African Freshwater Fish and Fisheries : a Biological and Cultural Heritage

C. Lévêque

Centre National de la Recherche Scientifique, Programme Environnement, Vie et Sociétés, F-92195 Meudon cedex, France

Abstract

Biodiversity is currently considered as an heritage for human societies. First, the present day composition and distribution of the African ichthyofauna are the results of a long and complex history, during which speciation and extinction processes interacted with climatic and geological events. Biological diversity is therefore the product of a long term coevolution between fish species and their aquatic environments. It is our **biological heritage**. It includes some 3000 species, and an unusual high number of primary division fish families compared to other continents. Why are there so many phylums and why so many living primitive fish groups are only represented in Africa ? Is Africa a major centre of origin for freshwater fish or are the climatic and geological events responsible for extinctions of several phylums in other parts of the world ? The question is still open and need better paleontological data.

Moreover the highly endemic fauna observed in East African lakes is a unique opportunity to study such matters as adaptive radiation, convergent evolution in different lakes, the nature of isolating mechanisms, and more generally the patterns of speciation. They are unique natural laboratories for the study of speciation, and studies conducted in African lakes provided good support to the theory of sympatric speciation.

Another aspect of the heritage is that over many generations a close relationship between human culture and environment has developed, including a large body of traditional knowledge about natural ecosystem functioning and responses to various uses. These include total protection of certain biological communities or species; protection of certain life history stages, or during certain seasons; restrictions on methods and amounts of harvest, and on certain social, age or sex groups from harvesting certain species; and restriction of access to certain localities to certain groups or individuals. This cultural biodiversity which is also the product of a long term co-evolution between societies and their environment is our **cultural heritage**.

Introductions of exotic species are a long standing management practice in aquatic environments. Among the many reasons to perform introductions, nostalgia of displaced peoples for familiar fauna to surround them would seem to rank fairly highly. The introduction of species in lakes to improve fish production relates to another type of culture : the culture of fishery officers which is strongly influenced by north European science. However, although aquaculture is of considerable antiquity, especially in the Far East, there is apparently very little tradition of fish culture in Africa. As a result, the world production of tilapines, originally endemic to Africa, amounts several hundreds thousand tonnes while production only amounts 6 000 tonnes in Africa.

The huge diversity of fishing gear which has been developed over centuries, should be considered as a technical and cultural heritage which is rapidly disappearing. The introduction of new fishing techniques, usually less selective, resulted in many cases in overfishing. The collective experience in recent years on the African Great Lakes, seems to show that large scale mechanised fishing is incompatible with the continued existence of the highly diverse cichlid communities.

Efforts at central fisheries management in Africa over the last few decades have not been particularly cost-effective and serious consideration needs to be given to re-instating community-based, traditional-type management structures. What can we learn from traditional management practices ? Should new management systems be based on the resource

management techniques of the industrialised countries or should they be developed by rehabilitating and adapting "indigenous" resource-management systems and upgrading traditional local-level institutions ?

The relation between societies and fish is not limited to food production. There are a number of fish treated as taboo in many traditional societies. Fish are also used as medicine by different tribes. Finally fish representation in popular art is widespread in Africa.

Western science may have invented the words "nature", "biodiversity" and "sustainability", but it certainly did not initiated the concepts. Indigenous, traditional and local communities have more or less sustainably utilised and conserved a vast diversity of plants, animals and ecosystems since the dawn of *Homo sapiens*. Furthermore, human beings have moulded environments through their conscious and unconscious activities for millennia, to the extent that it is often difficult to separate nature from culture.

Obviously, any human impact on the environment has not been always positive. Today, the rate at which humans are altering the environment, the extent of that alteration, and the consequences of these changes for biological diversity are unprecedented in human history. These pressures on the environment are due to a combination of increasing population, increasing per capita consumption, and inappropriate institutions for managing resources. The pressures are expected to grow and to be further exacerbated as climate change puts additional stress on the world's productive systems.

It is likely that one of the major environmental concerns of the next decades, will be the preservation of biodiversity in the context of sustainable development that is defined as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development implies using renewable natural resources in a manner which does not eliminate or degrade them, or otherwise diminish their usefulness for future generations. The concept of inter-generational equity (our responsibility towards future generations) is one of the central issues of the concept of sustainable development. Briefly speaking we have to transmit to the next generation what we received has heritage.

Biodiversity is currently considered an heritage for human societies. "Heritage denotes something of value, that is passed from one generation to the next. It is not only material items, but is also things like literature, oral tradition, behavioural customs and other cultural attributes and values" (Skelton, 1997). An heritage is not static. It may be improved by the present generation before being transmitted to the next. It may also be lost or dramatically damaged.

During the last two decades, the interaction between biodiversity conservation and sustainable socio-economic development has been increasingly recognised. Since the now dominant technological culture is often perceived as a major cause of loss of biological diversity, there is a serious interest in understanding how diversity of human cultures relates to the conservation of biological diversity, and whether the attempts to conserve biological and cultural diversity go hand in hand.

In this paper two main aspects will be considered :

1- The present day composition and distribution of the African ichthyofauna are the results of a long and complex history, during which speciation and extinction processes interacted with climatic and geological events. Biological diversity is therefore the product of a long term coevolution between fish species and their aquatic environments. It is our **biological heritage**.

2 - Any given human group may possess a wealth of culturally transmitted behaviour in this context. Such groups possess a variety of practices apparently leading to sustainable use of a wide range of biological resources and conservation of biological diversity as a whole. These include total protection of certain biological communities or species; protection of certain life history stages; restrictions on methods and amounts of harvest; and restriction of access to certain localities to certain groups or individuals.

This cultural biodiversity which is also the product of a long term co-evolution between societies and their environment is our **cultural heritage**.

1 - The biological heritage

1.1 - Composition of the African fish fauna

About 76 families have been recorded (including those with brackish-water species), with some 2,900 described species. However, given that many undescribed species are known to occur in the large Rift Lakes, as well as in some areas which have not been carefully investigated, the total number is probably over 3,000.

27 out of 76 families, are primary division fishes and represent 50% of the recorded species. Another 38% belong to the 2 families of secondary division fishes, of which the cichlids alone represent around 30%. The remaining 12% belong to 47 families of the peripheral division (Lévêque, 1997).

The total number of freshwater fish species in Africa is similar to the number of fish estimated for South America. However, the African ichthyofauna is more diversified than the South American one.

1.2 - Why are there so many primitive families in Africa ?

The modern African freshwater fish fauna was apparently already differentiated by the mid-Jurassic, when Gondwanaland broke up. One might therefore expect that representative of the different fish families were present on the main drifting sub-continents, and that they evolved by vicariance after the isolation. Indeed, some families with few species have a world wide distribution. One intriguing question is therefore why are there so many phylums and why so many living primitive fish groups are only represented in Africa ? Actually, the African fish fauna is characterised by a high number of families presently endemic to the continent which includes 14 of the 27 primary freshwater fish families (tabl. 1). They are probably among the most ancient families of fish.

Table 1. The endemic fish families of Africa.

POLYPTERIFORMES
Polypteridae
OSTEOGLOSSIFORMES
Pantodontidae
MORMYRIFORMES
Mormyridae
Gymnarchidae
CLUPEIFORMES
Denticipitidae
Congothrissidae
GONORHYNCHIFORMES
Cromeridae
Phractolaemidae
Kneriidae
CYPRINIFORMES
Hepsetidae
Citharinae
Distichodontidae
SILURIFORMES
Amphilidae
Malapteruridae
Mochokidae

One of the reasons for this exceptional phylogenetic diversity may be that the African continent has been at least partially exundated since 600 Myears ago, though large areas such as in the Sahara, Somalia and Ethiopia were at some time inundated by the sea. This long period of exundation may explain why Africa has a far more diverse fish fauna than South

America, and an unparalleled assemblage of archaic families, mostly endemic, that has evidently been there for a long time.

Few selected examples will illustrate the present situation in Africa. A first category includes African fish families exhibiting a world wide distribution, as a result of their Gondwanian origin. That is the case for the Osteoglossidae which includes today different genera living in Africa (*Heterotis)*, South America (*Arapaima* and *Osteoglossum*) and Australia (*Sclerophages*), while fossils osteoglossids have also been found in Asia, Australia and North America (Greenwood, 1973). Another example is provided by the Dipnoi which are the most archaic group of living bony fishes which originated in the Lower Devonian. Among the lungfishes, the family Protopteridae includes the four African species of *Protopterus* and the single species of *Lepidosiren* from South America. The related family Ceratodidae has a living representative in Australia (genus *Neoceratodus*), but many fossil lungfishes could be referred to this family which once had a much wider distribution.

Special mention has to be made of the cichlids, whose natural geographical distribution conforms to an essentially Gondwana pattern : Africa, Madagascar, Central and South America, India. According to estimates, 80 % of all Cichlid species are to be found in African freshwaters, the great majority being represented by lacustrine taxa. There are no comparable lacustrine biotopes and radiations in the Neotropics (Stiassny, 1991). The African cichlids (excluding *Heterochromis*) and Neotropical cichlids are sister groups (Stiassny, 1991).

Table 2. Intercontinental affinities of African fish families

Families	**intercontinental affinities**
Characidae	South America
Osteoglossidae Lepidosirenidae	South America & Australia
Cichlidae Nandidae	South America & Asia
Notopteridae Channidae Anabantidae Mastacembelidae Bagridae Schilbeidae Clariidae	Asia
Cyprinidae Cobitidae	Eurasia

A second category is represented by several families or phylums which have a distribution restricted to Africa and South Asia : Clariidae, Bagridae, Schilbeidae, Notopteridae, as well as bariiline and Mastacembeloidei (table 2).

However, a third category includes many other families (table 1) all endemic to Africa and probably, for many of them, date back to the early Mesozoic. Why did they do not occur in South America and/or Asia ? There is certainly not a single answer. Some of them probably differentiated after the drifting of continents. Another reason may be that families became extinct in other continents after separation of the continents. That could be the result of competition but past climatic and geological events were undoubtedly also responsible for extinctions.

Reconstructing phylogenies and past distribution is a difficult task which relies on the existence of fossils. In the absence of fossil records, there are no proofs that fish families were at some time present on other continents. But, meanwhile, the absence of fossils is not a proof that they were not present. Simply, fossils may have not been discovered yet. The discovery of fossils may deeply modify

our knowledge of the phylogeny of fish. Recently, remains of Polypteridae have been found in Paleocene levels of Central Bolivia (Gayet & Meunier, 1992). The family Polypteridae which was considered for a long time as endemic to Africa is therefore not and had in the past a more wider distribution. Gayet (1982) also reported Cypriniform-like remains from the Upper Cretaceous of Bolivia, but until now little emphasis has been given to these findings. *Molinichthys inopinatus*, is the only specimen of a Cyprinid recorded from South America, and the oldest known in the world. It is assumed to be a plesiomorph form, and that may lead to a fundamental reconsideration of the phylogeny of this family. No doubt the question of the origin of cyprinids will initiate other debates in the future. This finding may support the hypothesis of a pre-drift origin of cyprinids and weaken the hypothesis of Asia as a centre of speciation.

1.3 - East African lakes are unique natural laboratories for the study of speciation

The most striking feature of the fish of the East African Great Lakes (Victoria, Tanganyika, Malawi), is that each has its own highly endemic lacustrine Cichlid fauna which apparently evolved from a riverine ancestral stock. The term "species flock" is used to refer to those monophyletic groups of closely related species coexisting in the same area (Greenwood, 1984). In Lake Malawi, several cichlid species flocks have been identified as well as a flock of 10 species of the catfish *Dinotopterus*. Lake Victoria and Lake Tanganyika cichlid species flocks are also well known. In the latter lake, flocks of Mastacembelid (7 species), of the Bagrid *Chrysichthys* (6 species), of *Synodontis* (7 species) and *Lates* (4 species) also exist. It should be stressed that Africa has a greater variety of fish species flocks than any other continent.

The explosive speciation of cichlid fishes in the African Great Lakes has intrigued biologists for many decades. Different hypothesis have been proposed to explain the high frequency of speciation events that must have occurred : multiple invasions, lake fragmentation, stenotopy, etc... (Coulter et al., 1994; Fryer, 1996; Lévêque, 1997; Nishida, 1991). This rich fauna is a unique opportunity to study such matters as convergent evolution in different lakes, the nature of isolating mechanisms, adaptive radiation, and more generally the patterns of speciation.

The question of sympatric speciation has been a mater of controversy during the last decades and it has been widely discussed in relation to the African Great Lakes cichlids. For a long time the conventional wisdom was that sympatric speciation don't happen. New species formed only after two populations were separated by a physical barrier. However, studies conducted in African lakes provided good support to the theory of sympatric speciation. The case for sympatry is now so strong that the debate is less over whether sympatric speciation can take place than over how often and under what conditions. Works on African fish contributed to promote this hypothesis. Recently, Seehausen *et al.* (1997) showed how sexual selection could be the driving force behind speciation in the Lake Victoria haplochromine cichlids, because mate choice of females for differently coloured males maintains reproductive isolation between sympatric species and colour morphs. Females have a strong preference for males of a particular colour when light conditions are sufficiently good. The increased turbidity of the water owing to human activities is causing a breakdown of reproductive barriers. Females can no longer distinguish males of sibling species from their own when visibility is poor and hybridise with males from other species.

In addition to Great African Lakes, two examples of sympatric speciation are particularly convincing.

1- The data of a mitochondrial DNA analysis conducted by Schliewen *et al.* (1994) on cichlid species flocks endemic to the crater lakes Barombi Mbo (11 species) and Bermin (9 species) in Cameroon, suggest that they evolved within each lake after a single colonisation event. The size

and shape of each lake is such that subsequent diversification would have been sympatric - there are no discernible microgeographical barriers within these lakes which would have allowed separation of microallopatric subpopulations. Schliewen *et al.* (1994) noticed that the different fish have different diets - small cichlids feed on zooplankton while larger ones feed on insect larvae or fish. They postulated that the genetically based food preferences separated the first cichlids in the lake and led to different sizes. Therefore, trophic diversification alone may have been a key factor responsible for speciation after colonisation of these small, ecologically monotonous crater lakes.

2 - In Lake Tana, Nagelkerke *et al.* (1995) hypothesised that intralacustrine speciation had occurred among the large barbs and possibly is still going on. The different barbs morphotypes (at least 14 distinct morphotypes) prefer different habitats, as characterised by water depths and substratum types, which are not randomly distributed over the lake. Nagelkerke & Sibbing (1996) hypothesised that the only way that genetically based morphological differentiation could have become fixed is, at least partially, by assortative mating. Actually, there is a significant temporal or spatial spawning segregation or a combination of both, among the morphotypes. Some barbs spawn in the lake itself, or in the river mouths, while other migrate upstream for example. Lake Tana barbs probably constitute the last living cyprinid flocks after the Lake Lanao flock has been eradicated.

To summarise, the fish biological heritage in Africa is characterised by :
- a high number of species,
- a high number of old, archaic families,
- rich and diverse species flocks,
- a diversity of life history styles and behaviour,
- the existence of natural laboratories where it is possible to study speciation mechanisms and evolution at work.

One question may be raised : is Africa the continent where many of the Gondwanian phylums were able to survive while becoming extinct in many of the other continents ? In other words is Africa the last continent for several freshwater fish families ?

2 - Cultural heritage

Over many generations, a close relationship between human culture and environment has developed, including a large body of traditional knowledge about natural ecosystem functioning and responses to various uses. Local peoples amassed an extraordinary store of knowledge about the local natural resource base. As a result, many societies have developed complex management pattern for biological resources, and this local knowledge may yield new ideas about the conservation and management of natural resources.

2.1 - Fish as a biological resource

Fish catches in African inland waters amount 1 600 000 tons. Maximisation of yield has highest priority in developing countries with expanding populations and increasing food requirements. One of the major threats to the unique species flocks of ancient lakes are overfishing and introduction of new fishing practices (Lévêque, 1997). Technological innovations must have played a major role in affecting the patterns of resource use by human populations and they would thus tend to favour non-conservative use of biological resources.

• Species introductions

Species introductions are a long standing management practice in aquatic environments. Among the many reasons to perform introductions, nostalgia of displaced peoples for familiar fauna to surround them would seem to rank fairly highly (Welcomme, 1988). Many of the earlier movements of fish species may have been on this basis, even though they were seemingly irrational in that adequate local species already existed or that the species was poorly adapted to its destination. Several species such as *Salmo trutta* (from Europe) or *Micropterus salmoides* (from

North America) have been introduced for sport fishing in Africa.

The introduction of species in lakes to improve fish production relates to another type of culture: the culture of fishery officers which is strongly influenced by north European science. The focus is to increase production of proteins to provide food to local populations. There were so-called economic successes in introducing fish species in new aquatic environments. One of them is the introduction of two small Clupeids, the Tanganyikan sardines *Limnothrissa miodon* and *Stolothrissa tanganyikae*, in Lake Kivu and in Lake Kariba where a successful fishery has been established.

However, there were also so-called ecological catastrophes, the most well-known being the introduction of the Nile perch in Lake Victoria which resulted in the disappearance of many endemic haplochromines (see for instance Witte *et al.* 1992; Lévêque, 1997). In the early 1980s the impact of the introduced *Lates* upon the indigenous fish fauna was considered an ecological and conservation disaster (Coulter *et al.*, 1986; Ligtvoet, 1989). It was later recognised, that the haplochromine stock was already affected by fisheries before the establishment of *Lates*, and particularly by unregulated fishing or by trawling techniques introduced in the Tanzanian part of the lake (Ogutu-Ohwayo 1990). The Lake Victoria ecosystem is currently unstable and changes in the flora and fauna could also be expected as a result of a process of eutrophication (Hecky & Bugenyi, 1992). Lake Victoria is now invaded by water hyacinth, and the remaining fish fauna is therefore more an more threatened. There is little hope of restoring the original fish species diversity. The future of both remains uncertain.

• Aquaculture

Although aquaculture is of considerable antiquity, especially in the Far East, there is apparently very little tradition of fish culture in Africa, despite considerable efforts from many bilateral or international agencies to promote fish farming. Many tilapine species, originally endemic to Africa, are now firmly established in warm-water aquaculture throughout the world, and have been compared to "aquatic chickens". However, while the world production of tilapines amounts several hundreds thousand tonnes, production in tropical Africa (excluding Egypt) only amounts some 10 000 tonnes. The major obstacle to development of fish culture in Africa seems to be social not technical. African colleagues should probably be more prepared to identify the main causes of what may be considered as a "blocking". However, the result is there : fish farming is still in its infancy in Africa compared to Asia, while many fish species such as tilapines or the catfish *Clarias*, *Heterobranchus* and *Chrysichthys* are apparently good candidates for aquaculture.

• Biomanipulation of natural systems

Biomanipulation is a rather recent word in the scientific literature. However, fishermen knew for long time how to increase productivity in freshwater systems. Actually, catches from fisheries based on wild stocks are supplemented by traditional indigenous technologies designed to increase fish production. The acadja brush parks of Benin (Welcomme, 1972) (Fig. 1 and 2), the garse system in Benue (Stauch, 1966) (fig. 3), the hoshas of Egypt. The accumulation of branches in shallow areas favours concentration of fish by increasing production of natural food. In Benin, natural productivity in acadjas range from 5 to 10 tonnes ha^{-1} yr^{-1}, while the usual catch in non manipulated coastal lagoons is only 200 kg ha^{-1} yr^{-1}.

• Fishing methods and fishing gear (technoculture)

All around the world, indigenous people show remarkable ingenuity in fashioning any material that is to hand into something which will do for a fishing boat. Around Lake Chad and Lake Victoria for example, people built papyrus canoes which resemble those of ancient Egypt (Fig. 4 and 5). Each is composed of

hundreds papyrus stems fixed together with rope also made of papyrus. When papyrus is not available, leaves of palm trees may be used. On other lakes such as Lake Baringo (Kenya), the material consists of desiccated branches of the ambatch tree which festoon the shores (illustrated in Worthington & Worthington, 1933).

Figure 1 and 2. The acadja system in Lake Nokoue (Benin). (Photo by C. Lévêque, 1981).

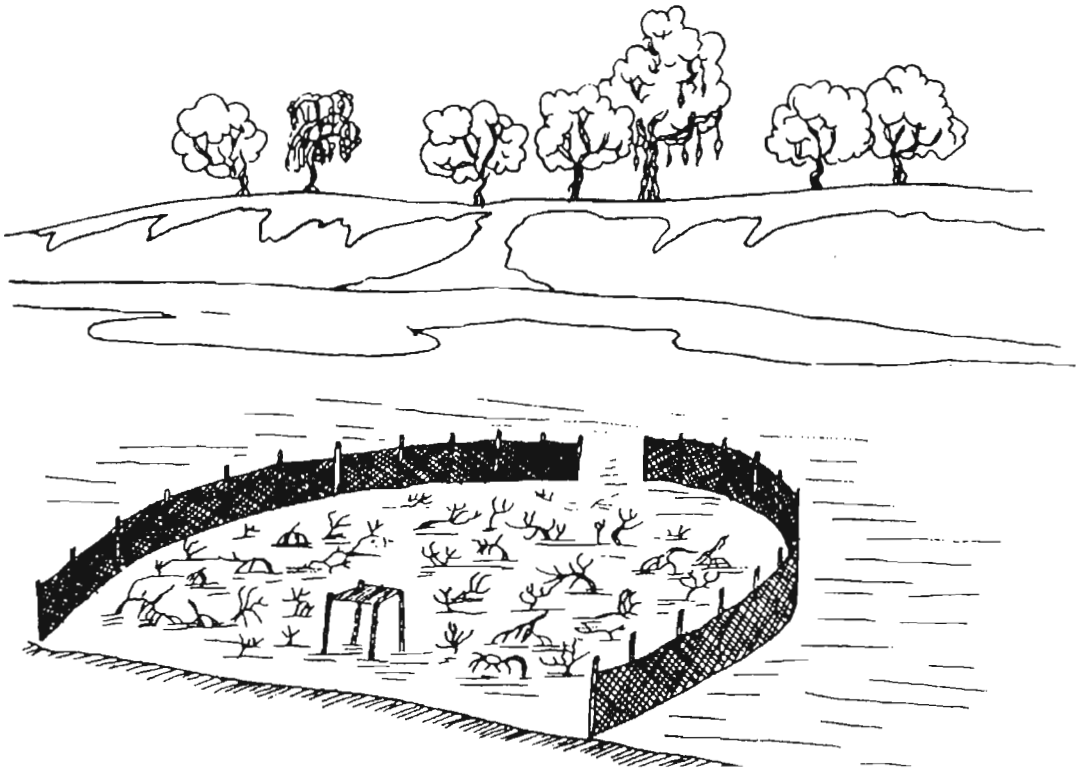

Figure 3. An equivalent of the acadja system in floodplains : the garse system in Benue (Cameroon) (from T. Monod, in Stauch, 1966).

Figure 4. Fishermen camp along the side of an island in Lake Chad (Photo by C. Lévêque, 1967).

Figure 5. A « Kadei », a papyrus boat built by fishermen on Lake Chad (Photo C. Lévêque, 1967).

Most African fishermen have accurate and rather objective knowledge of fish. There are many vernacular names given locally to fish, and sometimes to different stages of their life-cycle. That is the result of a daily activity which needs an holistic knowledge of fish and their habitats, behaviours, biology, etc..

Until the middle of this century, African inland fisheries were traditionally pursued with a variety of locally fabricated gear such as baskets, spears, seine nets, etc., Traditional fishing methods, ranging from simple harpoons to basket-work fish traps, are typically selective for both size and species and are adapted to the diversity of fish capture possibilities under particular environmental conditions. The huge diversity of fishing gear which has been developed over centuries, should be considered as a technical and cultural heritage which is rapidly disappearing. With the introduction and spread of new fishing technologies, many traditional practices became extinct. It is out of scope to review here the numerous fishing methods and fishing gear that have been used in ancient lakes. However, a few examples will illustrate the rich patrimonial knowledge in that field.

- At the beginning of the century in East Africa, were many of the diverse kinds of fish require special methods for their capture, the fishermen of the Lake Albert shores used fishing methods which mimic the food-webs observed in the lake (photograph in Worthington & Worthington, 1933). There is a tiny cichlid fish in Lake Albert, *Haplochromis albertianus*, which live in the bottom ooze and feed on detritus and dead plankton. This fish serves as food for the tiger-fish which, in turn, is eaten by the Nile perch. Lake Albert fishermen make bundles of grass or brush-wood, weight them with stones, and laid them at the bottom at a depth of 10 to 15 m. The little *Haplochromis* seeking shelter from the tiger-fish on the bare sandy bottoms, worms himself into the bundles. Every mornings,

fishermen haul up the bundles and extract the little fish. *Haplochromis* are fixed to a little barbless hook and are dangled still alive over the side of the canoe until a tiger-fish gulps it as it swims near the surface. The tiger-fish is then hauled in the canoe, affixed in its turn to a big barbed hook and allowed to swim away on the end of a stout rope. The great Nile perch gulps the tiger-fish and finds himself impaled by the sharp hook.

- In many places, fishermen take advantage of the reeds to built fishing gear. The *ngogo* of the Jaluo (Lake Victoria) (illustrated in Worthington & Worthington, 1933) is an enormous apparatus designed for fishing water near the shore. It resembles in some respects to a beach seine, but the " net " consists of a vertical fence made of innumerable papyrus stalks lashed together by plaited papyrus rope. The fence is about eight feet deep and two to three hundred yards long, a big work which occupies many men for many days.

- In lake Tanganyika, native fishermen (Bwari) have taken advantage of the powerful attraction of light to fish the Tanganyika " sardine ", or Ndagala (in Swahili). There was originally a brushwood fire on a platform in the bows of the canoe. Before 1937, 5 meter torches made of grasses were used. Attracted by light, the sardines swarm around the canoe and they are caught with very large fine meshed scoop-nets mounted on long poles called " lusenga " (Collart 1954). These light attraction is known from centuries, and in the old times, it was a unique scene to see the lights of hundreds of fishermen fishing Ndagala at night. Large dug out canoes were used (6 to 7 meters long). This technique has now been modernised by the introduction of kerosene vapour lamps since 1956, and large ring-nets are used.

After the Second World War, the introduction of nylon ensured the nylon gillnet's pre-eminence in most African fisheries. Later, in the 1960s, mechanised fishing and trawling were developed in the East African Lakes. Commercial gear often has a by-catch of unwanted species which has contributed to the overexploitation of resources.

Ribbink (1987) stressed the fragility of the cichlid communities endemic to the African Great Lakes when faced with the introduction of new fishing gear. Demersal trawl surveys have shown that fish communities in the most heavily fish areas in the south of Lake Malawi have been severely disrupted by trawlers; three large haplochromine species have been eliminated and further eight show statistically significant declines (Turner 1994). A number of authors have also recorded the effects of overfishing in Lake Victoria, from the decline of some species to the virtual disappearance of others and the history of the fishery has been briefly reviewed by Barel *et al.* (1991), Witte *et al.* (1992) and Craig (1992). According to Coulter *et al.* (1986), the collective experience in recent years on the African Great Lakes, seems to show that large scale mechanised fishing is incompatible with the continued existence of the highly diverse cichlid communities. Cichlids appear especially vulnerable to unselective fishing because of their particular reproductive characteristics.

Lake Tana is one of the few African lakes that have not yet been to much damaged by human activities. There are no introduced fish species or major sources of pollution. However, a European Union project has been implemented to develop fisheries. Fishing grounds have extended significantly during the last years, and fishermen take their largest catches at or near the spawning grounds at the mouths of the large rivers, taking mostly large ripe barbs. To prevent this unique species flock, measures must be initiated before another ecological crash occurs (Nagelkerke *et al.* 1994).

2.2. Social aspects of fisheries

The Traditional Ecological Knowledge as it has come to be called, is encoded in symbols, cognitive categories and languages that we may find hard to understand. In fact, effective in situ conservation depends not only upon use of local knowledge, but also upon effective control of land and resources by indigenous and local communities.

It has been claimed for long time that rational fisheries management is the only universal solution for a sustainable use of fish stocks. Most policies derive from the concepts of equilibrium population dynamics and stock assessment, and aim to achieve a level of fishing effort at which the stock or population is conserved at its level of maximum yield. "Although the principle of Maximum Sustained Yield has frequently been challenged, it is still *de facto* accepted as one of the main bases for management. Despite the apparent capacity to determine the levels of effort or access needed to conserve fish stocks, there as been an almost universal failure to do so. This failure may lie in part in the shortcomings of scientific advice, but for the major part lies in the difficulties of applying coherent management strategies for political and sociological reasons" (Welcomme, 1992).

Actually, the fisheries management principles that have prevailed during last decades were not very successful. Modern science seems unable to halt and reverse the depletion of resources and the degradation of the environment. Resource management has not been designed for the sustainable use of resources, but for their efficient utilisation as if they were boundless. As a consequence, efforts at central fisheries management in Africa over the last few decades have not been particularly cost-effective and serious consideration needs to be given to re-instating community-based, traditional-type management structures. Traditional community-based resource management systems have recently became of major interest to international organisations (UNESCO, FAO, IUCN). Where local communities of fishermen can control access to fishing space and enforce regulations, exploitation levels can be managed, and this is an essential condition for sustainable exploitation (Berkes & Kislalioglu, 1991).

What can we learn therefore from traditional management practices ? Can we identify some traditional practices which could replace the current inappropriate management practices ? Should new management systems be based on the resource management techniques of the industrialised countries or should they be developed by rehabilitating and adapting "indigenous" resource-management systems and upgrading traditional local-level institutions ? Is there any way to integrate scientific and traditional management systems ? These are the central questions to be answered in order to propose development models that take care of the environment and serve the needs of the people who use the fish resource. This is a really new challenge because, until recently, scientists and policy-makers knew little about traditional management systems and accorded them little credibility.

- ***Lessons from traditional community-based management***

It appears that there have been human groups whose interests were strongly linked to the prudent use of their resource base, who have evolved appropriate conservation practices. These practices were based on some simple and approximate rules of thumb that tended to ensure the long term sustainability of the resource base. There was probably a process of trial and error, with the continual acceptance of practices which appear to keep the resource base secure, coupled with the rejection of those practices which appear to destroy the resource base.

Pliya (1980) reviewed changes in the management of continental fisheries in Benin over the last century. Before the colonial period, access to water and fishing was controlled by religious authorities and the lakes were common properties of the villagers. There were many social prohibitions, religious beliefs, and local customs, the result of which was to forbid the use of some gear, to forbid access to some areas that were usually sacred places and to protect areas locally important for reproduction. Thus, the traditional society developed a set of social mechanisms that resulted in wise use of the common resource. During the colonial period, from the beginning of the century up to 1939, changes in social structures weakened the traditional authority in favour of central administration. But the "Eaux et Forêts"

service did not provide any legislation, and progressively the traditional rules were infringed. This resulted in an anarchic development of the fishery, rapidly leading to conflicts and over exploitation. After 1939, during the end of the colonial period and the beginning of independence, there were various attempts to improve the role of the Fishery Service. In favouring this service, the Government continued to weaken the traditional authorities that controlled the common property of water bodies and its management. The Government also recognised the private ownership of some water systems. In general, this was a dramatic failure, resulting in the late 1970s in the absence of any control. That gave rise to social conflicts and to the proposal by fishermen that traditional management should be rehabilitated. So, presumably, the anarchy continues but the administration apparently did not heed these proposals.

More or less similar trends were observed in Côte d'Ivoire (Perrot, 1989; Verdeaux, 1986, 1989) where the crash in the fish production of the Ebrie lagoon in 1982, is another example of the mismanagement (or absence of management ?) of the fishery. Until the early 20th century, the fishing organisation in such coastal lagoons, and the control exerted on the environment, lay in the hands of decentralised and self-governing lineal powers which regulated fishing activities. The adequacy of the regulation was secured by religious interdicts, each collective fishing ground being under the authority of deities. The period 1935-1982 was characterised in the Ebrie lagoon by a shift from collective ownership to individually appropriated means of production, and the use in the 1970s of gear (e.g. large seine nets) responsible for the overexploitation of the fish stock. Reinstatement of the traditional management systems would probably ensure social order and the preservation of the abundance of the resource.

In the Middle Niger valley (Mali), the political organisation of space includes traditional inherited authorities and gives rise to a series of similar "territories" occupied by groups which enforce homogeneous regulations (Fay, 1989a, 1989b). Fishing is regulated by "masters of the water" who supervise the use of allowable techniques, set opening dates for different fisheries, can extend fishing rights to outsiders, and conduct ceremonies for water deities. This political and symbolic organisation has evolved during recent decades as a response to the introduction of new fishing gear which makes sampling homogeneous, and of new powers which have brought a new organisation of space and a new definition to identities and relationships. Thus, the current situation does not amount to a conflict between tradition and modernity.

In the Logone floodplains (Chad), the "Chefs de Pêche" who have jurisdiction over a section of river belonging to a village sector, enforce a ban on fisheries in certain stretches of the river from December until the end of March. Afterwards, they invite villagers and inhabitants of surrounding areas to join in the collective fishing and villagers pay 10% of their revenues to the Chiefs. By maintaining the ban in certain parts of the river until water levels start to rise in April, the presence of spawning fish at the beginning of the flood is ensured. Under this system, overfishing is prevented (Dadnadji & Wetten, 1993).

• ***Towards new resource management practices***

If community controls are eroded, and State controls are ineffectual, the fishery resource is left without a framework to ensure that it is properly managed. With the social and environmental changes that are now underway, some kind of regulatory mechanism is more important than ever. There is a need to develop a new resource management science that is better adapted to serve the needs of ecological sustainability.

To be fair however, too much emphasis has probably been given to traditional community-based management systems. They were surely efficient in an historical context but are no longer adapted to present-day situations where increasing

populations, urbanisation, and changes in local and national economies, have led to different social structures and relationships between people and nature. Moreover, traditional management systems were not always very "democratic" and the power of the right owners resulted sometimes in some kind of "exploitation" of fishermen. In North Cameroon, most of the local chiefs (called Lamido) perceived up to 50% of the catch to allow fishing in the areas they controlled (Stauch, 1966).

Nevertheless, we have to learn from the diversity of traditional resource management practices and systems if we want to achieve the task of reconstructing this new resource management science so that it is better adapted to the real world. However, rejection of the monolithic scientific vision of resource management does not mean overall rejection of science. Freshwater ecology is in a unique position to be the cornerstone of a new science of resource management, that synthesises the best of the old and new wisdom towards a more sustainable future.

The precautionary principle emphasises growing awareness that fisheries management cannot be seen in isolation and must fit an integrated context which satisfies the requirement both for long-term resource sustainability and environmental conservation (Garcia, 1996). It puts the focus more clearly on uncertainty and related hidden costs of present decisions for future generations. It intends to promote fishery practices compatible with the requirements of ecosystems, resources and consumers, and therefore offers a good opportunity to progress towards sustainable fisheries development. It aims at promoting inter-generation equity by reducing the cost of our decisions for future generations.

2.3. Other relations between man and fish

The relation to fish is not limited to fisheries. There are a number of fish treated as taboo in many traditional societies. Several human populations refrain from eating electric catfish while others refuse lung-fish because it resembles a snake. Many refuse scaleless fish. In Central Africa, Lokele people do not eat small Phractolemidae because it has "blood like humans" (Gosse, 1962). For Songola-Enya tribe (Central Africa) most of the 9 taboo fish species are prohibited for nursing women, because they could cause specific illness to their children (Ankei, 1989). That is the case for 5 species of Distichodontidae and Citharinidae with yellow flesh. Crunching a bone of lung-fish, the sole fish that has no rayed fins, was a taboo for adult men. If they do not observed the taboo, they should become impotent. There are also lovely stories : if a non-married Lokele girl eat a butterfly-fish, she will fly with her lover before being married (Gosse, 1962).

Fish are also used as medicine by different tribes. Among Songola-Enya, a tiny fish (Amphilidae, *Belonoglanis tenuis*) is used for men's sexual energy because its flesh is always as hard as a log. Charm medicine made from electric catfish gives you the power of paralysing your enemies and the leather-like skin of puffer fish makes you skin resistant against whisps and blades (Ankei, 1989).

Conclusions

On one hand, African fish and fisheries are a biological heritage of unique value for science which needs to be preserved for ethical, philosophical and economical reasons. On the other hand, human societies developed an incredible number of fishing technics to catch the great variety of fish, as well as social rules to control access to this biological resource in a sustainable way. This original technoculture is rapidly disappearing while usually not well recorded.

Research programmes in relation with a sustainable use of aquatic living resources may focuse intensively on some topics :

- species biology and population dynamics;
- impact of fishing activities on freshwater biodiversity and ecosystem functioning;
- impacts of forecasted climate changes;
- application of the precautionary approach to fisheries;

• community based management of living resources.

There is a future undoubtly for African ichthyology.

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