under this program: 1) The Convention for Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (and the associated Protocol on Combating Pollution in Cases of Emergency); 2) a similar convention and protocol in the Eastern African Region (with an additional protocol concerning Protected Areas and Wild Fauna and Flora); and 3) the Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (World Bank, 1996).

Other conventions include the MARPOL Convention to regulate ship pollution, and the International Convention on Oil Pollution Preparedness, Response, and Cooperation (OPRC) (World Bank, 1996).

UNDP is developing an integrated coastal zone management training program.

East Africa

The **GEF** is supporting the multicountry Lake Victoria project; developing projects to manage regional fisheries in West Africa, and designing oil spill contingency plans in the West Indian Ocean (Environment Matters, Fall, 1996).

IUCN is developing a regional Marine Protected Areas program, focusing on Kenya, Tanzania, and Mozambique. The program will boost institutional capacity, improve management through participatory approaches, produce a biogeographic classification, and provide a training course for MPA planners and managers (Salm, 1996).

East Africa - The Nairobi Convention for the Protection, Management, and Development of Marine and Coastal Environments in the East African Region will come into force when 6 countries have ratified the convention. To date, just four countries have. The Convention requires establishment of a regional program to create protected areas and addresses pollution issues (Kelleher et al., 1995b).

Madagascar, Mauritius, Mozambique, Seychelles, Tanzania, and Kenya signed the 1993 Arusha resolution on Integrated Coastal Zone Management in Eastern Africa, including the Island States (World Bank, 1996). Many of the recommendations in this resolution have or are being implemented in at least some countries (World Bank, 1996).

The Indian Ocean Marine Affairs Cooperation Conference (IOMAC) provides a convenient means to enhance regional cooperation and action in the East African region (IUCN, 1995). The 1992 IOMAC workshop assessed conservation priorities. IOMAC has now established an Indian Ocean Conservation Program, with assistance from the New England Aquarium and Fauna International (Sri Lanka).

Islands of the Indian Ocean - The **EU** has recently embarked on a regional coastal zone management program in Madagascar, Mauritius, Comoros, Seychelles, and Reunion to address marine pollution, coral reef degradation, and protected areas management (World Bank, 1996).

West Africa

The Gambia/Senegal - are increasing cooperation to protect the resources of the Saloum Delta, an important wetland and mangrove area. Both countries now contain protected areas at this site.

Gulf of Guinea Ecosystems - The GEF, in collaboration with NOAA, IOC, UNEP, FAO, National Environmental Research Council (NERC), the Sir Alister Hardy Foundation for Ocean Science, and scientists from national marine resource agencies will assist the Cote d'Ivoire, Ghana, Nigeria, Benin and Cameroon in implementing coastal ecosystem assessment, monitoring, and mitigation.

Nigeria/Niger/Cameroon/Chad - Agreed in 1977 to jointly control the management of the flora and fauna in the basin of Lake Chad.

Southern Africa

Botswana/Malawi/Zambia/Zimbabwe - The Southern Africa Wetlands Project, sponsored by SADCC/IUCN/NORAD is assessing wetlands in each of these countries. The project will identify important wetlands (both within and outside protected areas) and make recommendations for sustainable development of the surrounding areas.

B. List of Acronyms

ADB	Asian Development Bank
AFR	USAID Africa Bureau
AID	Agency for International Development
BSP	Biodiversity Support Program
CATIE	Tropical Agricultural Research and Training Center (Costa Rica)
CIDA	Canadian International Development Agency
CRSP	Collaborative Research Support Program
DANIDA	Danish International Development Agency
DCA	Swiss Directorate of Development Cooperation and Humanitarian Aid
DDA	Swiss Development Corporation
DFA	Development Fund for Africa
DGIP	Division for Global and Interregional Programmes (UNDP)
EEC	European Economic Community
EWT	Endangered Wildlife Trust
FAO	Food and Agriculture Organization, United Nations
FINNIDA	Finnish International Development Agency
GIS	Geographic Information System
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit, (West Germany)
ICBP	International Council for Bird Preservation
ICLARM	International Center for Living Aquatic Resource Management
IOC	Intergovernmental Oceanographic Commission
ISF	IUCN Sahel Fund
IUCN	International Union for the Conservation of Nature
NEAP	National Environment Action Plan
NIDA	Netherlands International Development Agency
NORAD	Norwegian Agency for Development Cooperation

NRM	Natural Resource Management
ORSTOM	Office de la Recherche Scientifique et Technique Outre-Mer (France)
PSTC	Program in Science and Technology Cooperation
PVO	Private Voluntary Organization
RPSB	Royal Society for the Protection of Birds
SADCC	Southern African Development Coordination Conference
SIDA	Swedish International Development Authority
SOW	Scope of Work
SSC	Species Survival Commission, IUCN
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
URI	University of Rhode Island
WCI	Wildlife Conservation International
WSSA	Wildlife Society of Southern Africa
WWF	World Wide Fund for Nature

C. Scientific Glossary

Anaerobic - lacking free oxygen.

Anoxic - lacking free oxygen.

Aquifer - an underground layer of porous rock, etc. containing water.

Artisanal - small-scale fishing, generally to supply local markets.

Biodiversity - the variability of living organisms, the ecological roles they perform, and the genetic diversity they contain.

Biogeochemical - refers to nutrient cycling between organisms (living and dead) and the earth's inorganic material.

Biomass - the stock of fish present at any one time.

Catch - the yield of fish.

Clupeid - sardine-like fish.

Crustacean - a class of arthropods found mainly in freshwater and marine habitats, where they constitute a major component of plankton. Common crustaceans include shrimps, crabs, and lobsters.

Dambo - a type of seasonal freshwater wetland on inorganic soil.

Deltas - a usually fan-shaped deposit of sediments near the mouth of a stream, inlet, or estuary where stream flow loses momentum, resulting in meandering and sediment deposition.

Detritus - organic particles in the water column.

Ecosystem - a functional, open system comprising a group of organisms occupying a particular type of environment with identifiable spatial extent and boundaries.

Ecosystem, disturbed - an ecosystem that has non-native species and/or mechanical, thermal, hydraulic, or chemical disturbance by humans or non-native species.

Endemic - describing a species that occurs naturally only in a certain area.

Estuaries - bodies of water where marine and freshwaters meet and mix - where a river mouth widens into a marine ecosystem, with salinity intermediate between freshwater and salt, and where tidal action is an important biophysical regulator.

Eutrophication - nutrient enrichment in a body of water, usually by organic pollution such as fertilizers, sewage, etc., that leads to increased productivity by phytoplankton.

Ex situ - (L. situs, position) - out of site. As defined here, conservation of organisms outside of their natural habitat.

Fecundity - the fertility of an organism.

Feral - domesticated animals that live in the wild.

Floodplains - areas of land adjacent to a river channel that are periodically flooded.

Fringing coral reef - coral or coral-algal reef including a recognizable reef flat which extends directly offshore along the coasts of continents or high islands and lacking lagoons.

Gastropods - a class of molluscs that includes the snails, whelks, limpets, land and sea slugs, and conches.

Genus - a category used in the classification of organisms that consists of a number of similar or closely related species.

Geomorphological - refers to geological processes shaping the earth.

Geothermal - the heat inside the earth.

Groundwater - freshwater below the ground surface.

Haplochromine - a type of cichlid fish.

Herbivorous - animals which eat plant material.

Hominid - any member of the primate family Hominidae, which includes man and his fossil ancestors in the genus Homo.

Hydrological - concerned with the earth's waters, their distribution, and the water cycle.

Indigenous - describing a species that occurs naturally in a certain areas, as distinct from one introduced by man.

Indopacific - refers to the fauna common to the Indian and Pacific oceans.

Intertidal - habitat occurring between highest and lowest tide levels; area of shore influenced by the tides.

Intralacustrine - within a lake.

Lagoons - medium to large body of mixohaline (brackish water) to euhaline water (salt water) occupying a depression at least partially enclosed by a barrier or atoll reef(s), generally with depth of 5-60 m; depression ringed by perimeter or annular reef(s) of an atoll.

Littoral -zone influenced by the tides and/or waves.

Mangroves - ecosystem or vegetation type dominated by mangrove species adapted to or dependent upon brackish conditions; usually found in tidal or estuarine sites and often found in subtidal sites, although not submerged at high tide. Mangrove species do not generally tolerate complete submersion in salt water, even for short periods, but their roots may be in substrate that is intertidal or subtidal. Mangrove species may be found in freshwater (non-mangrove) or non-tidal sites, although obligate mangrove species are found only in haline wetlands.

Marais - French for freshwater swamps.

Mariculture - the culture of marine organisms.

Mbuna - a unique category of rock-dwelling, colorful cichlids of Lake Malawi, primarily found in the southern section.

Meromictic - permanently unmixed layers of water which usually become deoxygenated.

Metapopulation - a system of small local populations occupying a large set of patchy habitats (see Levins 1969; Roughgarden 1988).

Mudflats - a gently sloping, low energy environment covered with fine grain sediments (silts, clays).

Ornithological - having to do with birds.

Paleolimnological - the study of lake history from sediments.

Pans - shallow lakes.

Passerine - of, or relating to the largest order of birds (Passeriformes) which includes more than half of all living birds and consists chiefly of altricial (i.e., having the young hatched in a very immature and helpless condition) songbirds of perching habits. Example: sparrows.

Pelagic - that portion of the ocean not associated with the coasts; ocean seaward of the continental shelves or where bottom depths exceed 200 m.

Planktivorous - animals which eat plankton.

Primary Productivity - net primary productivity is the rate at which solar energy is incorporated into plant tissue.

Prosimians - primitive primates, such as lemurs.

Ramsar - refers to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat. Adopted in Ramsar, Iran, 1971. Contracting parties to the Ramsar convention have certain obligations, including, inter alia, the designation of wetlands in their country of international importance and the planning and implementation to conserve listed sites.

Recruitment - the addition of young, or juvenile, animals to an adult stock.

Reef Flats - horizontal surface of a reef, often in the low intertidal zone; comprised of cemented or loose sediments.

Riparian - either relating to, living in, or located on the bank of a natural watercourse such as a river, lake, or a tidewater.

Seagrass Beds - a habitat within the intertidal and/or subtidal zone characterized by having a sandy or muddy bottom and with the dominant vegetation being seagrass. An important nursery site and refuge for marine organisms.

Shellfish - invertebrates collected for food, such as oysters, shrimp, mussels, etc.

Species radiation - The evolution of species from a common ancestor.

Swamp Forest - forests that develop in still water areas around lake margins and in parts of floodplains where the water rests for longer periods. Their characteristics vary according to geographical location and environment.

Trophic - the position that an organism occupies in a food chain.

Upwelling - the vertical movement of water from the depths up into the surface layers of the ocean. Often increases productivity by bringing nutrients such as N and P up to the surface which can be utilized by phytoplankton.

Vector - an animal, usually an insect, that passively transmits disease-causing microorganisms from one animal or plant to another.

Waterfowl - birds that are dependent on bodies of water for either food or breeding.

Watersheds - the elevated area of land drained by a river system.

Wetlands - as defined by the Ramsar convention, "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Zooplankton - small animals, or the larvae of larger animals, which drift or swim in the surface layers of the ocean.

D. Keyword Index

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E. Case Study: Lake Victoria

"The potential loss of vertebrate genetic diversity as a result of this single ill-advised step is probably unparalleled in the history of man's manipulation of ecosystems."
Barel et al. (1985)

Lake Victoria, the youngest of the great lakes, used to support over 350 species of cichlids, as well as at least 51 other species such as endemic species of catfishes, electric fishes (mormyrids), carps, crustaceans, molluscs, and insects (Ogari, 1993). Nearly all of the cichlids (99%) are endemic haplochromines (Witte et al., 1993). Prior to the introduction of exotic fishes, the lake supported a highly diverse commercial fishery, at least 50% of which was based on herbivorous and detritivorous cichlids. Fisheries based on short food chains such as this are considered to be the most ecologically efficient. The tilapian cichlid called the "ngege", Oreochromis esculentus was the most important and desirable (Graham, 1929, Ogutu-Ohwayo, 1993).

In the early part of the century, modern fishing methods such as gill nets were introduced to the region (Figure 67). Mesh sizes, initially large, gradually reduced as a result of pressure for a higher return and the combination of more and more fishermen entering the fishery. The result was overfishing and a consequent rapid decline in the catch of the "ngege" and important anadromous fishes.

To replace the overfished stocks, at least four exotic tilapia species, including *Oreochromus niloticus*, were introduced in 1951. In 1954, the Nile perch, Lates niloticus, was either deliberately or accidentally introduced into the lake by British colonialists, reportedly for sport fishing (Fryer, 1960). Scientists argued that such an introduction would be unproductive; the yield of a predator could never be as great as that of its prey because of the loss of energy to the predator (Fryer, 1960). As predicted, the introduction of a top predator reduced the efficiency of the food web by 80% (Barel et al., 1985).

At first the local people did not like the fish at all, particularly its oily taste. In addition, the large size of the perch, which is up to 6 feet long and weighs up to several hundred pounds, necessitated that the fish be smoked instead of sun-dried as was done for the endemic cichlids. This not only involved more work, but led to local deforestation in some areas. Islands on Tanzania's side, for example, have been heavily deforested to obtain wood to smoke the perch. Prices of the perch remained low because of the lack of local interest in the fish.

For twenty years, the Nile perch and the haplochromines managed to coexist, with the perch contributing only 0.5% of the fishermen's catch in 1968. Several changes, however, occurred in the 1980's. First, the perch went through a series of local population explosions, aided by its high fecundity (producing over 16 million eggs), flexible feeding habits, and rapid growth (Figure 68).

Second, concurrent with the increase in the perch population, the populations of at least 200, and possibly as many as 350 haplochromine species, declined, as extrapolated from data from several areas of the lake (Figure 68, Table 12). Overwhelming evidence of the decline in haplochromines has been provided by surveys by different investigators — particularly the almost complete loss of the deep water fishes and the loss of nearly one-half of the cichlid species in the waters <20 m deep (Figure 68; data from Uganda, Kaufman, 1991). Deepwater fish are now only caught one to two at a time. The haplochromines may have been more vulnerable to ecosystem disturbances than other species because of the similarity of their genetic background; all of the native cichlids in the lake are monophyletic (Myers et al., 1991). Their low fecundity also limits their ability to recover. Most of the decline in fish species occurred between 1979 and 1986, even in areas without fishing pressure (Witte et al., 1992). Data from Kenyan waters indicates a drastic decline in the catches of native fishes, from 30 kilograms/ha in 1977 to less than 5 kg/ha in 1983 (cited in Kaufman, 1992). Data from Mwanza Gulf in Tanzania shows that of the 123 species found in 1979, 80 had disappeared from the catches by 1986 (Witte et al., 1992). It now appears that at least 50% of the cichlid species have become extinct

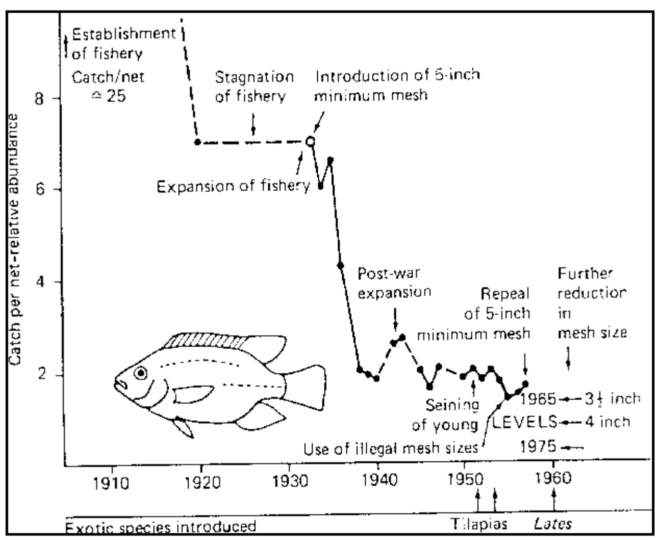

Figure 67. The decline of the tilapia fishery in Kenyan waters of Lake Victoria. After Fryer, 1972. From Lowe-McConnell, 1987b. Reprinted with the permission of Cambridge University Press.

(Kaufman and Ochumba, 1993; Witte et al., 1992), making this the largest mass extinction of vertebrates worldwide.

Third, the flaky, white flesh of the perch made it a popular export item. Donors and investors helped to establish processing plants, refrigerator trucks, and ships in the area. Between 1970 to late 1980, the annual catch of the lake increased at least four-fold, from 100,000 to 400,000 metric tons. Today, Lake Victoria's fisheries comprise 25% of the total inland fisheries in Africa and feed over 50 million people. Local people now literally call the perch "The Savior". The perch is exported as salted fish, whole fish, fish fillets, fins, skin (for leather), scales (for chicken feed), and swim bladders (for filtering wine). The fish has become an economic goldmine which has led to an all too-predictable "perch rush". In Uganda, the total fish production increased from 17,000 tons in 1981 to 130,000 tons in 1991 (Okaronon and Akumu, 1993). In Tanzania, 4141 fishing vessels caught $1.6 million of fish in 1983. In 1989, 7757 vessels caught $18.5 million.

The perch is currently being overfished, both for increased export demand and local needs. Continued decline in catches is reported from all three riparian states, even where fishing effort has increased, as in the case of Kenya which has shown a steady decline in catch rate since 1987 (Uganda: Okaronon and Akumu, 1993; Kenya: Rabuor et al., 1993). In a desperate effort to maintain the same catch in the face of a declining perch population, the net mesh size has been continuously reduced. Perch are now being caught before they even have a chance to reproduce. Forty-five percent of the catch is now juvenile perch less than 50 cm long (Budeba, 1992, pers. comm.).

Although there is clear evidence of overfishing, investments in fish processing for the export market proceed unchecked. Although Tanzania already has two fish processing plants, thirteen more are being planned. The export business does not appear to show any long-range planning or concern for a sustainable fishery. Harris (1992, pers. comm.) has reported discussions with businessmen which indicate they are primarily interested in recouping their initial investment and obtaining a profit within one and one-half to two years; if the fishery fails after that, so be it.

The Nile perch explosion also led to major socioeconomic changes. The poorer fishers, with less efficient vessels and gear, are finding it increasingly difficult to compete with wealthier individuals that can afford the stronger, larger, and more costly nets required for the perch (Barel, 1985). In the process, traditional fishing practices are being lost.

Table 12. The Trophic Groups in Lake Victoria and Their Estimated Species Diversities

Trophic Groups	Known	Described	Recommended Listing
detritivores/phytoplanktivores	13+	3	ENDANGERED
phytoplanktivores	3	0	ENDANGERED
epilithic algae grazers	3+	1	Probably secure
epiphytic algae grazers	7+	3	Probably secure
plant eaters	2	2	Status undetermined
pharyngeal mollusc crushers	9+	6	THREATENED
oral mollusc shellers/crushers	12+	8	THREATENED
zooplanktivores	21+	8	THREATENED
insectivores	29+	18	ENDANGERED (in part)
prawn eaters	13+	11	ENDANGERED
crab eater	1	0	Probably secure
piscivores sensu stricto	109+	42	ENDANGERED
paedophages	24+	8	ENDANGERED
scale eater	2	2	ENDANGERED
parasite eaters	53	6	ENDANGERED
unknown	53	6	
TOTAL	302+	119	

From Kaufman, 1991b.

The perch now makes up over 80% of the fish biomass (Barel et al., 1985). The lake's diverse fisheries have been reduced to three species: the Nile perch (*Lates niloticus*); the exotic tilapian cichlid (*Oreochromis niloticus*); and the native pelagic minnow, *(Rastrineobola argentea)*. In Ugandan waters, the perch contributes roughly 86% of the catch; the exotic tilapiine 11%, and the native minnow just 2% (Kaufman and Ochumba, 1993). Virtually all of the indigenous fish of commercial importance as staple and specialty foods have been eradicated.

Scientists at the 1992 Jinja conference drew the unmistakable conclusion that the lake's current fisheries are unstable. The only debate is when the perch population will crash. The stability of the current fisheries depends on a number of factors including the availability of food for the perch, fisheries management, and the changes to the environment of the lake, induced by the increasing human population in the basin (Welcomme, 1993). Kenya has already reported a decline in catch sizes, with Kenyan fishermen having to travel further out into the lake to catch any perch. The perch has been nearly completely fished out in Kenya's Winam Gulf. Tanzania has reported that their fishermen are shifting to smaller and smaller mesh sizes. The Tanzanian fishermen are now taking the perch before it even has a chance to reproduce; the mean harvest size in Tanzania is 42 cm, while the mean reproductive size is 52 cm.

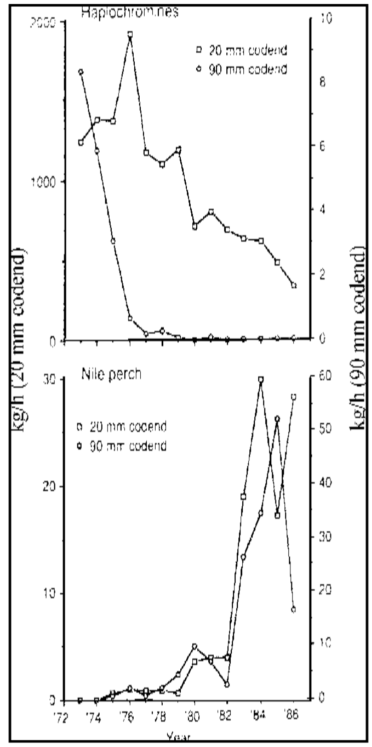

Figure 68. Mean catch rates of haplochromine cichlids and Nile perch. From Witte et al., 1992. Reprinted with kind permission from Kluwer Academic Publishers.

The food web in the sub-littoral and offshore areas of the lake has changed considerably. The perch has now turned to eating large amounts of the small native shrimp *Caridina nilotica* and to cannibalizing its own young. If the perch manages to deplete the prawn population, this could have serious repercussions for the ecosystem, since the prawn is an essential link in the food chain for other fauna besides fish. Scientists are afraid that the perch will soon deplete its prey. This, coupled with overfishing, is likely to cause the perch population to crash, and the fishing industry to fall into the trough of a boom-and-bust cycle.

Other changes in the lake are exacerbating the problem. The lake actually experienced profound changes long before the introduction of exotic species, primarily due to human activities within the lake basin and watershed. The lake's algae began to change as early as the 1920's, with dramatic occurring in the late 1960's in response to increases in nutrients, primarily phosphate (Hecky, 1993). Phosphate concentrations increased nearly 3-fold between 1960 and 1990.

What happened in the 1960's to cause such changes? More and more people settled around the lake. Heavy rains caused flooding which destroyed considerable stands of riparian forest. This paved the way for increased settlement along the water's edge. The loss of riparian forest also increased the input of nutrients into the lake, as the forest had acted as a filter for various nutrients, primarily nitrogen. Welcomme (pers. comm.) speculates that few had originally lived near the lake because of fear of the tsetse fly. The flooding and the subsequent loss of the habitat for the fly allowed immediate colonization.

The lake's litany of environmental "woes" include:

- *Eutrophication, leading to a two to three-fold increase in primary productivity and increase in turbidity:* The source of the nutrient inputs is largely agricultural runoff of fertilizers and livestock feces (the largest source of phosphate at least in Kenya's Nyanza Gulf, Aketch et al., 1992), as well as the dumping of virtually untreated municipal sewage and industrial discharges from the sugar industry and other factories, primarily in the upper basin areas of Kenya. Most of the rivers draining into Lake Victoria are on the Kenyan side; the catchment areas of these rivers are heavily populated (GEF, 1996). Although eutrophication greatly increased primary productivity in the lake when phosphate was the limiting factor, any further increases in eutrophication can only be harmful because of the concomitant reduction in the availability of light. Productivity is now, in fact, light limited. This means that additional increases in primary productivity are not possible. Currently there is no pollution control. The countries have a very limited capacity for monitoring water quality.

- *a four to five-fold increase in biomass;*
- *increased blue-green algal blooms*. Researchers have documented a significant decrease in silica indicating changes in the species composition of the phytoplankton from silicified diatoms to predominantly nitrogen-fixing blue-green algae;
- *a decrease in the area of papyrus swamps. The* papyrus surrounding the lake is being cut down to make mats for export. This has two consequences: it reduces the amount of available breeding grounds and refugia from the Nile perch, and it exacerbates sedimentation into the lake, which the papyrus used to trap (Inter-Press Service, 1995).
- *the invasion of water hyacinth,* which affects biological productivity by reducing the levels of dissolved oxygen and the penetration of sunlight;
- *increased anoxia and fish kills.* The increasing deoxygenation of the lake over the last two decades has greatly reduced the areas in which it can support life. A fishing survey in 1970 found fish living at all depths of the lake. Most of the lake was aerobic except for brief periods during the rainy season. Regular mixing occurred twice a year, bringing oxygen to the deeper depths and nutrients to the surface. Now the bottom third is hypoxic, with few fish species present (Hecky et al., 1994). In the early 1980's, scientists first reported the frequent appearance of dense algal blooms and associated anoxia in the lake's shallow waters (Ochumba and Kibara, 1989). In 1987, researchers measured oxygen levels in the lake and found no life below 30 meters. Similar results were found in a 1989 survey.

Recent results suggest that the lake is now stratified most of the year (Hecky, 1993). Depths below 40 meters are anoxic year-round and depths between 25-40 meters are subject to frequent, severe deoxygenation. Low oxygen levels throughout the water column can occur for up to five months at a time. The periods of mixing are no longer capable of bringing saturated oxygen from the surface to the bottom, and instead result in fish kills as the anoxic water is brought to the surface. Between November and June, the oxycline can move to depths as shallow as 5 meters, resulting in massive fish kills. Such kills have become more frequent. During the mixing period, the fish try to escape the resultant low oxygen levels by crowding into the lake's channels, gulfs, and bays. This has two consequences: it makes the fish very vulnerable to overfishing by beach seines and it gives the haplochromines few hiding places from the perch. The increased duration of the anoxia has caused most of the species to move out of the pelagic areas of the lake. The anoxia problem has been exacerbated by the fact that the lake is also getting warmer, which further reduces the level of available oxygen in the water.

There are three competing hypotheses to explain the drastic changes occurring in the lake: "1) the introduction of the Nile perch altered the food web so that biomass now accumulates at lower trophic levels; 2) nutrient inputs from the basin and atmosphere, such as increased atmospheric loading of nitrogen and sulfate have caused eutrophication and increased primary productivity; and 3) recent changes in climate have altered water column structure and caused mixing patterns to favor the development of blue-green algae and the loss of oxygen in bottom waters" (Kling, 1993).

The dominant hypothesis accounting for the demise of the haplochromines is predation by the Nile perch (see Witte et al., 1992, Kaufman, 1992), although other factors such as overfishing and deoxygenation certainly also contributed to their loss. Evidence includes:

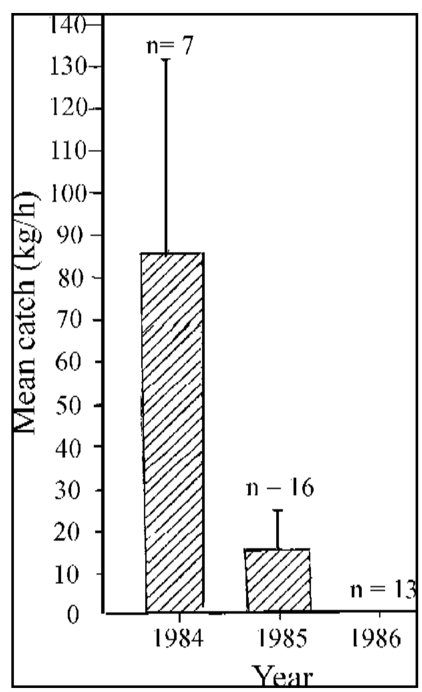

Figure 69. Mean catch rates of haplochromine fishes in bottom trawl catches. From Witte et al., 1992. Reprinted with kind permission from Kluwer Academic Publishers.

- haplochromines disappeared even in lightly fished areas (in fact, evidence suggests that overfishing only played a role in intensely populated areas and shallow waters);
- the decline in the haplochromine population coincided in time with the increase in the Nile perch population (see Figure 69); and
- the same pattern of haplochromine decline and perch boom occurred in Lake Kyoga (Witte et al., 1992; Kaufman, 1992). Stomach content analysis of Nile perch has indeed confirmed that haplochromine cichlids were their main prey item, at least until the cichlids had been depleted (cited in Witte et al., 1992).

Whether or not the Nile perch is solely to blame for the limnological changes cannot easily be proved. Evidence strongly suggests, however, that it greatly contributed to the problem by decimating planktivorous and detritivorous cichlids. Goldschmidt et al. (1992) speculate that the predation by the Nile perch on the planktivorous haplochromines (which used to form nearly 18% of the haplochromine community) and the planktivorous tilapians may be a partial explanation for the algal blooms. Such speculations are bolstered by data from lakes in Wisconsin (Kitchell, 1993) showing that changes in the populations of planktivorous fishes due to manipulation of the population of their predators can indeed regulate primary production rates and influence the magnitude and frequency of algal blooms. The perch may also have contributed to the problem of anoxia by eliminating the detritivorous haplochromines (Kaufman, 1992). Eighty percent of the haplochromines fed on the lake's detritus, retarding the accumulation of rotting biomass in the lake's depths. The function of the detritivorous haplochromines appears to have been replaced by the small shrimp *Caridinia nilotica*, the only organism that can survive the anoxia. Its efficiency in taking up the detritus, relative to the haplochromines, is unknown.

In conclusion, the ecosystem of Lake Victoria, dominated by the Nile perch, continues to be unstable, with on-going changes in species composition of both its flora and fauna. Okie (1992) notes that the Nile perch fishery is also proving to be highly unstable in other parts of Africa as well. At least 65% of Lake Victoria's species appear to be gone. The instability of the ecosystem is not simply damaging to the endemic fishes. It threatens the eight million people who live along its shores and are dependent on the lake for protein.

To add one positive note to this case study, it may not be too late to save the remaining haplochromines. Recent expeditions suggest that at least some parts of the lake and adjacent satellite lakes still have relatively intact shallow-water inshore cichlid assemblages (Kaufman and Ochumba, 1993), although these remnants are vulnerable to fishing with small meshed nets (Witte et al., 1992).

The loss of the haplochromines could only be rationalized if humankind learned from its mistakes. This does not seem to be the case. Some have argued that the introduction of the perch <u>was</u> successful in that it led to a dramatic increase in landings and income. There are a number of faults to this line of reasoning. First, it is impossible to separate the effect of the increased fishing effort that occurred during this time from the effect of increased production. Second, the increased production was likely the result of higher levels of primary productivity. Primary productivity is generally limited by the availability of nutrients; with the increased input of nutrients into the lake, productivity increased. Scientific logic alone should be able to dispel the notion that the introduction of a predator between man and the base of the food web would lead to increased productivity of the system.

"At a recent meeting on fish conservation, an African representative astounded...fisheries biologists and ecologists by announcing that he would, even in hindsight, introduce Nile perch to Lake Victoria all over again. The official's response reflects the desperate need for short-term gains in the very nations that harbor most of the world's aquatic biological diversity." (Kaufman, 1991b). But can the short-term gain possibly compensate for the economic costs of the impending crash of the perch and the cost of the loss of native cichlids— the loss of a stable fishery, aquarium fishes, genetic material, and scientific understanding? Even today, threats to the lake from introduced species continue. Local fishermen are clamoring for the introduction of another "savior" (Ogutu-Ohwayo, 1993). Another fish has apparently already been introduced — the black bass, *Micropterus salmoides*, which was found in 1989 to be established in the lake basin.

Will humankind ever admit its hubris in thinking it understands ecosystems so well as to manipulate them successfully?

About the author

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