# Rivers of the Lower Guinean Rainforest: Biogeography and Sustainable Exploitation - R.E. Brummett.[1] G.G. Teugels[2]

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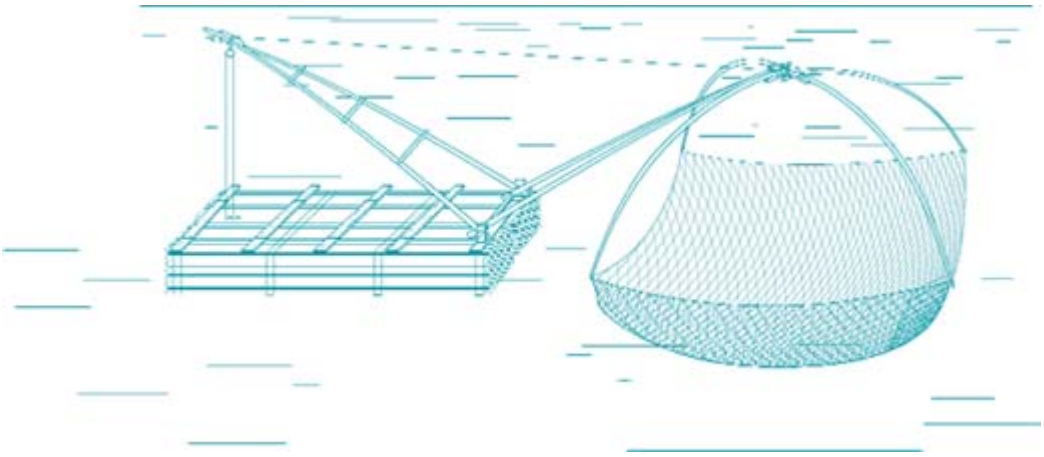

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**ABSTRACT**

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.

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 Lévéque (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 - | 600 | 70 000 | 570 | 166 |
| | Cameroon | | | | |
| 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, Kélé, 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 | 365 | | | |
| | Guinea | | | | |
| MITéMéLé | Equatorial | | | | |
| | Guinea | | | | |
| Gabon (Mbé, Komo) | Gabon | | | | |
| Ogooué (Abanga, Ayina, Dilo, Djoua, Ikoy, Ivindo, Lassio, Lébiri, Lekedi, Lékoko, Lékoni, Leyou, Lolo, Liboumba, Mounianzé, Mpassa, Mvoung, Ngounié, Nouna, Nsyé, Offoué, Okano, Oua, Sébé, Wagny, Zadié) | Gabon | 920 | 205 000 | 4 400 | 185 |
| NKOMI | Gabon | | | | |
| Ngové | Gabon | | | | |
| Ndougou | Gabon | | | | |
| MOUKLABA/NYANGA | Gabon | | | | |
| Kouilou (Bouenza, Lékourmou, Louéssé, Mpoukou, Niari) | P.R. Congo | 605 | 60 000 | 700 | 87 |

In addition to some 8 million people, the rain-forest 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 rain-forest 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 (Beadle 1981; 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 S/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).

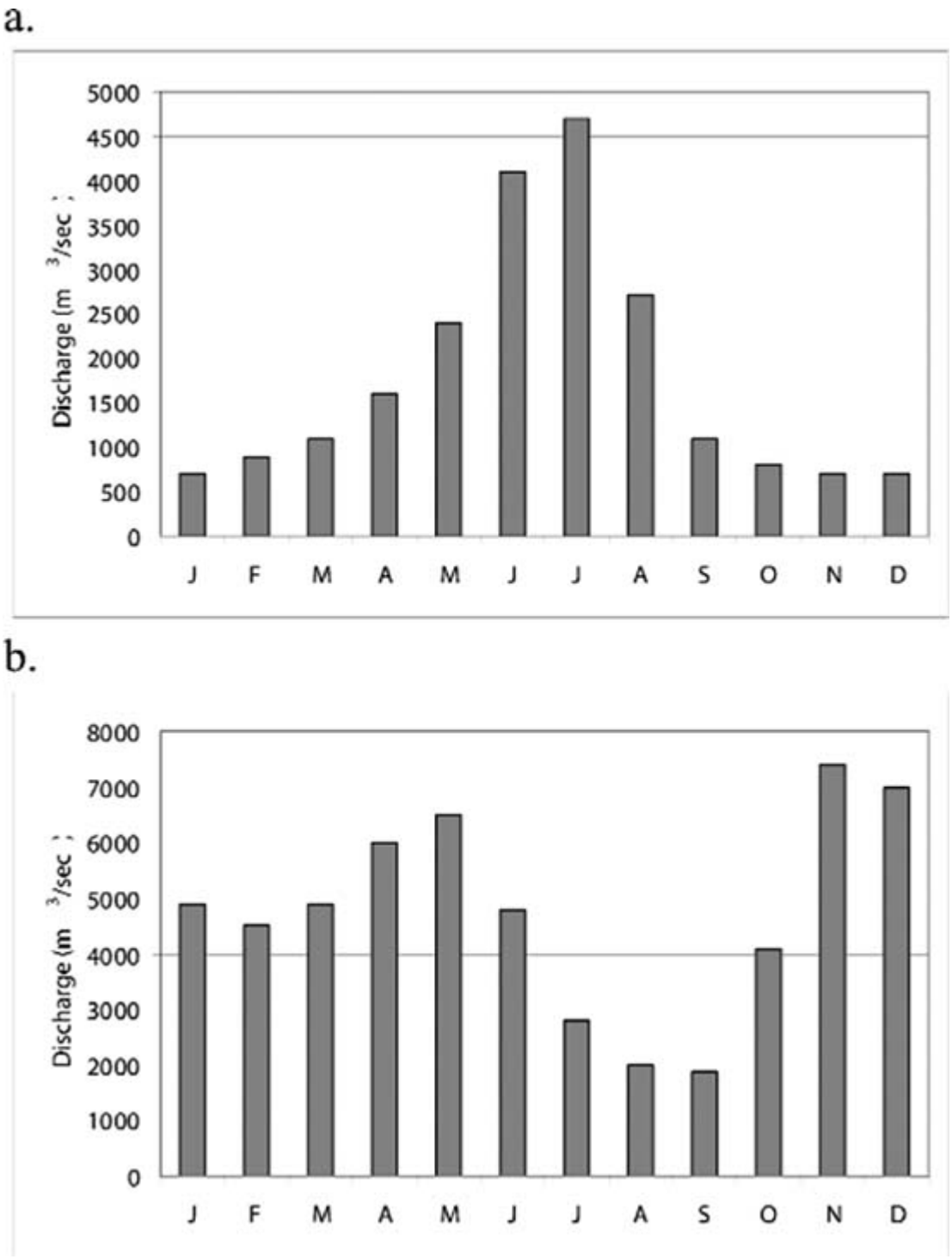


**Figure 2.** Typical discharge patterns for rivers in the northern part of the Lower Guinean Ichthyological Province represented by the Sanaga River, Cameroon (a), and the southern part represented by the Oogoue River, Gabon (b). Data from Lévéque (1997).

**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 rain-forests 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 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.