RIVERS OF THE LOWER GUINEAN RAINFOREST: BIOGEOGRAPHY AND SUSTAINABLE EXPLOITATION

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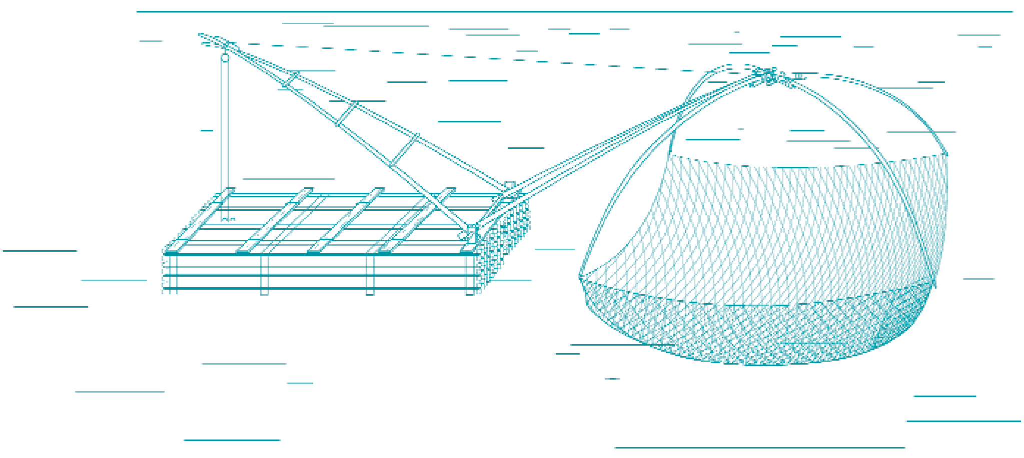


ABSTRACT

The Lower Guinean rainforest of Southern Cameroon, continental Equatorial Guinea, Gabon and the People's Republic of the Congo and its associated biodiversity is being destroyed at a rate of 1 million ha per year by poorly regulated timber exploitation and slash and burn agriculture. An important component of the rainforest is the river that drains it. Although very little studied and poorly understood, these rivers drain over 500 000 km^2 and have been estimated to contain at least 500 fish species, of which a large percentage may be endemic. In the process of deforestation, the fish are being destroyed along with the trees and other wildlife.

Keywords: rainforest rivers, Central Africa, fish biodiversity, sustainable management

The rivers and swamps of the Lower Guinean forest comprise the Lower Guinean ichthyological province and possess different species from those of the Sudano-Nilotic province to the north and the Congo province to the East and South. The icthyofauna of these rivers is dominated by the Siluriformes (6 families, 23 genera, 102 species), the Characiformes (2 families, 20 genera, 62 species), the Cichlidae (17 genera, 54 species) the Cyprinidae (10 genera, 79 species) and the Mormyridae (14 genera, 49 species). Among these are a large number of ornamentals, many of which are rare and unusual, fetching high prices in Europe and North America.

The 8 million people who live in the Lower Guinean forest depend heavily upon the integrity of the river ecosystem for their livelihoods. Estimates from Cameroon put the productivity of capture fisheries in forest river basins at 1.1 tons km^{-2} yr^{-1}. Extrapolated to the entire Lower Guinean forest, this translates into a cash value of over US$1.4 thousand million per year, more than twice the value of all other non-timber forest products combined.

Increasing population and poverty, coupled with false valuations of rainforest biodiversity, have led to unregulated logging, habitat destruction and over-exploitation. In addition, fishing rainforest rivers increasingly involves the use of poisons that are highly destructive of the entire food web. New and diverse natural resource management and exploitation strategies are needed to add value to rainforest river ecosystems to justify their preservation and improve the livelihoods of rainforest communities.

INTRODUCTION

The Lower Guinean ichthyological province (Figure 1) extends in an arc along the NE corner of the Gulf of Guinea from the Cross River in the NW to just short of the Congo in the SE and includes some 50 major and minor rivers (Table 1). It is sandwiched in-between the Nilo-Sudan and Congo provinces. To the west and north, the Cross and Sanaga Rivers form the boundary with the Nilo-Sudan fauna. To the east and south, lies the Congo basin, separated from the Lower Guinean by a series of highlands, terminating with the Chaillu Mountains in the PR Congo. The river systems of the Lower Guinean province drain over 500 000 km^2 of tropical rainforest (Mahé and Olivry 1999), forming an integral part of the rainforest ecosystem.

■ **Figure 1.** Ichthyological provinces of Africa, based on Roberts (1975) as modified by Lévêque (1997) and redrawn according to new hydrological basin mapping published by FAO (2000). 1 = Maghreb, 2 = Nilo-Sudan, 3 = Upper Guinea, 4 = Lower Guinea, 5 = Congo Basin, 6 = Quanza, 7 = Zambezi, 8 = East Coast, 9 = Southern, 10 = Malagasy.

Table 1: Major rainforest river systems in the Lower Guinean icthyological province. Main tributaries are in parentheses. Alternative names are indicated with a slash. Data from: Hugueny (1989), Peyrot (1991a), Vivien (1991), Teugels, Reid & King (1992), Mahé & Olivry (1999).

River	Country	Length (km)	Watershed (km^2)	Discharge (m^3/s)	Number of Fish Species
Cross (Manyu, Mbu, Mé , Mfi)	Nigeria – Cameroon	600	70 000	570	166
NDIAN	Cameroon		>1 000		
MUNGO	Cameroon	200	4 570	164	32
Wouri (Dibomba, Makombé , Menoua, Nkam)	Cameroon	470	11 500	308	51
Sanaga (Djerem, Lom, Mbam)	Cameroon	1 043	131 000	2 072	124
Nyong (Mfoumou, Ké lé , So'o)	Cameroon	520	27 800	443	107
KIENKé /KRIBI	Cameroon	130	1 100		
LOBé	Cameroon	130	2 305	102	32
Ntem (Kom, Nlobo, Mboro. Mvila, Mvini)	Cameroon	460	26 300	290	110 +
RIO MUNI (MBINI)	Equatorial Guinea	365			
MITé Mé Lé	Equatorial Guinea				
Gabon (Mbé , Komo)	Gabon				
Ogooué (Abanga, Ayina, Dilo, Djoua, Ikoy, Ivindo, Lassio, Lé biri, Lekedi, Lé koko, Lé koni, Leyou, Lolo, Liboumba, Mounianzé , Mpassa, Mvoung, Ngounié , Nouna, Nsyé , Offoué , Okano, Oua, Sé bé , Wagny, Zadié)	Gabon	920	205 000	4 400	185
NKOMI	Gabon				
Ngové	Gabon				
Ndougou	Gabon				
MOUKLABA/NYANGA	Gabon				
Kouilou (Bouenza, Lé kourmou, Loué ssé , Mpoukou, Niari)	P.R. Congo	605	60 000	700	87

In addition to some 8 million people, the rainforest harbours the greatest biodiversity on the continent: 400 mammal species, 1 000 bird species and over 10 000 species of plant, of which some 3 000 are endemic (CARPE 2001). An integral part of this rainforest is the systems of swamps, creeks and rivers that drain it. Except for incomplete lists of species generated by European explorers and tropical fish fanciers, practically nothing is known about the ecology of these aquatic ecosystems. Without even clearly knowing what might be lost, a combination of human population growth and unregulated exploitation of rainforests for wood and bushmeat now threatens the integrity of this ancient ecosystem.

MATERIALS AND METHODS

Since September 2000, WorldFish Centre has been working with rainforest communities in the Lower Guinean ichthyological province of Southern Cameroon. In partnership with the Institut de Recherche Agricole pour le Développment (IRAD) a number of biological studies have been carried out on biodiversity, reproductive seasonality, sexual maturation and feeding habits of the ichthyofauna of the Nyong River. With the collaboration of the Ministere de l'Elévage, des Pêches et des Industries Animales de Cameroun (MINEPIA), additional work has been done on exploitation strategies and a needs assessment of fishing communities on the Ntem River. This latter particularly focused on the role of women in aquatic resource exploitation.

In addition to these academic studies, efforts are underway to organize fishing communities on the So'o, Mungo (Moliwe) and Ntem Rivers in an effort to improve the efficiency and sustainability of river exploitation and management. Groups have been formed by the villages themselves and these have acted as the interface between WorldFish Centre, the Government of Cameroon and the local population. These groups have identified ecotourism and exporting ornamental fishes as high priority activities.

The ultimate goal of this work is to establish functional village-based monitoring and management programs that would ensure the sustainability of new and diversified natural resource exploitation. As background to this effort, WorldFish Centre undertook an extensive survey of existing knowledge on the rainforest river ecosystem, its current uses and threats to its integrity. This paper reports the outcomes of this research and uses the documented perceptions of current resource users within the province to identify needs and indicate the direction for further work.

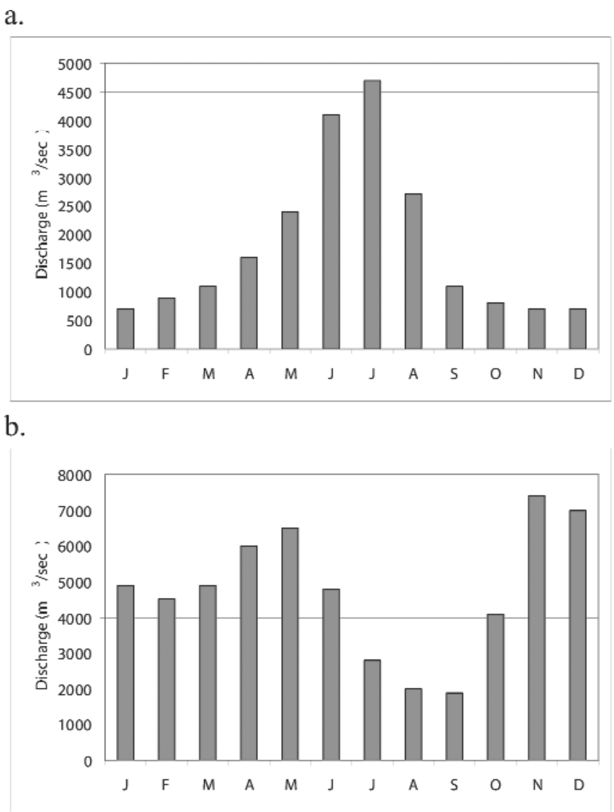
RESULTS AND DISCUSSION

Unlike the uplifting and rifting that affected eastern and southern Africa during the Miocene, the river courses in central Africa are extremely ancient, having not been substantially disrupted since the Precambrian (Beadle1981; Peyrot 1991a). Evidence reviewed by Lévêque (1997) seems to indicate that, at some time prior to the Miocene, there was a much greater overlap in African fish distribution than is currently the case. The Lower Guinean ichthyological province corresponds closely with the extent of humid forest refugia during the last dry phase of the continent, 20 000 – 15 000 years bp (Maley 1987; Schwartz 1991) and is similar to the distribution pattern of aquatic molluscs in the region (van Damme 1984). It seems likely that a more broadly distributed group of archaic taxa related to the modern species in the Lower and Upper Guinean provinces were repeatedly and/or progressively isolated during the several dry phases that reduced the extent of rainforest between 70 000 years bp and the present (Lévêque 1997).

In general, the aquatic resources of the Lower Guinean province are "blackwater" rivers, with a mean pH between 5 and 6 and electrical conductivity between 20 and 30 µS/cm. Water temperature is always between 20 and 30° C. The water in these rivers is clear and tea-coloured as a result of the low dissolved nutrient concentration, low light (due to narrowness of valleys, canopy cover and often cloudy skies) and the large amount of allochthonous vegetative matter that falls or flushes into the water from the surrounding forest (Welcomme and de Merona 1988).

In terms of hydrology, there are within the province two general types of river: 1) the tropical savannah type to the north (Cross, Mungo, Wouri, Sanaga), which have uni-modal discharge patterns (Figure 2a) and, 2) the 13 rivers that flow out of the present rainforest, which have a bimodal discharge pattern (Figure 2b). In general, the magnitude of fluctuation is greater in the north (up to 8 m on the

Lower Cross), while in the southernmost extent of the province, the partially spring-fed Niari and Nyanga exhibit minimal seasonality of flow (Peyrot 1991b).



■ **Figure 2.** Typical discharge patterns for rivers in the northern part of the Lower Guinean Ichthyological Province represented by the Sanaga River, Cameroon (a), and the southern part represented by the Oogoue River, Gabon (b). Data from Lévêque (1997).

FISH BIODIVERSITY

When defining the currently used ichthyological provinces of Africa, Roberts (1975) noted an empirical similarity in terms of shared species and closely related taxa between the fish diversity of the Lower Guinean and that of the Upper Guinean province of the rainforests of Sierra Leone, Liberia and Côte d'Ivoire. Most ichthyologists seem to accept the general categories defined by Roberts, despite a lack of quantitative examination of the possible historical connection between the two provinces (Teugels, Reid and King 1992, Lévêque 1997).

In a review of West African riverine biodiversity, Hugueny (1989) found a strong correlation between species richness, watershed area and river discharge volume. Using these relationships, one finds that the fish fauna of the Lower Guinean ichthyological province's river systems are disproportionately rich in relation to their sizes (Teugels *et al.* 1992). For example: the Cross River, with a watershed of 70 000 km^2, has an estimated 166 species (1 spp 421 km^{-2}). The Nyong River has a watershed of only 28 000 km^2 and contains 107 species (1 spp 262 km^{-2}). On the other hand, the Niger River, with a watershed of 1 100 000 km^2 has 254 species (1 spp 4 331 km^{-2}). The Bandama, a rainforest river in Côte d'Ivoire with a drainage basin of 97 000 km^2, but with a fauna similar to that of the Nilo-Sudan, has only 95 species (1 spp 1 021 km^{-2}) (Hugueny and Paugy 1995). Even the Congo River with a watershed of 3 550 000 km^2 and a very stable flow regime that has existed for at least 3 million years (Beadle 1981) has only 690 species (1 spp/5145 km^2).

Annex A is a provisional list of the freshwater component of the fish biodiversity of the Lower Guinean ichthyological province. From the available literature, 29 families, 119 genera and 500 species have been identified with some reliability. Apart from the large number of small Cyprinodonts (of which 70 percent are from the genus *Aphyosemion*), the freshwater fauna is dominated by the Siluriformes (6 families, 23 genera, 102 species), the Characiformes (2 families, 20 genera, 62 species), the Cichlidae (17 genera, 54 species) the Cyprinidae (10 genera, 79 species) and the Mormyridae (14 genera, 49 species).

A relatively large percentage of fishes in the lower reaches of rainforest rivers are of brackish water or even marine origin and may occur as far as 300 km upriver (Reid 1989; Baran 2000). For example, the lower 80 km of the main channel of the Ntem River in the Campo-Ma'an National Park of Cameroon contains some 110 species, of which 57 are typically found in brackish water (Djama 2001). Teugels *et al.* (1992) noted that 20 percent of the fishes in the Cross River have marine affinities. These species are not included in Annex A.

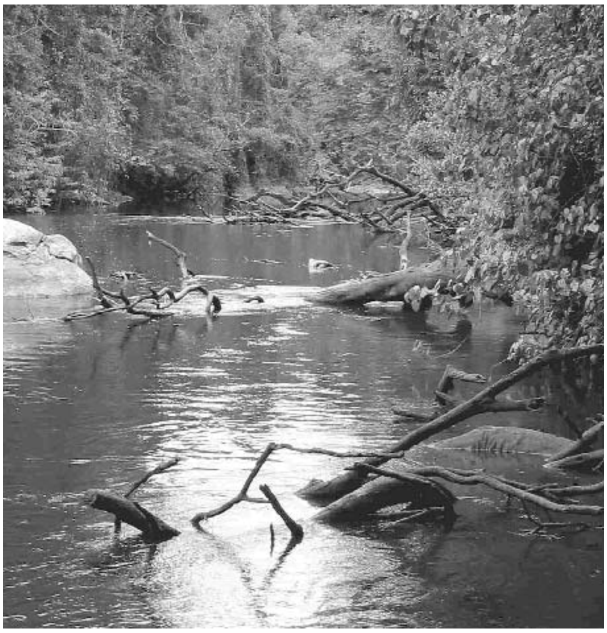
Endemism in rainforest fishes seems to be relatively high (Teugels and Guégan 1994), although it is very difficult from the scanty documentation to determine exactly how many of the single reports for a species are due to endemism, lack of adequate distribution data or simple misidentification (Stiassny 1996). In particular, the Cyprinodontiformes are prone to endemism, with some species occupying only a few hundred square meters of bog, or an isolated creek (Welcomme and de Merona 1988). These small fishes, of which there are at least 100 species in the province, account for a substantial portion of the overall species richness.

In addition, a number of fishes move up and down the river according to their reproductive seasonality. Cyprinids and Citharinids, in particular members of the genera *Labeo* and *Distichodus*, are reported by fishing communities in the Upper Cross and Ntem Rivers of Cameroon to undertake spawning runs during the latter part of the long rainy season (October-December) when rivers are swollen and marginal forests are flooded, providing cover and food for larvae and fry (Lowe-McConnell 1975; du Feu, 2001). The result of this is that species diversity measured over the year changes substantially according to which fishes are moving up or down stream at any particular point in time (Lowe-McConnell 1977).

The high fish species richness in the Lower Guinean province is probably the result of three main factors: 1) the relative stability of the hydrological regime in these rivers since the Eocene (compared to the Nilo-Sudan province), 2) the highly sculpted nature of the watershed (compared to both the Congo and Nilo-Sudan provinces) and, 3) the large number of microhabitats created in rainforest rivers by the forest itself.

Ecological Associations

The forested nature of the watershed is the major determinant of productivity and fish community structure in rainforest rivers. Stream width, depth, current velocity and substrate type have been identified as critical in determining the spatial distribution of most species (Lowe-McConnell 1975; Kamdem-Toham and Teugels 1997). These are all in one way or another, determined by the degree of canopy closure over the river from the surrounding forest. The low primary productivity in rainforest water means that food webs are mostly based on allochthonous plant materials from the forest. The hydrological regime and water temperature are directly influenced by the presence of the forest. The large amounts of dead wood influence depth and current velocity and provide shelter from predation, thus partitioning the stream and creating a large number of microhabitats (Figure 3).



■ **Figure 3.** The So'o river, Cameroon in mid-April 2002 showing the large amounts of allochthonous wood that creates both structure and food producing surface in rainforest river ecosystems. Photo by the author.

Both species diversity and richness increase as one moves downstream from swamp, to first-order forest stream (of which there are a particularly large number in African rainforests) to medium-sized tributary to the main channel, primarily through the addition of species rather than through replacement (Géry 1965; Welcomme and de Merona 1988; Kamdem-Toham and Teugels 1998). Flooded swamp forest, either permanent or annual, is a typical feature of rainforest river headwaters. These contain very low dissolved oxygen and very high carbon dioxide concentrations (pH is in the range of 4-5), but large quantities of allochthonous materials on a substrate of organic mud that generates abundant food for those species with accessory breathing organs or resistance to very low oxygen concentrations. A large number of larval fishes that survive by breathing from the air-water interface use the flooded forest as a nursery making this biotope particularly important to overall ecosystem integrity.

First order rainforest streams are typically <5 m wide, <50 cm deep and are characterized by long stretches of shallow riffle interrupted by deeper, lower-velocity pools into which fish shelter during periodic dry spells when streams stop flowing. Relief in rainforests tends to be low, so current velocity seldom exceeds 0.5 m/sec. Canopy closure ranges between 25 and nearly 100 percent. Substrate is typically composed of leaf-covered sand or gravel.

Medium-sized streams are transitional zones (Lévêque 1997). As one proceeds downstream, they feature decreasing canopy closure, current velocity, allochthonous material and electrical conductivity and increasing depth, fine sediment, large boulders, dissolved oxygen and pH.

The main channel of rainforest rivers is the most stable biotope and offers the greatest range of microhabitats (Welcomme and de Merona 1988). Citing Gosse's (1963) work on the Yangambi portion of the Zaire River, which is broadly similar to Lower Guinean ecosystems and shares a certain percentage of their biodiversity, Lowe-McConnell (1975) noted that, within the main channel, fish species richness and abundance are higher in shallow marginal waters along banks and islands than in mid-river. Gosse developed a "bank coefficient" that relates the length of water-bank contact (including bays, islands, etc.) to species richness. In these areas, sheltered from the main current, abundant aquatic vegetation representing a number of genera (*Anubias, Crinum, Commelina, Limnophyton, Nympahea, et al.*) creates habitats for a wide variety of species and their offspring (Kamdem-Toham and Teugels 1998).

The nature of forest river food webs means that most species rely on carnivory or detritivory of one type or another for survival and growth, planktivory being especially rare. Invertivores are the largest feeding guild in swamps and forest streams, while omnivory and herbivory are more common as one proceeds downstream. In general, fishes with highly specialized diets are more common downstream due to the larger number of specialized feeding niches (microhabitats). Although the high degree of evolutionary adaptation by fishes to the variety of rainforest river habitats means that for every family of fishes there seem to be a species or life-history stage for every habitat, some general trends among family preferences are evident (Table 2).

The Cyprinodontiformes of the genus *Aphyosemion* are typical species of small forest streams, often with very restricted distributions. In rainforest rivers, they are associated with shallower riffles through woody debris, moderate velocity and a closed canopy, abundant leaves on a gravel substrate and dense aquatic vegetation. They have two basic reproductive strategies, either laying eggs directly on or into the substrate, or laying adhesive eggs that stick to aquatic plants and individuals exhibit a certain amount of flexibility between the two (Sterba 1966). They eat mostly insect larvae. Cyprinodonts are

Table 2: General patterns of fish family distribution across habitats and ecological niches within rainforest rivers. Habitats are modified from the system adopted by Lowe-McConnell (1975) based on the categories of Matthes (1964).

Habitat	Detritvores	Planktivores	Herbivores	Invertivores	Carnivores	Omnivores
Main Channel, Pelagic	Alestiidae	Clupeidae Denticipidae?			Alestiidae Centropomidae	Alestiidae Cyprinidae
Main Channel, Benthic	Bagridae			Cyprinidae	Bagridae	Bagridae
Second & Third Order	Citharinidae Cyprinidae Mormyridae			Mochokidae Mormyridae	Gobiidae	Mochokida
Streams Including Marginal-Littoral & Quiet Backwaters of the Main Channel Forest Streams	Cichlidae Citharinidae Cyprinidae Mormyridae	Poeciliidae	Alestiidae Cichlidae Citharinidae Mochokidae	Anabantidae Cichlidae Cyprinidae Mochokidae Mormyridae Polypteridae Schilbeidae	Channidae Malaptururidae Nandidae Notopteridae Polypteridae	Alestiidae Bagridae Cichlidae Clariidae Mochokidae
Swamps	Citharinidae			Amphilidae Anabantidae Aplocheilidae Bagridae Clariidae Cyprinidae Mochokidae Poeciliidae Schilbeidae	Amphilidae Cichlidae Hepsetidae Mastecembelidae	Alestiidae Clariidae Kneriidae Mochokidae
	Clariidae Mormyridae			Anabantidae Mormyridae Pantodontidae Phractolaemidae	Channidae Eleotridae Protopteridae	Clariidae Mornyridae Polypterdae

important forage species, being consumed by a wide variety of carnivorous species. In addition, they have considerable value as ornamentals and have been widely exported by aquarium fanciers.

There are a wide variety of Siluriformes in rainforest rivers, the most characteristic and commercially important as food fish being members of the Bagridae and Mochokidae, particularly the genera *Auchenoglanis*, *Parauchenoglanis* and *Synodontis*. These catfishes live in larger streams where they spend most of their time under heavy cover amongst submerged branches and tree roots under the banks, emerging at night to feed on benthic invertebrates. Little is known about their reproduction, but at least some species move into marginal swamps or weedy areas during high water to spawn.

The Citharinidae and Cyprinidae undertake large-scale reproductive migrations and so vary in habitat over the course of their life cycle. During the latter part of the long rainy season (October-December) large numbers of these fish move from the main channel up into first order streams where they reproduce en masse, leaving their offspring to feed in the forest, while themselves returning downstream. Their lifestyles and diets are extremely varied, ranging from piscivory to herbivory. Although full of bones, the larger species are important as food for human communities.

The Cichlidae tend to prefer smaller streams and quiet backwaters. They represent the entire range of diets from herbivory to piscivory and the juveniles of some species even eat detritus. Their complex social behaviours and vibrant colours make them attractive aquarium fish, but most species are small and they are not common in local fish markets. Cichlids breed year round in shallow marginal areas where the majority provide substantial levels of parental care.

The Mormyridae are well adapted to the variety of habitats available in forest rivers and exist in most of them, but the majority are found in second order streams of moderate depth and current. While some Mormyrids are diurnal shoal feeders, most are nocturnal insectivores probing about in the sediments for larval forms and using their electrical generating ability to navigate and identify conspecifics in the dark. They reproduce during high water periods when flooded swamps are available as nurseries. Mormyrids contribute substantially to the commercial and subsistence fisheries of the forest.

As in other river systems on other continents, juveniles and adults of many rainforest river species occupy different habitats in order to avoid competition and/or cannibalism. In general, adults tend to dominate areas with good foraging opportunities leaving smaller/younger individuals to shallower and swifter habitats where larger individuals cannot reach. Smaller species in general tend to be more specific in their habitat preference than are larger species (Kamdem-Toham and Teugels 1997).

Current Exploitation Systems

Welcomme (1976) estimated the total number of first order rainforest streams in Africa at over 4 million with a combined total length equal to half of all watercourses, making these the largest single riverine ecosystem on the continent. Of the 8 million people who live in the Lower Guinean rainforests, nearly 20 percent are more or less fulltime fishers. Estimates from Cameroon put the productivity of capture fisheries in forest rivers basins at 1.1 tonnes km^{-2} yr^{-1} (du Feu 2001). Extrapolated to the entire Lower Guinean forest, this translates into a cash value of approximately US$1.4 thousand million per year, more than twice the value of all other non-timber forest products combined. Average fish consumption in Cameroonian rainforests is around 47 kg $person^{-1}$ $year^{-1}$, compared to 10 kg for the general population (Obam 1992).

Fishing in rainforest rivers is severely constrained by the large quantities of wood that accrue in the streambed. By far the most common types of gear are passive set nets, traps and hook-lines of which there are a great variety in accordance with the diversity of the fish fauna. Also common, is a hook-and-line fishery dominated by small children and mainly targeting immature cichlids.

Seasonal spawning migrations are reported for a number of species, ("most" according to Lowe-McConnell, 1975). Fishing communities have learned to take advantage of these runs by constructing mesh barriers constructed of tree trunks and branches, bound together by vines and held in place by large stones (Figure 4). At the height of the rains, these structures are submerged and gravid adults pass easily over them. After spawning and spending several months upstream in flooded forests to forage, the adults once again head back downstream. However, by this time the water levels have declined and the fish find themselves trapped when they try to avoid the barrier. Juveniles apparently pass through the mesh without problem.

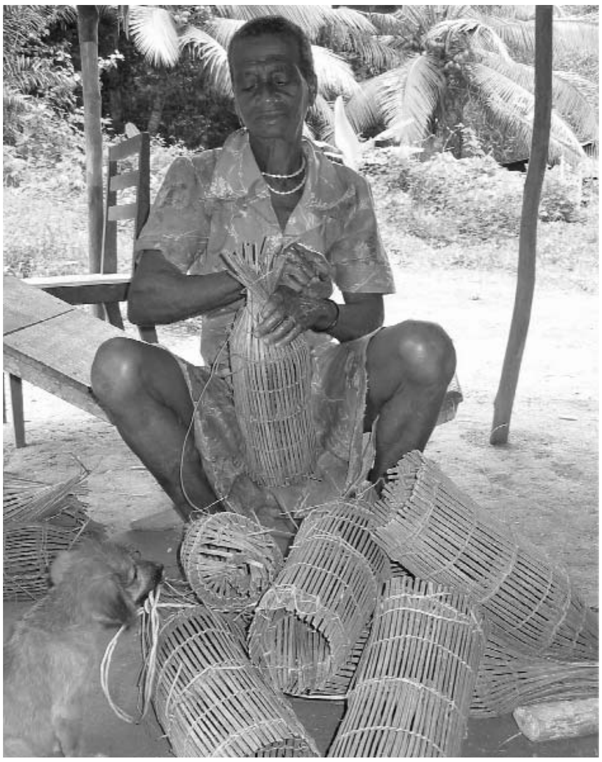
■ **Figure 4.** A traditional fish dam constructed with locally available materials on the main channel of the So'o River, a tributary of the Nyong in South-Central Cameroon. Fish migrating upstream at high water to feed in flooded forests and spawn can swim over the top of the dam. As water levels decline, returning adults are captured while juveniles pass through the mesh.

In Cameroon, a special type of reproductive event, known as the “dok” takes place during the long rains in October-November. Doks involving *Labeo batesii* and *Distichodus spp*. have been documented in the Upper Cross and the Ntem, respectively. They typically last no more than a few hours or days. According to du Feu (2001), who interviewed fishers on the Upper Cross River in Cameroon, the village is alerted to the imminence of the spawning event by the upstream movement of fish. Two hours after the fish have passed, the water turns white with milt, at which time the villagers set nets to block the return of spawned out adults on their return downstream. Men do the fishing with cast nets or even clubs, while women clean and smoke the catch. Eggs are normally not taken to ensure the continuation of the runs for future generations.

There are at least two traditional fisheries that are allocated entirely to women. One involves the construction of small earthen dams across first order forest streams during the dry season to capture small Channids, Clariids and Mastecembelids. As water levels decline, the dams prevent fish from migrating downstream. When the water gets low enough, the women wade in and bucket out the remainder, catching the fish by hand or with the help of baskets. This practice is widespread in both the Lower Guinean and Congo ichthyological provinces and adds substantially to the protein intake of forest communities. Another fishery that is the exclusive domain of women is the use of woven basket traps to catch the freshwater prawn, *Macrobrachium vollenhovenii* (Figure 5).

Village leaders normally regulate access to a fishery. Such management techniques as prohibiting the collection of fish eggs during spawning runs and the prohibition of certain gears are traditionally enforced through the use of magic charms or “ju-ju”. Villagers are free to fish as long at they follow the basic regulations. Visiting fishers, of which there are considerable numbers (an estimated 80 percent of fishers on Cameroonian rivers are of Malian or Nigerian origin) must first seek permission of the village leadership and then pay a token fee, normally in the form of palm wine or a percentage of the catch.

Despite these traditional management systems, over-fishing has become an increasing problem as the human population grows and puts increasing pressure on resources. In addition, the use of fish poisons has become increasingly frequent. Some of these are from local plants and cause only temporary harm, but most poisoners now use Lindane or Gammelin 20, an organochlorine insecticide used in cocoa production and highly destructive of the entire food web. Human deaths have been reported as a result of eating poisoned fish. A recent survey conducted on the Ntem



■ **Figure 5.** Fishing for freshwater prawns (*Macrobrachium vollenhovenii*) using woven basket traps is a traditional activity reserved exclusively for women in the Ntem River Basin.

River just upstream from the Campo-Ma'an Forest Reserve in Southern Cameroon found that insecticide fishing had completely disrupted local aquatic ecosystems and had permitted the extension of the range of the electric catfish, *Malapterurus electricus* into the small rivers where they were previously not found. Because of the powerful shocks emitted by this fish, women have been forced to abandon their traditional dam fishing in the area.

Integrated Watershed Management

The productivity of rainforest river ecosystems depends upon maintaining the integrity of the entire series of biotopes of which it consists. Without the forest, there would be no material inputs that feed the fish in the lower reaches. Without the first and second order rainforest streams, there would be no reproductive migrations and, consequently, the number and diversity of fish would be drastically reduced. Without the main channel system, the overall productivity of the river would be seriously diminished.

Unfortunately, increasing population and poverty, coupled with false valuations of rainforest biodiversity have led to habitat destruction and overexploitation (Stiassny 1996). The Congo Basin has already lost an estimated 46 percent of its rainforest to logging and conversion to agriculture and continues to lose forested watershed at an average rate of 7 percent per year (Revenga *et al.* 1998). In addition, these forests are being harvested in a largely irresponsible manner that not only takes out the valuable timber, but also crushes the under story, alters stream courses and increases runoff and siltation. Roads, saw mills and other infrastructure associated with logging attracts people into the forest, resulting in wholesale transformation of the ecosystem (Burns 1972, Garman and Moring 1993).

Kamdem-Toham and Teugels (1999) described the changes that occur in and around the rainforest rivers in the Ntem River basin as a result of poorly managed logging operations:

- Absence of forest canopy above streams
- Heavy siltation
- Abundant primary production (algae)
- Uniform watercourse; absence of riffles; pools dominant habitat type
- No cover/shelter for fish

In terms of water quality, these changes in habitat resulted in large decreases in water clarity and dissolved oxygen and large increases in temperature and conductivity. In undisturbed sites, water was clear brown with a mean temperature of 23.5°, dissolved oxygen between 2.5 and 4.2 mg l^{-1} (measured at noon) and electrical conductivity between 20 and 30 υS cm^{-1}. In sites affected by logging, the water was cloudy with a mean temperature of 34°, dissolved oxygen of <1.0 mg l^{-1} and average electrical conductivity of 48 υS cm^{-1}. Changes of this magnitude can wreak havoc on aquatic life and may last for many years (Chutter 1969; Growns and Davis 1991).

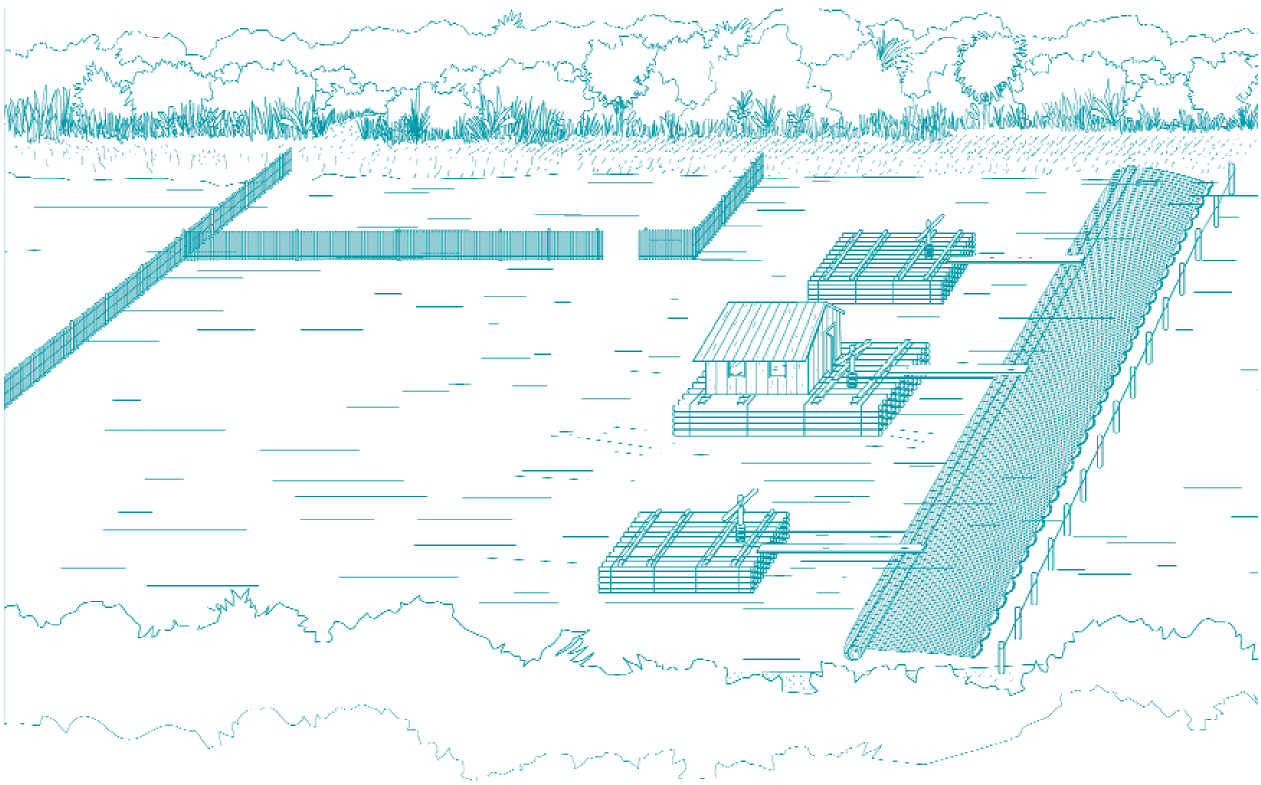
Forestry management practices exist that could substantially reduce the negative impacts of logging (Davies and Nelson 1994; Smith, Brown and Pope 2001). An economic and social re-evaluation of rainforest river fisheries in relation to timber exploitation might encourage changes in current forest management policy (CARPE 2001). However, substantial work needs to be done if the vested interests of politicians and logging companies are to be thwarted.

A first step is the generation of expert systems that can be used to monitor the status of aquatic ecosystems as changes take place in the watershed. Several attempts have been made at the generation of a workable Index of Biotic Integrity (IBI) such as that used to track changes in temperate zone streams, but parameterisation has been a problem. The best effort to date in Central Africa is that of Kamdem-Toham and Teugels (1999), but gaps still exist. Existing datasets on aquatic biodiversity and ecology in Central Africa are weak, at best and this makes it very difficult to develop quantitative tools (Lévêque 1997).

Coupled with this valuation exercise should be the development of improved management and exploitation strategies that could actually increase the value of aquatic ecosystems and justify their preservation, while at the same time improving rural livelihoods. Forest river ecosystems are currently unmanaged and unregulated in any formal sense. The Department of Fisheries in Cameroon does not even have a policy or planned program of work on riverine ecosystems outside of a number of small dams (M.O. Baba, Director of Fisheries, personal communication, Yaoundé, April 2002). The most widely promoted method of increasing the productivity of aquatic ecosystems in Central Africa is to increase fishing pressure through the introduction of subsidies on motors and other fishing equipment and this without any clear idea as to the size of the resource or level of current exploitation.

While some increased pressure might be warranted in some areas, the upper limit for this strategy is probably already in sight for most places. Careful regulation of fishing gear and seasons based on scientific data might be a more widely applicable strategy for increasing catches of certain species in some rivers. In addition, integrated aquaculture in rainforest watersheds could take advantage of abundant water supplies and organic matter and might even be used in stock-enhancement or ranching where feasible or necessary. This might not be exclusively limited to the traditional food fishes. Species with value (both locally and internationally) as ornamental aquarium fishes are unusually abundant in rainforest rivers and fetch much higher prices per kilogram than food fish (Tlusty 2002).

Working with communities to both develop the tools and manage ecosystems might be worth trying (CARPE 2001). WorldFish Centre community based management of aquatic ecosystems program in Bangladesh has produced positive outcomes. Other agencies working in the rainforest, most notably the Centre for International Forestry Research (CIFOR) and the World Wildlife Fund (WWF) have had some success in community forestry management and such efforts need to be strengthened and broadened to include the most valuable non-timber forest product of them all: rainforest fishes.



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Annex A. A provisional list of the freshwater fishes of the Lower Guinean Ichthyological province defined by Roberts (1975) and modified by Lévêque (1997). To compile this list, fish lists from Vivien (1991), Teugels *et al.* (1992), Kamdem Toham & Teugels (1997), Gosse (1999) and FishBase (2000) were compared and rationalized. Species with brackish or marine affinities are not included.

FAMILY	GENUS	Species
Alestiidae	*Alestes*	*bartoni*
		batesii
		jacksonii
		macrophthalmus
		schoutedeni
		taeniurus
		tessmanni
		tholloni
	Brycinus	*imberi*
		intermedius
		kingsleyae
		longipinnis
		macrolepidotus
		nurse
		opisthotaenia
	Alestopetersius	*hilgendorfi*
	Arnoldichthys	*spilopterus*
	Brachypetersius	*gabonensis*
		huloti
		notospilus
	Bryconaethiops	*macrops*
		microstoma
		quinquesquamae
	Hydrocynus	*forskalii*
	Micralestes	*acutidens*
		elongatus
		humilis
	Nannopetersius	*ansorgii*
		lamberti
	Phenacogrammus	*major*
		stigmatura
		urotaenia
	Rhabdalestes	*septentrionalis*
		smikalai
Amphilidae	*Amphilius*	*baudoni*
		brevis
		longirostris
		pulcher
		thysi
	Doumea	*typica*
	Paramphilius	*goodi*
	Phractura	*ansorgii*
		brevicauda
		clauseni
		gladysae
		intermedia
		longicauda
		scaphyrhynchura
Anabantidae	*Ctenopoma*	*garuanum*
		kingsleyae
		maculatum

FAMILY	GENUS	Species
		nebulosum
		nigropannosum
		petherici
	Microctenopoma	*nanum*
Aplocheilidae	*Aphyosemion*	*abacinum*
		ahli
		amieti
		amoenum
		arnoldi
		aureum
		australe
		avichang
		bamilekorum
		batesii
		bitaeniatum
		bivittatum
		bualanum
		buytaerti
		calliurum
		cameronense
		celiae
		cinnamomeum
		citreinpinnis
		coeleste
		cyanostictum
		dargei
		edeanum
		elberti
		escherichi
		exigoideum
		exiguum
		fallax
		franzwerneri
		fulgens
		gabunense
		gardneri
		georgiae
		hanneloreae
		heinemanni
		hera
		herzogi
		hofmanni
		jorgenscheeli
		kekemense
		kouamense
		lamberti
		loennbergii
		louessense
		lugens
		maculatum
		marmoratum
		mimodon
		mirabile
		ndianum
		ocellatum
		oeseri
		ogoense

FAMILY	GENUS	Species
		ottogartneri
		pascheni
		passaroi
		primigenium
		puerzli
		punctatum
		pyrophore
		raddai
		rectogoense
		riggenbachi
		robertsoni
		rubrolabiale
		schluppi
		seegersi
		sjoestedti
		splendidum
		splendopleure
		striatum
		thysi
		tirbaki
		volcanum
		wachtersi
		zygaima
	Diapteron	*abacinum*
		cyanostictum
		fulgens
		georgiae
	Epiplatys	*berkenkampi*
		callipteron
		esekanus
		grahami
		huberi
		infrafasciatus
		neumanni
		sangmelinensis
		sexfasciatus
		singa
Bagridae	*Anaspidoglanis*	*ansorgii*
		boutchangai
		macrostoma
	Auchenoglanis	*ahli*
		ballayi
		guirali
		longiceps
		monkei
		pantherinus
		pietschmanni
	Chrysichthys	*aluuensis*
		auratus
		dageti
		filamentosus
		furcatus
		nigrodigitatus
		ogooensis
		persimilis
		longidorsalis
		nigrodigitatus

FAMILY	GENUS	Species
		ogooensis
		persimilis
		thysi
		walkeri
	Parauchenoglanis	*akiri*
		altipinnis
		buettikoferi
		fasciatus
		grandis
		guttatus
		maculosus
	Platyglanis	*depierrei*
Centropomidae	*Lates*	*niloticus*
Channidae	*Parachanna*	*africana*
		insignis
		obscura
Cichlidae	*Chilochromis*	*duponti*
	Chilotilapia	*rhoadesii*
	Chromidotilapia	*batesii*
		finleyi
		guentheri
		loenbergi
		kingsleyae
		linkei
	Gnathochromis	*pfefferi*
	Gobiocichla	*ethelwynnae*
	Hemichromis	*bimaculatus*
		fasciatus
		stellifer
	Konia	*dikume*
		eisentrauti
	Myaka	*myaka*
	Nanochromis	*riomuniensis*
	Oreochromis	*macrochir*
		schwebischi
	Parananochromis	*caudifasciatus*
		gabonicus
		longirostris
	Pelvicachromis	*pulcher*
		subocellatus
		taeniatus
	Pungu	*maclareni*
	Sarotherodon	*caroli*
		galilaeus
		linnellii
		lohbergeri
		melanotheron
		mvogoi
		steinbachi
	Thysochromis	*ansorgii*
	Tilapia	*bakossiorum*
		bythobates
		cabrae
		cameronensis
		camerunensis
		deckeri

FAMILY	GENUS	Species
		flava
		guineensis
		gutturosa
		imbriferna
		kottae
		margaritacea
		mariae
		nyongana
		snyderae
		spongotroktis
		tholloni
		thysi
	Tylochromis	*sudanensis*
		trewavasae
Citharinidae	*Congocharax*	*gossei*
		spilotaenia
	Distichodus	*engycephalus*
		hypostomatus
		kolleri
		notospilus
		rostratus
	Hemistichodus	*vaillanti*
	Ichthyoborus	*monodi*
	Nannaethiops	*unitaeniatus*
	Nannocharax	*altus*
		fasciatus
		intermedius
		latifasciatus
		maculicauda
		micros
		ogoensis
		parvus
		rubrolabiatus
		rubrotaeniatus
	Neolebias	*ansorgii*
		axelrodi
		kerguennae
		powelli
		trewavasae
		unifasciatus
	Phago	*loricatus*
	Xenocharax	*spilurus*
Clariidae	*Channallabes*	*apus*
	Clariallabes	*attemsi*
		brevibarbis
		melas
		pietschmanni
	Clarias	*agboyiensis*
		buthupogon
		camerunensis
		ebriensis
		gabonensis
		gariepinus
		longior
		maclareni
		macromystax

FAMILY	GENUS	Species
		jaensis
		pachynema
		plathycephalus
		submarginatus
	Gymnallabes	*alvarezi*
		typus
	Heterobranchus	*longifilis*
Clupeidae	*Cynothrissa*	*ansorgii*
	Laeviscutella	*dekimpei*
	Pellonula	*leonensis*
		vorax
	Sierrathrissa	*leonensis*
	Thrattidion	*noctivagus*
Cyprinidae	*Barboides*	*gracilis*
	Barbus	*ablabes*
		aboinensis
		aloyi
		altianalis
		alvarezi
		aspius
		batesii
		bourdariei
		brazzai
		brevispinis
		brichardi
		bynni
		callipterus
		camptacanthus
		cardozoi
		carens
		catenarius
		chlorotaenia
		compinei
		condei
		diamouanganai
		guirali
		holotaenia
		hypsolepis
		inaequalis
		jae
		lagoensis
		lucius
		malacanthus
		martorelli
		mbami
		micronema
		miolepis
		mungoensis
		nigeriensis
		nigroluteus
		occidentalis
		prionacanthus
		progenys
		rouxi
		roylii
		stauchi

FAMILY	GENUS	Species
		punctitaeniatus
		stigmatopygus
		sublineatus
		sylvaticus
		taeniurus
		tegulifer
		thysi
		trispilominus
	Garra	*dembeensis*
	Labeo	*annectens*
		batesii
		camerunensis
		coubie
		cyclorhynchus
		lukulae
		ogunensis
		parvus
		senegalensis
		variegatus
	Leptocypris	*crossensis*
		niloticus
	Opsaridium	*ubangense*
	Prolabeops	*melanhypoptera*
		nyongensis
	Raiamas	*batesii*
		buchholzi
		nigeriensis
		senegalensis
	Sanagia	*velifera*
	Varicorhinus	*fimbriatus*
		jaegeri
		mariae
		sandersi
		steindachneri
		tornieri
		werneri
Denticipidae	*Denticeps*	*clupeoides*
Eleotridae	*Eleotris*	*daganensis*
		feai
	Kribia	*kribensis*
Gobiidae	*Awaous*	*lateristriga*
	Sicydium	*crenilabrum*
Hepsetidae	*Hepsetus*	*odoe*
Kneriidae	*Grasseichthys*	*gabonensis*
	Parakneria	*abbreviata*
Malapteruridae	*Malapterurus*	*electricus*
Mastacembelidae	*Aethiomastacembelus*	*marchei*
		sexdecimspinosus
	Caecomastacembelus	*batesii*
		brevicauda
		cryptacanthus
		decorsei
		flavomarginatus
		goro
		longicauda
		marchei

FAMILY	GENUS	Species
		marmoratus
		niger
		sanagali
		sclateri
		seiteri
Mochokidae	*Atopochilus*	*savorgnani*
	Chiloglanis	*batesii*
		cameronensis
		disneyi
		micropogon
		niger
		polypogon
	Hemisynodontis	*membranaceus*
	Microsynodontis	*batesii*
	Synodontis	*albolineatus*
		annectens
		batesii
		eupterus
		guttatus
		haugi
		marmoratus
		nigrita
		obesus
		ocellifer
		polyodon
		rebeli
		robbianus
		schall
		steindachneri
		tessmanni
Mormyridae	*Boulengeromyrus*	*knoepffleri*
	Brienomyrus	*adustus*
		batesii
		brachyistius
		curvifrons
		hopkinsi
		kingsleyae
		longianalis
		longicaudatus
		sphecodes
	Campylomormyrus	*curvirostris*
		phantasticus
	Gnathonemus	*petersii*
	Hippopotamyrus	*castor*
	Isichthys	*henryi*
	Ivindomyrus	*opdenboschi*
	Marcusenius	*abadii*
		brucii
		conicephalus
		friteli
		mento
		moorii
		ntemensis
		paucisquamatus
	Mormyrops	*anguilloides*
		batesianus
		caballus

FAMILY	GENUS	Species
		zanclirostris
	Mormyrus	*caballus*
		felixi
		hasselquistii
		rume
		tapirus
		thomasi
	Paramormyrops	*gabonensis*
	Petrocephalus	*ansorgii*
		ballayi
		catostoma
		guttatus
		microphthalmus
		simus
	Pollimyrus	*adspersus*
		lhuysi
		marchei
		pedunculatus
		polylepis
		walkeri
	Stomatorhinus	*polylepis*
		walkeri
Nandidae	*Polycentropsis*	*abbreviata*
Notopteridae	*Papyrocranus*	*afer*
	Xenomystus	*nigri*
Pantodontidae	*Pantodon*	*buchholzi*
Poeciliidae	*Aplocheilichthys*	*camerunensis*
		luxophthalmus
		scheeli
		spilauchen
	Hylopanchax	*stictopleuron*
	Hypsopanchax	*catenatus*
		zebra
	Plataplochilus	*cabindae*
		loemensis
		miltotaenia
		ngaensis
		terveri
	Procatopus	*aberrans*
		nototaenia
		similis
Phractolaemidae	*Phractolaemus*	*ansorgii*
Polypteridae	*Erpetoichthys*	*calabaricus*
	Polypterus	*retropinnis*
Protopteridae	*Protopterus*	*dolloi*
Schilbeidae	*Parailia*	*occidentalis*
		pellucida
	Pareutropius	*buffei*
		debauwi
	Schilbe	*brevianalis*
		djeremi
		grenfelli
		intermedius
		micropogon
		multitaeniatus
		mystus
		nyongensis