REVIEW OF THE PRESENT STATE OF THE ENVIRONMENT, FISH STOCKS AND FISHERIES OF THE RIVER NIGER (WEST AFRICA)

R. Laë[1] S. Williams[2] A. Malam Massou[3] P. Morand[4] O. Mikolasek[5]

[1] IRD, BP 1386, 99 341, Dakar, Senegal
[2] Department of Agricultural Economics, Obafeni Awolowo University, Ile-Ife, Osun State, Nigeria
[3] INRAN, Département GRN, BP 429, Niamey, Niger
[4] Centre de Recherche Halieutique, Avenue Jean Monnet - B.P. 171, 34203, Sète, France
[5] CIRAD-GAMET, TA 30/01, 34398 Montpellier Cedex 5, France

Correspondence to: Raymond Lae, IRD, Route des Hydrocarbures, Bel-Air, BP 1386, 99341 Dakar, Senegal
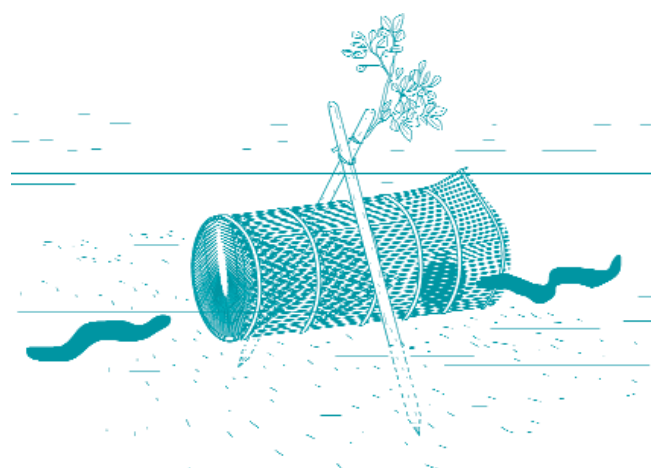
Key words: Niger River, biodiversity, capture fisheries, aquaculture, management

ABSTRACT

The Niger River is the fourth most important river in Africa. It is 4 200 km long with an estimated watershed area of 1 125 000 km². It traverses a variety of ecological areas shared by a number of countries in the West African Region: Guinea, Mali, Niger and Nigeria for its main course; Cote d'Ivoire, Burkina Faso, Benin, Chad and the Cameroon for its tributaries. The mean annual flow is 6 100 m³ s⁻¹. Since the beginning of the century, the Niger River has been subjected to several natural and anthropogenic perturbations: first, a very long drought period started in the 1970s when the discharges decreased strongly and the areas

flooded were considerably reduced. Second, the building of dams and numerous irrigated perimeters fed by water pumping modify the hydrologic conditions of the Niger, increasing the effects of drought. These hydrological variations led to changes in the flora of the river-floodplain system and also to fragmentation or disappearance of habitats usually occupied by numerous fish species. The biological cycle of the fish that were adapted to the former hydrological cycle was modified to varying degrees, although the species richness of the river evaluated at 260 fish species did not change. Nevertheless, fish abundance changed from 1968 to 1989, fish landings declined from 90 000 metric tonnes to 45 000 metric tonnes in the central delta and large-sized species were gradually eliminated to be replaced by a sequence of small-sized and more productive species. The river is fished by dynamic and labour intensive small-scale fisheries, conducted by full and part time fishers, using diverse fishing gears adapted to various biotopes and seasonal variations in the ecosystem and the fish communities. Women play an important role in fish processing (drying or smoking fish) and marketing. In several countries around the Niger River watershed, the fish stocks have been reduced by dramatic increases in fishing activities. Aquaculture has been introduced as an accepted strategy to meet the very high demand for fish products. Aquaculture was introduced in Nigeria and Cote d'Ivoire in the 1950s based on indigenous species of tilapias and catfishes but is still in an embryonic state. The River Niger Commission was created in 1964 and evolved in 1980 into the Niger Basin Authority (NBA) to promote cooperation among the member countries and to develop its resources, notably in the field of energy, water resources, industry, agriculture, forestry exploitation, transport and communications.

GENERAL INFORMATION ON THE NIGER RIVER

The Niger River is the fourth longest river in Africa (4 200 km). It is classified as a Sudanian river as it drains the arid Sahellian savannah for the main part of its course (Figure 1). The Niger River rises in the Fouta Djalon mountains of Guinea and flows northeast through Mali where it forms a seasonally inundated floodplain of 20 000 km^2 known as the Central Delta. North of Gao in Mali, the river bends sharply to the southeast, travels through Niger, the Republic of Benin and Nigeria where the river enters the Gulf of Guinea. It is joined in its lower course by its major tributary, the Benue, that rises in the Adamoua massif of Cameroon from where it is fed by rivers originating on a high central plateau. The Niger has a coastal delta which covers 36 260 km^2, most of which is heavily forested and also a costal fringe of saline mangrove swamps, estuaries and freshwaters (Welcomme 1985).

The Niger River plays an essential role in the life of a densely populated and large region of West Africa. It is an important waterway both for navigation associated with active trading (in Mali from Koulikoro to the Niger bend and in Nigeria on the lower Niger River) and for small canoe traffic over the whole of its course. The riparian, rural populations benefit from its important fish resources. Its floodplains and floodplain tributaries in the inner delta are used for the cultivation of rice, cotton and wheat. In addition, the floodplains are vital to the cattle-herding nomads who use the access to water and the pastures that are created anew every year as the water recedes. New developments (hydroelectric and irrigation dams) are now liable to give the river a significant economic role.

Information concerning the River Niger in Guinea, Mali, Niger and Nigeria is rather poor, often qualitative and descriptive, with few quantitative data, mostly scattered in various reports and research studies. In the past hydrobiological investigations focused on important economical ecosystems, such as the
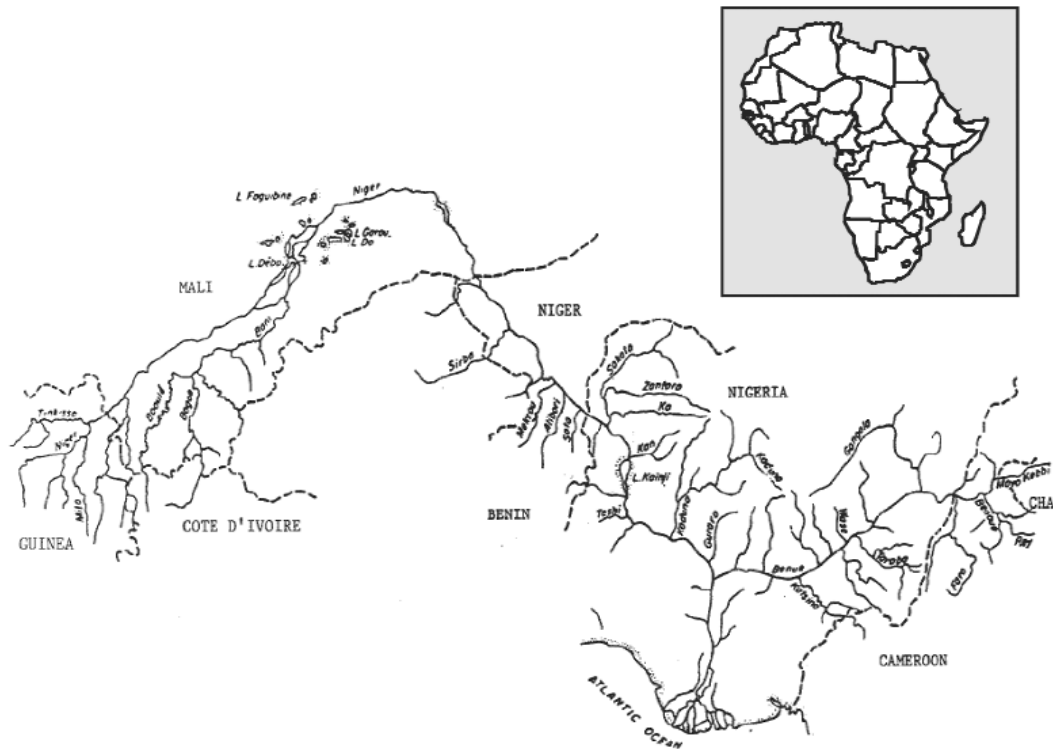
■ **Figure 1 .** Rivers and lakes of the Niger-Benue system (Welcomme 1972).

Central Delta of the Niger or Lake Kainji in Nigeria. The quality and accuracy of information may vary greatly from one country to another or from the main channel of the river to lakes or floodplains.

WATER INPUT, WATER QUALITY AND HABITAT MODIFICATION

NATURAL ENVIRONMENT

Guinea, Mali, Niger, Benin and Nigeria, are traversed by the Niger River and Cameroon, Burkina Faso and Côte d'Ivoire by its tributaries. The course of the Niger can be subdivided into four parts (Brunet-Moret *et al.* 1986a, 1986b):

The Upper Niger Basin is limited downstream by the entry of the river into the Central Delta. In Guinea, the Niger River receives four important tributaries: Tinkisso, Niandan, Milo and Sankarani. The Bani River has much of its course in Côte d'Ivoire but joins the Niger River in Mali at Mopti. It is formed by three major tributaries: Baoulé, Bagoé and Banifing.

The Central Delta is situated downstream of Segou. The rivers Niger and Bani feed this large area. Flooding occurs in July and August, with 90 percent of the water coming from Guinea and Côte d'Ivoire. The highest floods cover the whole basin in September and October. Subsidence begins in November and December and the lowest water levels are in April and May when the floodplain pools dry up and only the rivers Niger and Bani and some lakes retain water. During a good hydrological period there is a three-month time lag between the onset of the flood in the south (Ke Macina) and in the north (Dire) of the delta. During the same hydrological cycle, flooded areas can vary from 20 000 km² at the maximum flood, to 3 500 km² at the end of the low water season (Raimondo 1975).

The Middle Niger Basin stretches from the point of discharge of the Central Delta at Lake Faguibine to the border of Nigeria. Water inputs from left bank tributaries (Tossaye to Malanville) and right bank tributaries coming from Burkina Faso are insignificant. However, the right bank tributaries com-

ing from Benin (Mekrou, Alobori and Sota) induce local floods in Benin, with their maximum in September. This is as important as the Guinean flood, which takes place in March. The Niger River is 550 km long within Niger and its floodplains cover approximately 600 km² during the flood season and 90 km² during the dry season.

The Lower Niger Basin stretches from the Nigerian border from Niger about 162 km north of Lake Kainji to the point of discharge into the sea. The Sokoto River joins the Niger approximately 75 km downstream of the Nigerian border. This tributary extends upstream with a broad floodplain for about 387 km (Hughes and Hughes 1991). There are many major tributaries in Nigeria, including the rivers Anambra, Sokoto, Rima, Kaduna, Gbako and Gurara along the Niger River up to the confluence with the Benue at Lokoja. The Benue river also has significant tributaries, the Gongola, Taraba, Donga, Katsina-Ala and Mada Rivers. The Benue itself originates in the Adamaoua Mountains in Central Cameroon and has a total length of approximately 1 400 km. The upper reaches of the Benue and Niger in Nigeria form narrow valleys and contain falls and rapids. Most of the lower portions, however, are free of rapids and have extensive floodplains (3 000 km² and 1 800 km², respectively) and braided stream channels. In the south, the Niger forms a vast delta which covers 36 260 km² and consists of a network of distributaries where saline water penetrates for a considerable distance (Van den Bossche and Bernacsek 1990). Wetlands cover over 15 000 km² in this area and are separated by numerous islands (Van den Bossche and Bernacsek 1990; NEDECO 1959, 1961; Scott 1966; Ita 1993). There are definite wet and dry seasons which give rise to changes in river flow and salinity regimes. During the wet season (May-October) salinity falls to almost zero throughout the delta. River flow in the dry season (November-March) is still sufficient to keep the maximum salinity in the mouth at 28$^0/_{00}$. Studies in the Bonny estuary, which is part of the delta, showed that salinity, conductivity, pH, dissolved oxygen and alkalinity exhibited spatial and temporal variations (Dublin-Green 1990). The lowest salinities of 14-24$^0/_{00}$ and the maxima of

19-31$^0/_{00}$ were recorded in the late wet season and late dry season, respectively, in both the upper and lower reaches of the estuary. On the basis of salinity, the Bonny estuary can be classified into three zones (Blaber 1997): upper reaches (mesohaline at all seasons except in the late dry season, salinity < 18$^0/_{00}$), middle reaches (polyhaline at all seasons, salinity 18-27$^0/_{00}$) and lower reaches (polyhaline at all seasons, salinity above 27$^0/_{00}$).

HYDROLOGY

The flood of the upper and middle Niger lasts from July to November with the low-water period from December to June. As the river receives tributaries from different climatic areas, the merging of the different flood regimes may produce a second peak, as in the north of Nigeria (Figure 2). In the lower course of the Niger, the river receives water from the Benue, its
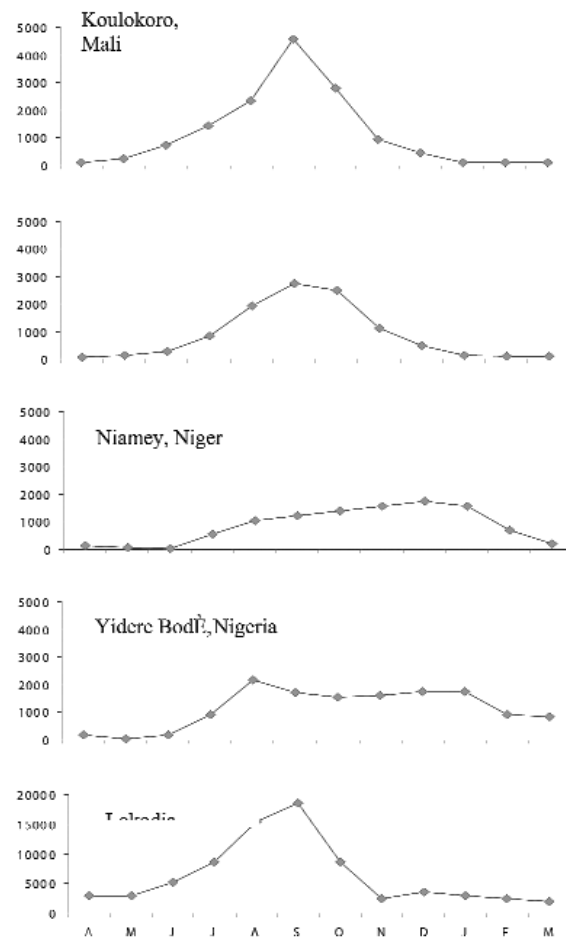
■ **Figure 2.** Evolution of flood regimes in the Niger River from Mali to Nigeria.

major tributary, as well as important local precipitation that strongly increases the flow.

Climate and recent climatic changes

The seasonal pattern and amount of rainfall in any one region of the river depends on the latitude and the position of ITCZ (intertropical convergence zone), which migrates from 5 N (December to March) to 20

Niger. Precipitation ranges from 250 to 750 mm, with one rainy season of 3 to 4 months;

● The equatorial zone in southern Nigeria (terminal delta), characterized by two rainy seasons, two dry seasons and a very high precipitation (4 000 mm). In Nigeria, primarily the distance from the ocean to the hills determines the climate and as such the temperature is always warm and precipitation

Table 1: Climatic characteristics of the whole Niger basin (temperature T, relative humidity U and inter-annual precipitations).

Parameter	Guinea		Mali		Niger		Nigeria	
	Macenta	Siguiri	Bamako	Gao	Niamey	Kandi	Jebba	Onitsha
T° ann. average	24	26.9	28.5	29.6	28.9	27.8	41.5	38
T° x month (x)*	(3)34.6	(3) 38.0	(4)39.4	(5) 42.6	(4) 41.4	(3) 38.8	(5) 48	(6) 38.5
T° n month (n)*	(12)14.0	(1)13.8	(1)17.6	(6) 27.7	(5) 27.3	(4) 25.2	(12) 12	(12) 27.5
° x ann % **	96	85	73	55.5	62.0	80.7	75	99
° n ann % **	58	39	33	18.1	26.7	39.7	32	65
1/2 (° x+° n) % March	69	40	26	23.5 (march)	19.6 (march)	34.9 (feb)	29	67
1/2 (° x+° n) % August	85	81	79	64.1	75.4	81.9	65	85
P (inter-annual precipitation) mm	2 100	1 250	985	255	585	1 053	680	3 100
Number of dry months ***	1 to 2	6	7	10	8	6 to 7	3 to 5	1 to 2

* ( ) : maximum temperature (x) and minimum (n) month number

** Ux and Un = maximal and minimal annual average relative humidity;

(Ux + Un)/2 = average relative humidity of the driest (March) and wettest (August) month

*** According to the definition of Gaussen, one month is considered as dry when Pmm < 2T° C

N (July-August). Consequently, the Niger River passes through four main climatic areas (Table 1):

● The tropical transitional zone at the head of the Niger basin and its affluent, with a rainy season which is 8 months long from April to November and annual precipitations higher than 1 500 mm;

● The Sudanian zone extending from the north of Guinea and Côte d'Ivoire to the south of Mali in the west and again in the north of Nigeria in the East. Annual precipitation ranges from 750 to 1 500 mm, with a 5 to 7 month rainy season;

● The Sahelian/sub-desert zone covering the Central Delta and the river downstream from it in Mali and

decreases from the coast in the south to the Sahel in the north (650 mm).

The regularity of droughts has been among the most notable aspects of Sahelian climate in recent years, particularly in the drier regions in Mali, Niger and northern Nigeria. There are similarities in the long-term discharge pattern of the rivers Bani and Niger, as shown in hydrological data collected since the beginning of the century: 1913, 1945 and 1972 are years of unusually low discharges for these two rivers (Figure 3). The rate of water flows recorded for the decade 1980-1990 are by far the lowest recorded since
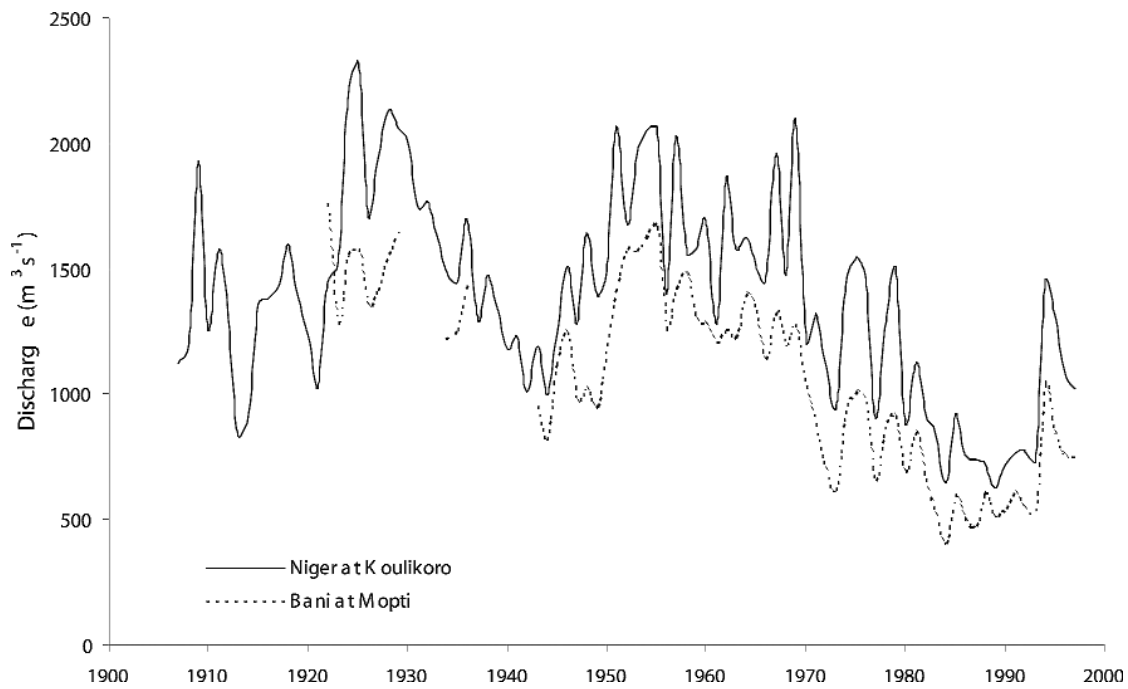
■ **Figure 3.** Average annual discharge rates (m³/s) for the Niger river at Koulikoro and the Bani river at Mopti (La° & Mah° 2002).

the beginning of the century (Mahé *et al*. 2002). The occurrence of wet and dry years is not randomly distributed in time (Lévêque 1995).

This regular decrease of water flows has modified the way in which the floodplains are flooded. In the Central Delta, for instance, the areas flooded during the drought were considerably reduced as was the duration of the flood. Quensière (1994) estimated the maximum flooded area to be 43 900 km² in 1957, as against only 9,500 km² in 1984. Adjacent lakes can show different flooding pattern situations according to rising amplitude (Koné 1991). Thus there are (i) lakes that are fed annually by the flood: *Faguibine, Fati, Oro, Tele, Korientzé*; (ii) lakes that are only fed in average years (hydrology of 1988): *Aougoundo and Niangay*; (iii) lakes that are only fed in wet years (hydrology 1979): *Korarou, Tanda, Kabara*; and (iv) lakes that are fed in very wet years (hydrology of 1969): *Daounas*.

Vegetation

The vegetation cover of floodplain lakes has been well documented in Daddy, Wari and Mohammed (1989) and effects of dryness on the various vegetal types of floodplains by Deceuninck (1989). If the flood lasts for less than 3 months *Vetiveria nigrita* (long-lived grass) replaces *Echinochloa stagnina*, *Oryza longistaminata* and some aquatic plants. The immediate consequence of this is to modify the biotic capacity of floodplains that normally offer abundant and varied food to fish during the flood.

In Lake Kainji, the emergent aquatic macrophytes include *Echinochloa stagnina*, *Cyperus distans*, *Pistia stratiotes*, *Nymphaea lotus*, *Lemna paucicosta*, *Phragmites karka*, *Ipomoea aquatica*, *Sacciolepis africana* and *Ceratophyllum demersum*, of which *E. stagnina* represents the major component. In 1971, emergent macrophytes were estimated to cover only 0.5 percent of the lake surface area versus 8.9 percent in 1977 (Obot 1984). The grass mat serves as spawning and feeding ground for numerous fish species (Ita 1984; Balogun 1988) and as livestock fodder during

the dry season. The aquatic emergent vegetation represents an obstacle for small craft navigation.

Nigeria has the third largest mangrove forest in the world. It consists mostly of red mangrove, *Rhizophora racemosa*, with its characteristic stilt or prop roots. The mangrove floor is important for a lot of smaller flora and fauna and so ultimately for the whole food chain. Other trees include the smaller black mangrove and white mangrove. A unique salt fern can be found in higher areas of mangroves, while the exotic nypa palm (*Nypa fruticans*) colonizes cleared areas. Other types of vegetation include freshwater raphia swamps, floodplain forest and upland rainforest (Moses 1990).

HUMAN IMPACTS

IRRIGATION AND DAMS

Water was regarded for a long time as an inexhaustible resource but the recent drastic reduction of floodplains and the drying out of some sections of the Niger (Niamey in June 1985) has raised concerns of the local people. Marie and Témé (2002) identify the following activities as removing more water from the river:

- Traditional irrigation based on natural immersion (Mali, Niger, Nigeria),
- Improvement of the traditional system by controlled immersion at rising water level (construction of dams, polders and other structures for the control and circulation of water in channels),
- Entirely controlled water diversions (Baguineda irrigated perimeter and Niger Office in Mali),
- Control of water by pumping, exploited collectively or individually (areas of Mopti, Tombouctou: mainly Dire for the culture of corn and Gao. This is a general feature of riparian agriculture on the Niger).

There are relatively few impoundments on the Niger River as compared to other major river systems. However, four dams have been built on the main river or its tributaries that have created reservoirs as follows:

Lake Selengue: A hydroelectric dam was built in 1980 in Selengue on the Sankarani River upstream of Bamako to provide electricity for the Mali capital. The reservoir surface area is 400 km^2 and during the flood the flow rate of the river entering the reservoir is estimated at 123 m^3 s^{-1}.

Lake Markala: The dam was built in 1943 at Markala 250 km downstream of Bamako in Mali in order to store water for gravity irrigation of a depression that was formerly an arm of the Niger. This new area, known as the "Office du Niger", allowed a significant development of agriculture and currently produces rice and sugar cane. For this purpose up to 158 m^3 s^{-1} of water is used, representing 5 percent of the river flow during the flood.

There is only one hydroelectric dam in Niger at Kandaji, except for a submersible dam that provides the capital Niamey with drinking water. As the hydrological cycle is disrupted downstream, a co-operation agreement between Mali and Niger allows for artificial flood releases at low waters to maintain a minimal flow.

Lake Kainji: The only mainstream impoundment on the Niger River is Lake Kainji in Nigeria, located about 1 200 km upstream from the mouth of the river. The hydroelectric dam was built from 1962 to 1968 and the surface of the reservoir when full is about 1 300 km^2.

Lagdo Reservoir: The upper course of the Benue River was impounded in 1982 for hydroelectric power generation, irrigation and fisheries. The surface of the reservoir covers 700 km^2.

All these structures have had an impact on the natural dynamics of the river downstream of the dams and on fish abundance and diversity. The impacts are

not always documented or clear (Petts *et al*. 1989). In Mali, the Markala and Selengue dams have contributed to an increase in the impact of drought by further lowering the already reduced flood flows: the annual loss in total fish catches in the Central Delta is estimated to be 5 000 tonnes (Laë 1992a). The dams also affect upstream fish production by disrupting longitudinal migrations of fish. But electric power production at Selengue, which requires large volumes of water, has created better flows during the dry season than those encountered before the Sahelian drought. Consequently, the survival rate of spawners has increased ensuring adequate reproductive success every year (Laë 1992a). The better flows have allowed the development of seasonal rice culture in irrigated areas, with water releases ranging between 80 to 100 $m^3 s^{-1}$ that translates to 70 percent of the average river flow (Marie and Témé 2002).

In Nigeria, changes in the fish fauna of the Niger followed the construction of the Kainji dam (Lelek and El Zarka 1973; Adeniji 1975). Fish catches between Jebba and Lokoja decreased by 50 percent in the three-year period from 1967 to 1969 (Otobo 1978). This was amplified by changes in the fish community composition with a decline of Characidae, Mormyridae and Clariidae and an increase of predatory species like *Lates niloticus* or some Bagridae species (Sagua 1978). In the same way, downstream the fisheries of the Anambra basin registered a 60 percent decline, following the drying out of the floodplains caused by the construction of the dam (Awachie and Walson 1978).

In the Niger Delta, environmental problems are complex, interconnected and caused by many factors including flooding and erosion. Land degradation and direct loss of land to habitation and cultivation are common problems throughout the Niger Delta arising mainly from flooding and erosion. Flooding, which normally lasts from three to five months annually, has been made worse by dam construction on the Niger

River over the last 30 years. The loss of sediment input to the delta has increased the rate of coastal and river bank erosion.

POLLUTION

Invasive species

The presence of water hyacinth was noted in several countries crossed by the Niger River and its tributaries: Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger and Nigeria (Akinyemiju 1987; Akinyemiju and Imevbore 1990; Akinyemiju 1993a, 1993b; Harley 1994; Chikwenhere 1994; Dembele 1994; Olaleye and Akinyemiju 1996, 1999, 2002). Water hyacinth is not present upstream of Bamako but it proliferates at the points of discharge of polluted water where concentration of organic matter is high (Bamako and Segou). Biological control, using weevils (*Neochetina bruchi* and *N. eichhorniae*), was effective in Mali in permanent sites such as ponds but must be sustained every year in the sites subjected to river rise and fall.

In Niger, since 1989 the river has been invaded by water hyacinth obstructing fishing activities. Currently the invasive plant is present over more than 60 percent of the river course interfering with fishing gears in favourable fishing areas (floodplains and backwaters). It is also modifying the water ecosystem by depletion of inorganic nutrients essential for primary production. In addition, the combined effects of droughts and human impacts (itinerant agriculture, overgrazing, abusive wood cutting) has led to an increase in erosion, removal of muddy banks, considerably reduced water volume and modified water quality (e.g. high turbidity, deoxygenation). No chemical pollution from industrial or urban effluents has been reported in Niger.

Water hyacinth is also of concern in both fresh water and brackish water sectors of the delta.

Environmental pollution

In Nigeria, people inhabiting the Niger Delta have suffered extensive environmental pollution and the crisis is still on going. Chief among the pollutants

is oil. The Niger Delta is endowed with immense natural resources, particularly crude oil. Nigeria's refining started in late 1965 near Port Harcourt. Later three other refineries were built in 1978, 1980 and 1990 increasing Nigeria's refining capacity to 445 000 barrels per day. In addition, Nigeria has the largest natural gas reserves in Africa, with 21.2 billion cubic meters per day produced in 1988. As a consequence, environmental problems arise from oil and gas-related development activities, oils spills, refinery operations, oil transportation, gas flaring, dredging of canals and land taken for the construction of facilities. Areas near such outfalls are subjected to chronic pollution, which is of significance for fish resources and fisheries (Robinson 1997; Egborge 1998; Akinyemiju and Imevbore 1990; Akinyemiju 1993a, 1993b, 1994; Olaleye and Akinyemiju 1996, 1999, 2002).

STATUS OF FISH BIODIVERSITY

SPECIES RICHNESS OF THE NIGER RIVER

The fish communities of the Niger River belong to the Nilo-Sudanian Province. The Upper Niger and Central Delta harbour 130 to 140 species (Daget 1954; Lévêque, Paugy and Teugels 1990), which belong to 62 genera and 26 families. In the middle Niger, 98 species belonging to 22 families, have been recorded (Coenen 1986; Daget 1962; Bacalbasa-Dobrovici 1971). Among these species, 83 are regularly fished while 15 are of a very small size and/or are very rare. In the lower Niger, 160 species have been recorded in Lake Kainji (Ita 1978, 1993; Balon and Coche 1974), with 9 fish families of economic importance. On the Benue River, 113 species were collected in the Mayo-kebbi (Blache *et al*. 1964) versus 128 in the Benue River (Stauch 1966). Until recently, the fauna of the Niger Delta was largely ignored, due to the inaccessibility of the riverine and swampy areas. The Delta has a lower diversity of freshwater fish than recorded in equivalent biotopes in West Africa. When comparing lagoon and estuarine ecosystems, there are 79 species in the Lagos lagoon of Nigeria (Fagade and Olaniyan 1972, 1973, 1974), 130 species in the Ebrie

lagoon (Albaret 1994) and 102 species in the Fatala estuary in Guinea (Baran 1995). By 2002 there were a total of 311 freshwater fish species recorded from the rivers and lakes of Nigeria.

All these species have adapted to the seasonal and inter-annual variations of the hydrological cycle of the river both in freshwater and brackish water ecosystems involving a succession of favourable and unfavourable environments and the appearance and disappearance of natural habitats. Feeding, growth and mortality are closely linked to the seasons. For instance, spawning of most of the species takes place at the beginning of floods (Benech and Dansoko 1994), growth is restricted to rising and high waters, while mortality rates are higher during the declining water level and dry season. Fish breeding and feeding migrations are dependent on water discharges. In response to the variations in the hydrological cycle, fish community composition and abundance can change greatly from one season or one year to another.

GROUPING OF SPECIES IN ECOLOGICAL CLASSES

In freshwater ecosystems, two major groups of fish can be identified on the basis of their adaptive strategies (Quensière 1994):

1. Migratory fish exploit environmental variability and have high fecundity and a short breeding period at the beginning of the flood. As spawners concentrate in few sites and fish later disperse in the whole river, genetic mixing is enhanced. Some species such as *Hydrocynus brevis* and *Bagrus bayad* are short distance migrants while others such as *Alestes baremoze, Alestes dentex* and *Brycinus leuciscus,* are long distance migrants.

2. Opportunistic species are less mobile and show various behavioural and physiological adaptations that help them to survive in the anoxic environments of floodplains. Some species have anatomical features such as lungs (*Protopterus annectens, Polypterus senegalus*), arborescent respiratory organs (*Clarias anguillaris, Heterobranchus bidorsalis*),

supra-branchial organs (*Ctenopoma kingsleyae*) or highly vascularised intestines (*Heterotis niloticus, Gymnarchus niloticus*). Other species show physiological or behavioural modifications including breathing from the water surface film (Cichlidae, *Hemisynodontis membranaceus*). These species generally have low fecundity but can breed several times a year. Survival of the young is improved by various degrees of parental care ranging from territorial behaviour associated with nest building to mouth brooding.

The relative abundance of these two groups depends on the variability of the hydrological cycle both in space and time (Lowe-McConnell 1975).

In brackish water, the great seasonal changes in the salinity regime of the delta, with periods of high and low salinity, has led to the classification of the fish into three groups according to their seasonal distribution.

Group 1. Species that occur in the system throughout the year and can tolerate the great change in salinities between the dry and wet seasons. Most fall into the marine migrant category and include the commercially important clupeid *Ethmalosa fimbriata*. The remainder are freshwater species: *Chrysichthys nigrodigitatus*, *Sarotherodon melanotheron* and *Tilapia guineensis*.

Group 2. Species found in the system only between December and May (mainly dry season) when the salinity fluctuates between $0.5^0/_{00}$ and $28^0/_{00}$. They are all marine migrants and all juveniles.

Group 3. Species found only when salinities fall below $1^0/_{00}$. They are primarily freshwater species such as *Schilbe mystus*, *Clarias lazera*, *Lates niloticus* and Mormyridae.

ENDANGERED SPECIES AND SPECIES THAT HAVE DISAPPEARED

In river-floodplain ecosystems, the end of the dry season is marked by a fall in Shannon index diversity with a relative increase of some families such as Cichlidae, Clariidae and Centropomidae (Laë 1995). As the same species are affected by a long-term drought, this phenomenon could be extrapolated to an inter-annual scale as is shown by analysis of fresh fish traded in the port of Mopti (Mali) (Quensière 1994).

Before 1970, fish communities were typical of good flood regimes with a remarkable abundance of *Synodontis* spp, *Polypterus senegalus* and *Gymnarchus niloticus.*

From 1973 to 1979, the nine most abundant species were similar but secondary species disappeared or became infrequent. At the same time, the relative abundance of *Clarias anguillaris*, *Heterobranchus bidorsalis*, *Chrysichthys auratus*, *Bagrus bayad*, *Schilbe mystus* and *Auchenoglanis occidentalis* increased.

From 1985 to 1991, changes in population structure accelerated and species such as *Citharinus citharus*, *Alestes* sp., *Synodontis* sp. and *Heterotis niloticus* joined the group of secondary species. On the other hand, *Bagrus bayad*, *Clarias anguillaris* and *Chrysichthys auratus* increased in catches.

These modifications illustrate the reaction of fish stocks to drought and increasing fishing effort and reinforce the observations of Roberts (1975) concerning adaptations of fish communities to various stresses. In the Central Delta, some species were very rare at least until the end of the drought period (1994): *Heterotis niloticus*, *Distichodus* spp, *Citharinus citharus*, *Bagrus docmak*, *Polypterus senegalus*, *Malapterurus electricus*, *Clarotes laticeps* while others disappeared from the catches: *Gymnarchus niloticus*, *Parachana obscura*, *Arius gigas*, *Citharidium ansorguii*, *Hepsetus odoe*, *Alestes macrolepidotus* (Laë

1994, 1995; Wetlands International 1999). However, most of these species are relatively abundant in other places in Mali (Lake Selengue) and reversion to more normal hydrological regimes would probably lead to the re-invasion of the delta by these species, either because they are still there or because they would migrate back into the delta from upstream or downstream areas.

In Niger, field observations do not substantiate the fact that some species are becoming rare. The notable differences between the inventories of Daget (1962) and Coenen (1986) relate to the absence of 2 species, *Arius gigas* and *Papyrocranus afer*, but only for taxonomic reasons. Nevertheless, in a context of droughts, river species are less underprivileged than those undertaking lateral migrations towards adjacent floodplains. Even if biodiversity is not endangered at a national level, it could be at a local one. Coenen (1986) showed that the condition of fisheries of Gaya bay (at the border between Niger and Benin) was giving serious cause for concern. The fall in fish recruitment due to drought, combined with strong fishing effort, lead to a lowering of length of fish caught to a point when juveniles form the major part of fish landings. However, the promised collapse is still not observed.

In Nigeria, as in the other Niger River countries, all natural lakes and reservoirs are supplied with fish by the inflowing rivers, The fish stocks in these major rivers are replenished from the adjacent floodplains after each flood season during which the fish breed. Drought or damming will disrupt the natural cycle of flooding which is bound to affect fish species diversity both in the natural or artificial aquatic ecosystems as well as in the wetlands. Given the size of its basin higher species diversity might be expected for the Nigerian reaches of the river than is the case. Welman (1948) listed 181 species; Reed (1967) listed 161 species from Northern Nigeria while White (1965) listed 145 species within the upper Niger (future Lake Kainji area). Ita (1993) reported that fish species in the Anambra, Kaduna and Sokoto/Rima, the major tribu-

taries of the Niger, are low in diversity, in the range of 23, 28 and 22 species, respectively. Ita (1993) also noted that Lake Kainji topped the list with a total of 160 species, followed by Jebba reservoir with 52 species. While Lake Kainji Lake retained some of the riverine features within its northern arm, the number of species declined after impoundment from 160 to approximately 97. Ita (1993) reported that this decline is to be expected because of the reduction in the flow rate affected flow dependant species adversely. Some mormyrids, for example, disappeared as soon as the impoundment was completed, although these fish species were still found in some of the inflowing rivers. In conclusion, the low species diversity is linked to the dam location that is nearer to a tributary than to a confluence of the main rivers. This characteristic is linked to the rapids and rocky terrain preferred by a limited number of freshwater species.

INTRODUCTION OF EXOTIC SPECIES

Very few species have been introduced in Guinea and Mali. In Guinea *Oreochromis niloticus* was introduced in 1986 from Liberia for aquaculture but it has not established itself in the wild. In Niger, no exotic species were caught in natural environments (river and ponds) although some introductions of common carp (*Cyprinus carpio*), coming from Nigeria, were reported. Future introductions of exotic species for fish farming are not to be excluded. Selection of spawners for fish farming in ponds should be done from local species because some experiments showed that local strains have similar or better growth performances than the already domesticated ones (*Oreochromis niloticus* and *Clarias anguillaris*, Bouake stocks, Côte d'Ivoire) or wild ones coming from other rivers in West Africa (Senegal, for instance). This precaution will make it possible to safeguard the genetic resources of the Nigerian species without contamination and introgression risks.

In Nigeria, nine species were introduced since the 1970s, mainly for aquaculture: *Cirrhinus mrigala* and *Labeo rohita* from India*,* grass carp

Ctenopharyngodon idella, common carp *Cyprinus carpio* from Austria and Israel, silver carp *Hypophthalmichthys molitrix*, channel catfish *Ictalurus punctatus* and *Micropterus salmoides* from USA, guppy *Poecilia reticulata* from the UK and *Xiphophorus maculatus*. Among these species, only *Cyprinus carpio* is widely used for aquaculture. *C. carpio, P. reticulata* and *X. maculates* are probably established in the wild but their ecological effects are unknown.

STATE OF FISHERIES

Artisanal fishing is very intensive in fresh and brackish waters, with clear seasonal variations characterized by a decrease in exploitation at the time when fish is dispersed in floodplains or during the rainy season. Fishers modify their fishing techniques according to hydrological cycle (Daget 1949; Laë *et al.* 1994; Laë and Morand 1994). Environmental degradation has resulted in a diversification of fishing methods with the emergence of new technologies adapted to fish rejuvenation and the extension of fishing to new biotopes.

Number of fishers involved in fishing

Fishers can be classified into three main groups (Laë *et al.* 1994):

I Artisanal fish harvesters, using rudimentary gears (two-hands nets, harpoons) and only fishing in ponds and channels. They are extremely numerous but for them fishing is a minor activity for personal consumption. To this group belong Malinké in Guinea, Rimaïbe, Marka and Bambara in Mali, Haoussa and Zarma in Niger.

II Sedentary fishers living in permanent villages or camps are scattered among the fishing communities along the river and its distributaries. They practice traditional fishing during declining or low waters and use more standard techniques like gill nets or seine nets. They usually have secondary activities and are of Bozo or Somono origin in Guinea and Mali, Sokoto or Sorko in Niger.

III Migrant fishers forming units with intensive fish-ing activities (Bozo in Mali, Ijaws, Itsokos, Urhobos, Ilajes, Adonis, Junkuns and Hausawas in Nigeria). Their fishing gears and techniques are modern and specialized. As they move far from their villages, they cannot conduct other activities. In Mali they have to pay a royalty (maaji) for fishing (Fay 1989; Kassibo 1990). In Nigeria entry into the fishery is free even if they, like the local fishers, join the fishers' cooperatives within which they participate actively in the management and/or co-management of the aquatic resources with the local water chiefs called 'Bulamas' or "Sarkin Ruwa". Fish is always processed and marketed in order to reduce fish losses to the minimum. There is a degree of control of access to water bodies by the sedentary fishers and farmers that conflicts with the extensive fishing strategies developed by migrant fishers.

In Guinea, fishery statistics are rare. Several missions of experts were carried out to evaluate continental fishing and fish culture (e.g. Matthes 1993). The number of professional or full time fishers is perhaps 6 000 and fish catches may reach 6 000 to 8 000 tonnes y^{-1}. According to fragmentary data collected by interviews, fishers work from 90 to 170 days a year. Their individual annual catch ranges from 0.9 to 2.3 tonnes y^{-1}. The main fishing gears used are hand lines, bow nets, stow nets, gill nets, cast nets, multihook lines.

In Mali, the population of the delta increased significantly from 70 000 Bozos and Somonos in 1967 (Gallais 1967) to 80 000 in 1975 (Ministere des Ressources Naturelle et de L'Elevage 1975) and 225 000 in 1987, of which 62 000 were active fishers (Quensiere 1988; Morand, Quensiere and Herry 1990). On Lake Selingue, the number of fishing units is about 800 and the fishers are mainly coming from the Central Delta. The latter use fishing structures and practices of their birth village (Laë and Weigel 1995).

In Niger, fishing is practiced all the year. During the 1960s, there were roughly 1 500 active fishers (Daget 1962; Bacalbasa-Dobrovici 1971) and 2 600 in 1980 (Sheves 1981; Price 1991). From 1983 to

1985, fishing effort declined by 50 percent due to the Sahelian drought and relatively high fishing pressure (Malvestuto and Meredith 1989). As in Mali fishing effort doubled during the 1970s.

In the lower Niger, the number of fishers in freshwater ecosystems is estimated at 10 000 on the Niger River, 6 300 on Lake Kainji, 3 900 on Lagdo reservoir and 5 140 on the Benue River (Ita 1984; van der Knaap, Malam, Bouba *et al*. 1991; Welcomme 1985). National household surveys have no disaggregated data on the number of fishers involved in fishing activities on the Niger River. The estimated population is about one million fishers divided between the north-west and south-west portion of the Niger River in Nigeria including the Niger Delta in the southern zone. The population of fishers has decreased greatly between 1990 and now, because of lack of Governmental input subsidies for the purchase of canoes, nets and outboard engines. In the Niger Delta, the brackish water sector is an important component of the artisanal fisheries but there is no adequate information on the numbers of canoes and fishers operating in

the brackish water area. The number of canoes operating in the estuaries, lagoons and inshore ranged from 95 127 (95 percent non- motorized) in 1971 to 109 638 (81 percent non-motorized) in 1984. It is apparent that the non-motorized canoes operate mostly in creeks, estuaries and coastal lagoons. The following is the total number of artisanal fishers by category in the Delta: there were 264 144 full-time fishers in 1991 as compared with 666 320 in 2000; in 1991 there were 192 958 part-time fishers as compared to 486 566 in 2000; and in 1991 there were 9 500 occasional fishers as compared to 24 422 in 2000 (Federal Department of Fisheries Statistics 2000). The grand total recorded for 1991 was 466 602 compared to 1 177 308 in 2000.

GEAR AND CATCH LEVELS, COMPOSITION

Artisanal fishing adapts to the cycle of flooding and retreat of water over floodplains. Water reaches floodplains via channels and backwaters, which ensures lateral extension of the flood. During the falling water, fish that stayed for 4 to 5 months on the floodplains return to the river. Rising and dropping water level and fish migrations involve significant
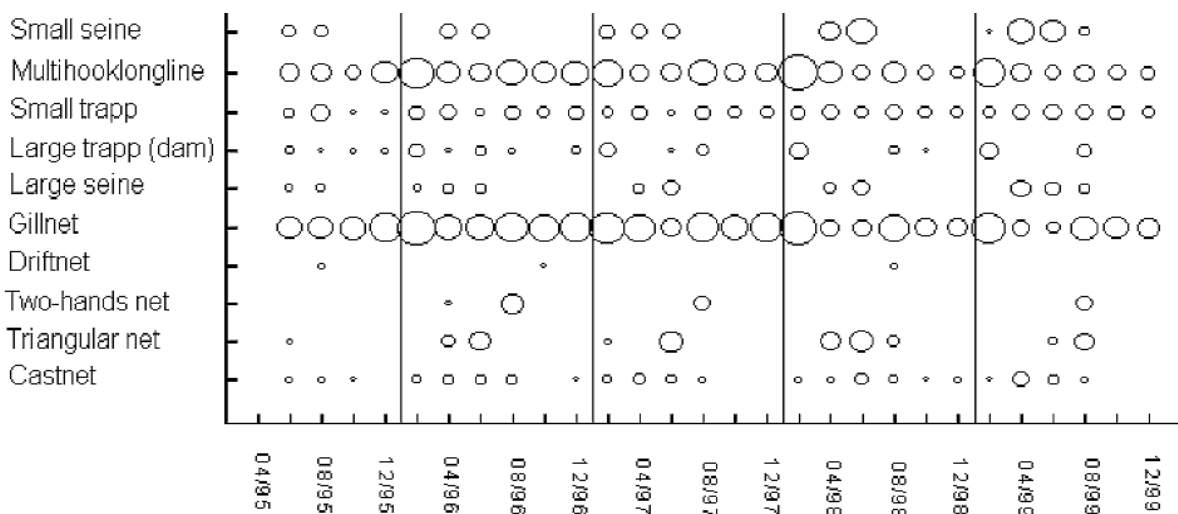
■ **Figure 4.** Fish gear utilization in the Central Delta of the Niger from 1995 to 1998 (bimonthly surveys). Circles are proportional to fishing intensity. In 1998, small seines are more used during the dry season to the detriment of gillnets (Kodio, Morand, Dienepo *et al.* 2002).

space-time variability in fish abundance and consequently a change in location of fishing areas during the year. Variations in water level also prevent using the same fishing gear throughout the year. In estuaries, the same is required due to seasonal changes in water salinity. There is a very close relationship among fished biotopes, hydrological seasons and fishing gears (Figure 4). Seasonal fishing techniques are essential for ensuring sufficient yield in order to satisfy the needs of the fishers.

Fishing gears used on the Niger River can be grouped into six major categories:

Active fishing methods

- hunting gears (harpoons, used mainly in ponds in process of draining)
- launched or push nets (triangular nets, two-hands nets, cast nets, frequently used by occasional fishers)
- seines: small seines handled by one or two men at low water, or large seines (purse seines or beach seines) from 400 to 1 000 m total length, operated by a team of 20 fishers;

Passive fishing methods

- gill nets (mono- or multi-filaments nets, for fishing at the surface, at medium depth or just above the bottom). Fixed nets or drift nets, with small or large meshes, are adapted to target specific species
- traps (small traps used in shallow water and large traps that are 5 m long and of 2 m height. The latter are used for damming entirely some river arms during the falling water)
- lines (baited lines fishing close to the bottom and unbaited multi-hook lines that block demersal fish)

In the Central Delta, the total fish catch was estimated at 48 600 tonnes in 1990-1991 and fish were captured mainly using fixed and drift nets (40 percent). The most frequently used mesh sizes ranged from 20 to 35 mm knot-to-knot. The rest of the fish was captured using small traps (15.7 percent), cast nets (14.9 per-

cent), multi-hook lines (10.6 percent), large (7.8 percent) and small (4.3 percent) seines. The fish were captured by migrant fishers (59.2 percent), sedentary fishers (36.1 percent) and farmer-fishers (4.7 percent). Seventy-six species were recorded in the fish landings, many of which occurred in small numbers (Laë 1995). Seventeen species accounted for 85 percent of the total catch. Cichlidae dominated (26.6 percent), with *Oreochromis niloticus* (10.2 percent), *Tilapia zillii* (8.3 percent), *Sarotherodon galileus* (6.2 percent), *Oreochromis aureus* (1.9 percent). Clariidae (*Clarias anguillaris*) were also well represented, with 18.7 percent of the total. They were followed by Characidae (13.6 percent) with *Brycinus leuciscus* (6.2 percent), *Hydrocynus brevis* and *H. forskali* (5.2 percent) and *Alestes* (2.2 percent), then Bagridae (11 percent), with *Chrysichthys* (5.4 percent), *Bagrus* (2.8 percent) and *Auchenoglanis* (2.7 percent), Cyprinidae, with *Labeo* (5.3 percent) and Centropomidae (*Lates niloticus* 3.8 percent).

In Nigeria, the fishing gears used in the estuaries are mainly longlines locally called "*lingo*", castnets ("*brigi*"), clap nets, unbaited long lines with closely arranged hooks locally called "*mari mari*" and set and drift gill nets. Large gill nets and fixed gear for harvesting fish and shrimp predominate. The demersal target species exploited by artisanal fishing units are croakers (*Pseudotolithus*), threadfins (*Galeoides, Pentanemus, Polydactylus*), soles (*Cynoglossus*), marine catfish (*Arius*), brackish water catfish (*Chrysichthys*), snapper (*Lutjanus*), grunters (*Pomadasys*), groupers (*Epinephelus*) and the estuarine white shrimp (*Palaemon*). Bonga (*Ethmalosa*) dominates the pelagic fishery but there are modest catches of shad (*Ilisha*), sardine (*Sardinella*), various jacks (*Caranx* spp.) and Atlantic bumper (*Chloroscombrus*).

Apart from fishers, birds also prey upon stocks. In Nigeria, 74 species of aquatic birds are associated with Lake Kainji and the littoral zones and open water

support most of the birds, feeding on *Sarotherodon galilaeus*, *Oreochromis niloticus* and *Chrysichthys nigrodigitatus,* among others (Okaeme *et al*. 1989; Ita 1993). In the Central Delta, birds are omnipresent and fish predation is obviously far from being negligible. This aspect is evoked by Welcomme (1979) who estimated that birds could represent the main source of predation in the floodplains.

HISTORICAL FISH CATCH, ACTUAL FISH CATCH AND TRENDS

Although historical data are rare, it is possible to trace the main changes over a period of about fifty years. In the 1940s, fishing was free and profitable, fish were abundant and the number of fishers was relatively low (Daget 1949). For instance, Blanc, Daget and d'Aubenton (1955) recommended that fishing be intensified in the Central Delta in order to reduce the number of adult fish and to support juvenile growth.

Later on fishing pressure increased strongly due to a growing number of fishers (doubling every 20 years). Intensification of fishing also resulted from the introduction of synthetic nets - according to Durand (1983) the use of nylon could have increased the fish-

ing effort by a factor of 20 - and absence of control over the fishing due to the weakening of traditional authorities (Fay 1989). On the Niger River modern fishing gears were introduced including synthetic gill nets, multihook lines, cast nets and large seines. There has been an increase in individual practices as opposed to the formerly restricted traditional techniques. At the same time drought and high fishing effort led to targeting more juveniles and reducing mesh size (Laë and Weigel 1994). Thus, while 50 mm mesh was used before 1975, the use of 30 to 50 mm mesh-sized nets dominated from 1975 until 1983 and this was further reduced after 1983 to the now dominant 24 to 33 mm mesh-sized nets. Motorized boats were not introduced because of their high cost and the cost of maintenance and fuel.

The total annual catches on the Niger River and its tributaries are estimated to be about 300 000 tonnes. Fish catches (Figure 5) in Guinea (maximum of 4 000 tonnes) and Niger (maximum of 16 000 tonnes) are insignificant when compared with those in Mali (maximum of 133 000 tonnes) or in Nigeria (maximum of 161 000 tonnes). From 1950 to 1970, the growth of fishing on the Niger River led to an increase in annual
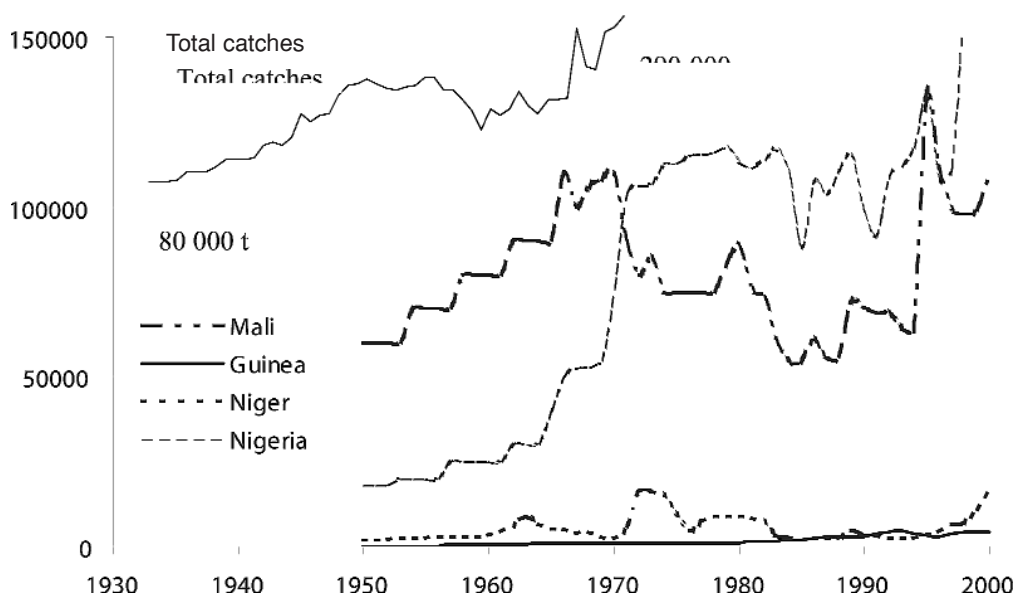
■ **Figure 5.** Annual fish landings (metric tonnes) in continental waters of Guinea, Mali, Niger and Nigeria. Insert gives total fish landings in the Niger basin from 1950 to 2000. From FAO statistical data.

fish landings from 80 000 tonnes to 200 000 tonnes. Thereafter fish production showed large fluctuations with a general downward trend from 209 000 tonnes in 1973 to 167 000 tonnes in 1991. This drop in catch was directly linked to the decrease in flooded areas due to the drought that prevailed in West Africa (Laë 1992b). Since 1995, the total fish landings have been increasing (288 000 tonnes), mainly due to better floods in the Central Delta.

In Niger, in the 1960s annual fish landings were about 4 000-5 000 tonnes, with a catch per fisher of 2.7-3.3 tonnes (Daget 1962; Bacalbasa-Dobrovici 1971). In 1978, before the drought years, total catches were close to 7 000 tonnes (Talatou 1995) and then dropped in 1983, 1984 and 1985 to 1 600 tonnes, 1 200 tonnes and 900 tonnes, respectively (Malvestuto and Meredith 1989). This was undoubtedly the result of the severe Sahelian drought. Since 1985, the annual fish catch fluctuates from 2 000 tonnes to 4 000 tonnes, depending on freshwater input and more recently (1999 and 2000) it has been reaching over 10 000 tonnes. (FAO statistical data).

In Mali, yields showed a rising trend from 40 kg ha^{-1} in 1968 to 120 kg ha^{-1} in 1990 due to an increase in productivity caused by the shift of the fishery to younger and smaller fish (Laë 1995). This was a consequence of increasing fishing pressure resulting from floodplain area reduction and concentration of fishing activities. Changes in the environment and increasing fishing pressure have lowered the average size of long lived fish species, such as *Alestes dentex*, *A. baremoze* and *Tilapia zillii* in fish catches between the 1950s and 1990s (Daget 1952, 1956; Laë *et al*. 1994) (Figure 6).

IMPORTANCE OF LOCAL CONSUMPTION, FISH TRADING AND FISH PROCESSING

Considerable disparity exists at country level, but generally fisheries are labour intensive. An estimated 20 percent of the total agricultural workforce is directly or indirectly involved in the sector. Women play an important role in fish processing and marketing. Most of this employment is generated in remote
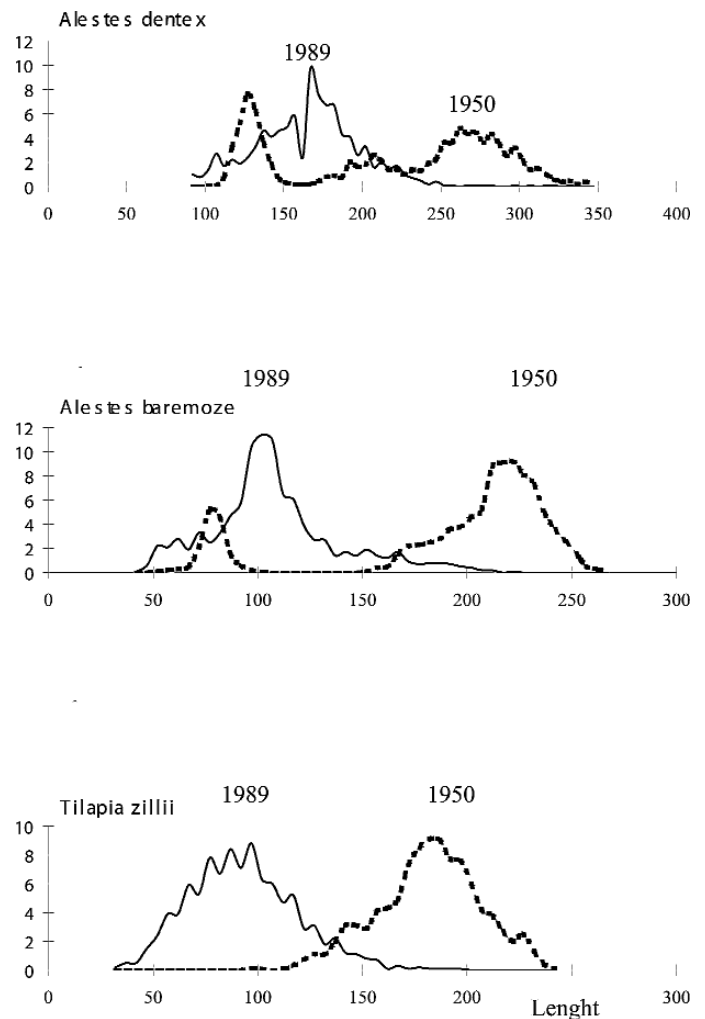
■ **Figure 6.** Evolution of catch length for Alestes dentex, Alestes baremoze and Tilapia zillii from 1950 to 1989 in the Central Delta of the Niger River (Laˆ 1995).

inland or coastal areas, far from the main urban settlements, thereby helping to slow down the rural exodus.

In Guinea, marine fish landings are about 120 000 tonnes versus 4 000 tonnes for freshwater fish. As a consequence, even if continental consumption and trading is locally important, it is negligible at a national level.

In Mali, the fisheries sector is of major importance in the national economy, as it contributes to food security, job creation and increases the national wealth. With the return of normal floods, the sector recently consolidated its functions concerning the maintenance of social balance in Malian populations (Breuil and Quensière 1995): with a 100 000 tonnes annual pro-

duction, the current fish consumption is about 10.5 kg habitant^{-1} y^{-1} versus 7.8 kg hb^{-1} yr^{-1} for meat consumption. The fishery sector generates 284 000 employment opportunities including 71 000 directly for production. This accounts for approximately 7.2 percent of the working population. With a gross added value of about 30 billion FCFA, the whole fishing network contributes approximately 4.2 percent to gross domestic product. The fisheries sector also contributes to the trade balance: over the last 20 years the marketing of fish has evolved under the impact of drought, lower catches and population growth, the last of which has led to an increase in fish consumption. Today, a significant proportion of fish formerly exported to Côte d'Ivoire, Ghana and Burkina Faso is now sold internally. Fish processing is essential because it is impossible to quickly distribute a product that is highly perishable. The proportion processed in Mali accounts for 75 percent of total catches. The major processing techniques are drying, smoking and burning. In spite of the use of chemicals such as K' Othrine and Gardona for slowing down fish deterioration, long storage involves significant losses of the processed fish, estimated between 15 and 20 percent by Coulibaly *et al*. (1992).

Three fish marketing channels can be identified starting from the fishing camps: (i) wholesale markets which first centralize, then redistribute the fish production towards distant areas; (ii) medium wholesale markets located in production and consumption centers; (iii) retail markets in cities and villages (Breuil and Quensière 1995). Fish is transported from fishing places by fishers themselves or their representatives, by tradesmen who move from camp to camp, or by wholesalers. Transport is generally by large canoes, trucks or vans. Trips between fishers camps and wholesale markets are simple and involve only a small number of middlemen whereas redistribution towards retail markets requires the intervention of many more.

In Niger, fish supply is limited but fish demand is also reduced by the low purchasing power of poten-

tial consumers. Fish consumption is about 0.3-0.5 kg hb^{-1} yr^{-1} versus 7 kg hb^{-1} yr^{-1} for meat consumption, but may reach 0.8-1.2 kg hb^{-1} yr^{-1} in urban environments (Lobet and Abdoulkadry 1993). This estimate does not take into account subsistence farming which could reach 15 to 20 percent of total production. Freshwater fish imports from Burkina Faso and Nigeria and fish exports to Nigeria have been stable over the last few years. Fresh fish coming from Mali could make a more important contribution since saltwater fish imports (nearly 1 000 tonnes of chinchard from Senegal and Ivory Coast) have stopped following the devaluation of the franc CFA in 1994.

In Nigeria, in 2000 the total fish landings were about 467 098 tonnes, with more than two thirds coming from artisanal and industrial marine fisheries. In the mid-1960s, estimates indicated that Nigerian fisheries annually harvested 120 000 tonnes of fish and imported 180 000 tonnes, mostly air-dried. In 2000, 236 801 tonnes came from coastal and brackish waters, 181 268 tonnes from inland rivers and lakes, 25 720 tonnes from aquaculture, 23 308 tonnes from industrial and marine fisheries and 557 884 tonnes were imported. The total fish consumption was 1 024 981 tonnes. The per caput supply was 6.95 kg hb^{-1} yr^{-1}. At that time the population of the Niger Delta was about seven million people and it is increasing at about three percent a year. The total Nigerian population is more than 110 million and represents an important demand for fish. In this context more than 500 000 tonnes of fish are imported as against an export of only 8 200 tonnes. Frozen fish is imported to supplement local production. Consumption of frozen fish increased nearly tenfold between 1971 and 1990. Imported frozen fish are usually small pelagic species originating from elsewhere in the region (e.g. S*ardinella* from Mauritania, horse mackerel from Namibia), but sizeable amounts of herring or mackerel are also imported from Europe, notably from the Netherlands. Retail traders buy the fish in blocks and, after thawing, usually sell it "fresh" or smoked. Prices of imported frozen fish are relatively low and often depress fish prices on local markets.

MAIN REASONS BEHIND THE DECLINE IN FISH CATCHES

The upper and middle Niger River have been strongly modified from 1950 to 1990 by two consecutive droughts, by the building of dams and by a rapid intensification of fishing activities. The impact was mainly felt in the Central Delta. The two drought periods, which occurred in 1973 and 1984, were responsible for a decrease in the flow of the rivers Niger and Bani. Consequently, there was a modification of the floodplains and the areas flooded were considerably reduced, as was the duration of floods. From 1969 to 1986 floodplains contracted from 20 000 km^2 to 5 000 km^2 and their fish production decreased from 90 000 tonnes to 45 000 tonnes (Figure 7). The decrease in

lowering the already reduced flood flows. The annual loss in total catches in the Central Delta, due to the two dams, was estimated to be 5 000 tonnes (Laë 1992a).

The increase in fish yields observed since the drought period (40 kg ha^{-1} y^{-1} in 1968 compared to 120 kg ha^{-1} y^{-1} now) comes from an increase in the concentration of fish, an increase in intra- and inter-specific fish competition and an increase in vulnerability to fishing equipment. Considerably higher fishing intensity is certainly responsible for the increasing dominance of young fish: in 1950 the average age at capture of *Alestes dentex* and *A. baremoze* was over 2 years (Daget 1952) and that of *Tilapia zillii* was almost 3 years (Daget 1956). In 1990, many species were bei
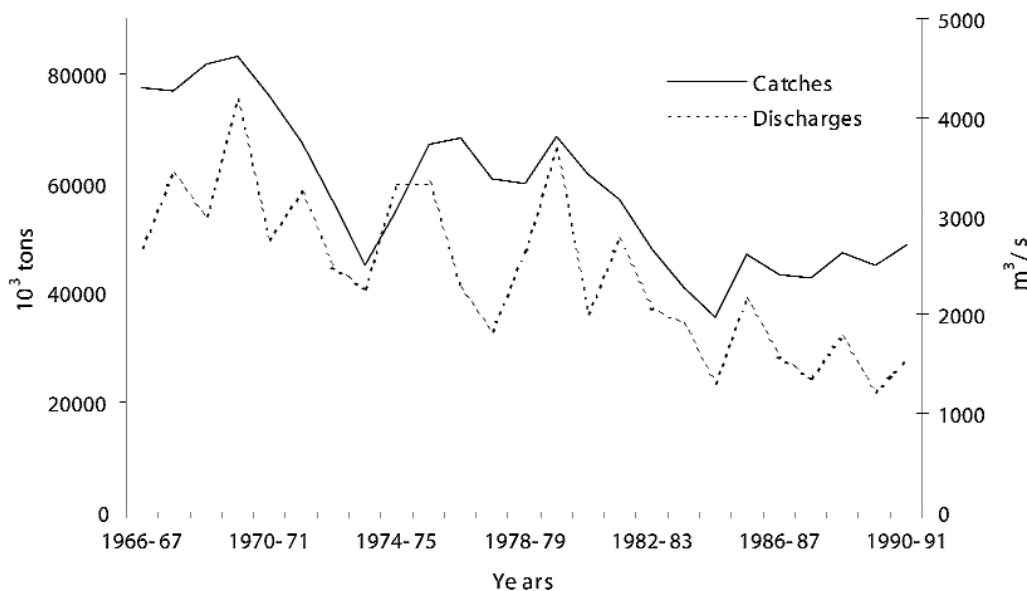
■ **Figure 7.** Plots of catch (metric tonnes) in the central delta of the Niger and Niger River discharge at Koulikoro upstream of the delta (La° & Mah° 2002).

fish landings is directly linked to the reduction of flooded land (Welcomme 1986; Laë 1992b) and, knowing the water discharge entering the delta at the beginning of the flow, it is possible to predict fish catches for the following fishing year (Laë and Mahé 2002).

Markala dam, built in 1943 and Selengue dam, built in 1984, increase the effects of drought by further

caught in their first year (Laë 1992b), including *Labeo senegalensis* (86 percent of 0+ in catches), *Brycinus leuciscus* (82 percent), tilapias (82 percent for *Sarotherodon galilaeus,* 78 percent for *Tilapia zillii* and 68 percent for *Oreochromis niloticus)*, *Lates niloticus* (76 percent) and *Chrysichthys auratus* (72 percent). By contrast, other species such as *Chrysichthys nigrodigitatus*, *Alestes dentex*, *Auchenoglanis biscutatus*, *Brycinus nurse* and *Alestes*

baremoze seem to be fished at a greater age as the percentage of 0+ fish in the catches varies between 20 percent and 40 percent. The weighted average of all catches showed that 69 percent were 0+ fish. The increase in productivity thus comes from younger fish stocks the growth rates of which have declined and longevity increased with fish weight (Peters 1983).

Another factor responsible for the decline in fish stocks is watershed degradation as a result of the combined effect of drought and human activities (itinerant agriculture, overgrazing, illegal cutting of wood). In Niger, this results in an increase in erosion and higher silt loadings, which, in turn, leads to formation of considerable sandbanks. Muddy habitats are destroyed, water volume is reduced and water quality deteriorates, as indicated by a high turbidity and low dissolved oxygen concentrations.
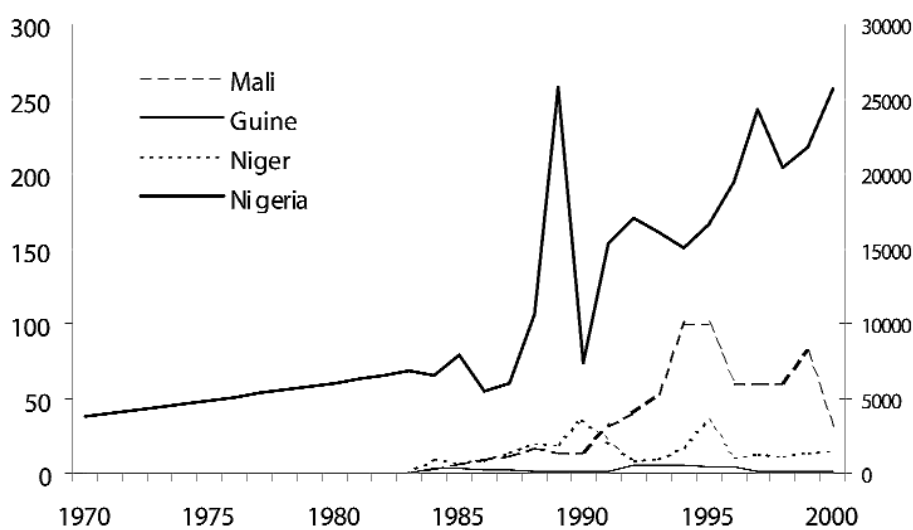
FISH FARMING

Aquaculture has not been a traditional practice in Africa and remains a new form of food and income generating activity, in spite of various efforts to improve its development and utilization since the 1950s. Aquaculture statistics (Figure 8) in West Africa are often not very accurate because of the relatively low economic profile of the sector and the lack of financial resources to monitor developments and rural production. However, one can distinguish between traditional and modern fish farming.

Traditional fish farming: Fishers used to build brush parks in some backwaters that are joined with the river during floods, in order to retain the largest fish (Oswald, Mikolasek and Kodako 1998). After several months without fishing, a collective fishing is organized during the dry season by traditional authorities. This practice is widespread in Mali, Niger and Nigeria where temporary ponds are also used for fish stocking and grow-out. In most cases, landowners are still in charge of fish resources. In Niger traditional acadjas are also used in Dole pond (Oswald *et al*. 1998) where fermented bran (1 or 2 kg) may be added every day. The time before harvesting can vary between 3 weeks and six months.

Modern fish farming: Malian aquaculture is of a recent date and aims to make good the deficits in fish production caused by the Sahelian droughts (Breuil and Quensière 1995). In the past several financial backers were involved in aquaculture development:

■ **Figure 8.** Annual fish farming production (metric tonnes) in continental waters of Guinea, Mali, Niger and Nigeria. Production of Guinea, Mali and Niger is very low (< 100 tonnes/year). From FAO statistical data.

USAID from 1979 to 1982 in the irrigated perimeters of San, OUA in 1986 to encourage fish culture in ponds of the irrigated channels of the Niger Office; a French NGO (AFVP) in 1987 to improve village fish culture (200 ponds); UNDP from 1987 to 1992 supporting a fish farming development project. The projects mainly concerned *Oreochromis niloticus* and *Clarias gariepinus* (village pisciculture). The strong competition between intensive fish culture, mainly for markets and prices and fishing did not allow its development. Commercial fish culture is not adapted to local conditions whereas auxiliary fish culture using improved fishponds finds some success with fishers. For a long time Niger sought fish farming techniques that would be best suited to its situation as a land-locked country. Fish farming is often associated with major projects such as intensive breeding of tilapias in the Niger River (Mikolasek *et al.* 1997) or extensive fish production in ponds (Doray *et al.* in press). Except for a few operations where the actors are easily identifiable, nothing is known about local fish culture. However, effective fish farming exists on a small scale in Niger, independently of international projects and funding (Mikolasek, Massou and Allagdaba 2000). These practices started recently, mainly from the 1980s. Private initiatives and local know-how emphasize the real opportunity for aquaculture development although this remains a minor activity at national level (Mikolasek *et al.* in press).

The recent development of the sub-sector has not been homogeneous and only a few countries have registered significant increases in production. Nigeria, one of the Niger basin countries, made significant progress during the last 30 years, with a growth in fish production from 4 000 tonnes in 1970 to 25 720 tonnes in 2000. Nigeria is the most important aquaculture producer in the sub-Saharan Africa. More than twenty species of fish are farmed, with fish production mainly based on tilapias, catfishes and cyprinids. While fishers are not entirely involved in fish farming activities on the Niger River, the fish supply crisis is leading

local and state government extension officers to discuss this as an alternative fish production strategy for poverty alleviation and food security strategy.

PRINCIPAL MANAGEMENT MEASURES

Major challenges to be faced by integrated management and community-based management

Sustainable productivity of the Niger River fisheries depends both on the quality of the aquatic environment and on the hydrological conditions. Strong inter-annual variability of the natural environment points to the need for resilience in the fish species. The following factors make the plateau model appropriate for the analysis and management of fisheries: intensive fishing activities would not result in a decrease in total catch, as usually suggested and fish landings would remain relatively constant even when fishing pressure is increased threefold beyond the point when the asymptote is reached. In floodplain-river ecosystems the existence of a leveling off or plateau has been observed by many authors (Ryder 1965; Welcomme 1989; Laë 1992b, Laë 1997) and simulated (Welcomme and Hagborg 1977; Morand and Bousquet 1994; Bousquet 1994). Adoption of this model will strongly reduce the negative direct impact of fishing effort and fish landings on fish. Indeed, the risk of true biological overexploitation (collapse of fish stocks by overfishing) is very low for these artisanal fisheries, as long as destructive techniques (poison, explosives, etc.) are not used and as long as a minimal quantity of spawners survives at the end of the low water season, i.e. at the end of the fishing period.

This model emphasizes the environmental conditions as being particularly significant. This is a major challenge because, except for natural drought, the degradation of the river observed for several decades is generally caused by economical activities not involved in the fishing sector - management of floodplains for rice, pumping and water uptake for different agricultural crops, arms and channels filling due to wind, alluvial inputs related to desertification or deforestation of

closed areas, gravel extraction for construction, pollution from pesticides used in agriculture, industrial or urban wastes, river bed degradation and pollution by gold extraction activities, oil and gas production.

Another challenge for Sahelian fisheries management is to arbitrate between the various private or public fisheries stakeholders. The goal is to better respond to economical or socio-political demands, which usually represent divergent interests. For example if it is accepted that fish production in river and floodplain ecosystems is limited by natural conditions, which group of fishers should be given access to the fishery: the migrant fishers (professional), or the resident ones (often farmer-fishers)? The choice is difficult because the level of legitimacy of the two groups is not the same, the results in terms of fishing performance (production reliability) will not be the same and the benefit received by local managers will consequently differ. Similar arguments pertain in brackish waters where artisanal and industrial fisheries are in competition for different ecophases of the same fish species.

The choice of which processing and marketing sectors to promote when people involved in fresh or processed fish trade are rarely the same and added values are differently shared by these two sectors is difficult. It is, similarly, difficult to decide which institutions (government services, micro- or macro-local authorities, professional associations) should benefit from receipts and taxations collected from fishing, marketing and distribution activities.

It is clear that the main needs as regards fishery management in the Niger basin relate to two major areas, namely environmental degradation and socio-economical priorities.

NATIONAL AND INTERNATIONAL LAWS AND INITIATIVES

Until the beginning of the 1990s in Mali, as in the other countries of the Niger basin, the government was the owner of all water areas. For this reason, the government tried to apply, at least in theory, a centralized management model. This was based on the payment of licenses for fishing rights, on the supply of technical and logistic support and technology transfer and on the enforcement of a national regulation to prevent overfishing (e.g.: minimum mesh sizes). This model of management responded imperfectly to the management needs, as it was in total contradiction with the former traditional practices and this has caused many problems. Another weakness of this system was that it was to be uniformly applied to the whole country, which prevented the adaptation of management to the variety of natural environments and fishing practices. The government mode of management, largely based on coercion, required significant institutional costs. All these shortcomings pointed to the need for a change in the contractual relations between the official owner (government) and the users of the fish resources.

At the end of the 1980s Mali tried to change its fishing governance processes by improving the involvement of stakeholders in management. This process was strongly accelerated with the introduction of a decentralization policy in 1995. It remains to be seen whether the new fishing management model is efficient in dealing with the key questions of Sahelian fisheries management.

Environmental policies are both limited by strong financial problems and hard resistance to changes resulting from various pressure groups that are water or watershed users. Nevertheless, little progress has been achieved on river environment conservation in spite of Mali being a member of the Niger Basin Authority and in spite of the recent creation of the River Niger Agency in Mali. The relative weakness of fisheries administration in Mali does not allow it to strongly defend the interests of the sector within national authorities in charge of the regional planning. However, implementation of the decentralization policy allows real progress with regard to problems of

arbitrations on socio-economic priorities at local level. Elements of policies for the establishment of participation and partnership conditions with fishing communities have been applied by public administrations. Among them are the following:

The capacity to adopt specific regulations in the local context: legislation makes provision for development of differentiated rules such as "local conventions", which can vary according to the regions and fishing places. There already exists a decentralized administrative structure (e.g. Office of Rural Development of Selengue for Lake Selengue) for each large lake fishery endowed with a significant competence for managing their fisheries.

The creation of recognized authorities allowing the participation of communities in the development, implementation and supervision of management measures: these are the "fisheries councils", which will assist elected representatives of territorial communities in their decisions concerning fishing.

The possibility to restrict open access and to implement local management: in 1995 legislation introduced the concept of "piscicultural land" at the level of local authorities (specifically rural communes established by decentralization), which allows them to control fishing pressure on fish resources, in accordance with the new prerogatives that the decentralization laws confer to them.

Decentralization empowers local authorities to manage the fish resources of government land (the Niger River and lakes). Two conditions are required: local authorities have to make an official request and to prove that they are able to deal with the management of the resources by developing a planning process. Taxes collected as part of this management could then be paid, partly, to the general budget of the local collectives, a quota being reassigned to the government.

In Niger, a number of inter-state organizations cooperate in management of the Niger River resources: the Niger Basin Authority (NBA), the Authority for Development of Liptako-Gourma Area (ALG), AGRHYMET and ACMAD. In addition, cooperation agreements concerning water resource management exist between Niger and Mali, Niger and Nigeria. It is now accepted that development of capture fisheries and fish farming, which is a priority of the government, must be considered through a transfer of responsibilities from the government to a civil society and through promotion of local initiatives and the private sector. The framework could rely on the three following: (i) participative and local management of the river ecosystem (conservation) and fish resource by fisher communities; (ii) fishery management of the permanent and temporary ponds by the local populations; (iii) development and integration of fish farming in irrigated culture areas.

The first two rest on: (i) know-how and existing initiatives (Oswald *et al*. 1998; (ii) a process moving toward local development as part of community-based management (water and fish); (iii) an already elaborate legal tool allowing public property management by a private person; and (iv) biotechnical models for fish community management.

In the short term, this approach requires legal work to draw up enforcement texts within the fisheries law. In the longer term, socio-juridical studies are needed to identify organisational structures to be proposed to managers and operators. This process requires a good knowledge of both fish resource appropriation and management styles by local people and existing production systems.

The main expected results are: creation of fishing reserves, better protection of floodplains, better use of traditional knowledge, harmonization of management rules between the different countries sharing these resources, better local communities liability in

resource management and better control of fish handling techniques. All these measures must lead to the autonomy of the future organization structures.

In Nigeria, the Code of Conduct for Responsible Fisheries (CCRF) that was prepared and adopted by governments under the aegis of the United Nations Food and Agriculture Organization, is being promoted as a strategy for fisheries management nationally as well as regionally. Thus, Nigeria and 25 other West and Central African countries participating in the on-going Sustainable Fisheries Livelihood Program by DFID and FAO are obligated to bring this document to the notice of all fishing communities within the country. Currently, the DFID/FAO Sustainable Fisheries Livelihood Program (SFLP) is the platform that is being used to disseminate this information. It is hoped that capacity building of the extension agents will in the long run improve the promotion of SFLP and CCRF which will lead to rehabilitation of the aquatic resources in particular fish species that are at risk of extinction in the upper and lower basins of the Niger River.
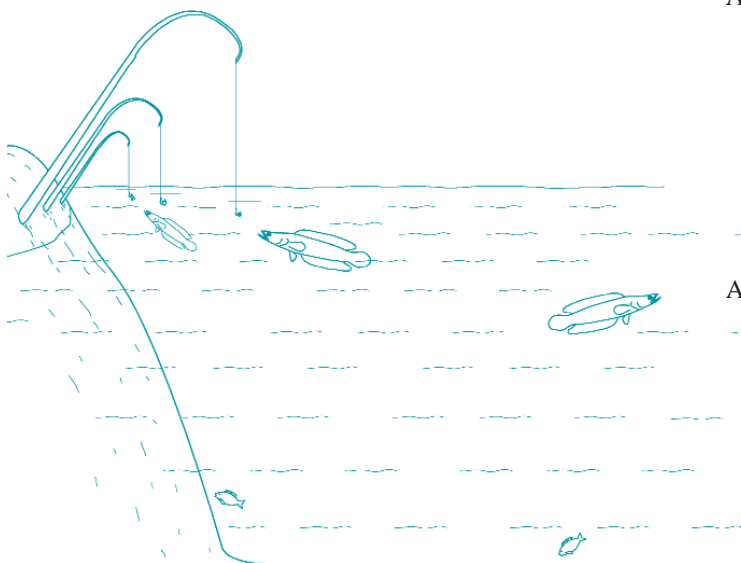
REFERENCES

Adeniji E.O. 1975. Observations on agriculture and fisheries downstream of the Kainji dam. *In* A.M.A. Imevbore & O.S. Adegoke, eds. *The ecology of lake Kainji, the transition from river to lake*. Ile-Ife, Nigeria, University of Ife Press. pp. 181-186.

Akinyemiju O.A. 1987. Invasion of Nigerian waters by water hyacinth. *J. Aquat. Plant Manag.*, 25: 24-26.

Akinyemiju O.A. 1993a. *Herbicidal control of water hyacinth: A pilot demonstration at Ere fishing channel, Ogun State, Nigeria.* A report submitted to Ogun State Agricultural Development Project OGADEP, Abeokuta, Nigeria.

Akinyemiju O.A. 1993b. *Herbicidal control of water hyacinth at Abiala Creek, Delta State, Nigeria.* A Final Report for Shell Petroleum Development Company, Warri, Nigeria.

Akinyemiju O.A, eds. 1994. *Baseline and post-impact ecological studies following application of Glyphosate to control water hyacinth at Abiala Creek, Delta State, Nigeria.* A Final Report for Shell Petroleum Development Company, Warri, Nigeria.

Akinyemiju O.A. & Imevbore A.M.A. 1990. *Herbicidal control of water hyacinth in Nigeria: A field pilot demonstration at Kofawei Creek, Igbokoda, Ondo State, Nigeria.* A Final Report submitted to the Presidency, Federal Republic of Nigeria, Lagos.

Albaret J.J. 1994. Les poissons: biologie et peuplements. *In* Durand, Dufour, Guiral & Zabi, eds. *Environnement et ressources aquatiques de Côte d'Ivoire. Tome II, Les milieux lagunaires.* pp. 239-279. Paris, Éditions de l'ORSTOM. 550 pp.

Awachie J.B.E. & Walson E.C. 1978. Atalla fishery of the lower Niger, Nigeria. *CIFA Tech. Pap./Doc. Tech. CPCA,* N° 5: 296-311.

Bacalbasa-Dobrovici N. 1971. Rapport au Gouvernement du Niger sur le Développement et la Rationalisation de la Pêche sur le Fleuve Niger. AT N 2913. Rome, FAO/PNUD.

Balogun J.K. 1988. *The bio-ecology of the Niger perch, Lates niloticus Linn. in the Kainji Lake*. Department of Zoology, University of Ibadan, Nigeria. (Doctoral dissertation)

Balon E.K. & Coche A.G. 1974. Lake Kariba: A man-made tropical ecosystem in Central Africa, *Monogr. Biol.,* 24: 767 pp.

Baran E. 1995. Dynamique spatio-temporelle des peuplements de poissons estuariens en Guinée - relations avec les milieux abiotiques. Université de Bretagne Occidentale, France. 225 pp. (Doctoral dissertation)

Blaber S.J.M. 1997. Fish and fisheries of tropical estuaries. Chapman and Hall. *Fish and Fisheries Series,* 22: 367 pp.

Blache J., Miton F., Stauch A., Iltis A. & Loubens G. 1964. Les poissons du bassin du Chad et du bassin adjacent du Mayo Kebbi. Étude systématique et biologique. *Mém. ORSTOM*, 4: 483 pp.

Blanc M., Daget J. & d'Aubenton F. 1955. Recherches hydrobiologiques dans le bassin du moyen Niger. *Bull. Ifan*, 17, Sér. A. 17 pp.

Benech V. & Dansoko F. 1994. La reproduction des espèces d'intérêt halieutique. *In* J. Quensière ed. *La pêche dans le Delta Central du Niger.* IER-ORSTOM-KARTHALA. pp. 10-25.

Bousquet F. 1994. Des milieux, des poissons, des hommes: Étude par simulation multi-agents. Le cas de la pêche dans le Delta Central du Niger. Lyon University. (Masters thesis)

Breuil C. & Quensière J. 1995. Éléments d'une politique de développement durable des pêches et de la pisciculture au Mali. MLI/91/005-PAMOS, Rome, FAO. 89 pp.

Brunet-Moret Y., Chaperon P., Lamagat J.P. & Molinier M. 1986a. Monographie hydrologique du fleuve Niger. Tome I – Niger Supérieur, Éditions de l'ORSTOM, *Coll. Monographies Hydrologiques*, 8. 396 pp.

Brunet-Moret Y., Chaperon P., Lamagat J.P. & Molinier M. 1986b. Monographie hydrologique du fleuve Niger. Tome II – Cuvette lacustre et Niger Moyen, Éditions de l'ORSTOM, *Coll. Monographies Hydrologiques,* 8. 506 pp.

Chikwenhere G.P. 1994. Biological control of water hyacinth *Eichhornia crassipes* in Zimbabwe, result of a pilot study. *FAO Bulletin Phytosanitaire*, Vol. 424: 185-190.

Coenen E. 1986. *Résultats des études ichthyo-biologiques sur le Niger*. Projet Développement des Pêches, Ner/79/018.

Coulibaly A., Gerbe A., Stomal B., Weigel J.Y. 1992. *Etude des filières traditionnelles de transformation du poisson au Mali.* Rapport Iare-Isfra-Orstom-Resed. 155 pp.

Daddy F., Wari M. & Mohammed A. 1988. Wetland studies: Natural resources evaluation of Tatabu floodplain and the restoration of Lake Tatabu Ndakolowu, Niger State, Nigeria. *NIFFR Annual Report*, 50-60.

Daget J. 1949. La pêche dans le Delta Central du Niger. *Journal de la Société des Africanistes*, 191: 1-79.

Daget J. 1952. Mémoire sur la biologie des poissons du Moyen Niger. Biologie et croissance des poissons du genre Alestes. *Bull. Inst. Fr. Afr. Noire A*, 14: 191-225.

Daget J. 1954. Les poissons du Niger Supérieur, *Mémoire de l'IFAN*, No. 36, Dakar.

Daget J. 1956. Mémoire sur la biologie des poissons du Moyen Niger. Recherches sur *Tilapia zillii* Gerv. *Bull. Inst. Fr. Afr. Noire* A, 18: 165-233.

Daget J. 1962. Les poissons du Fouta-Djalon et de la basse Guinée. *Mem. IFAN*, 65. 207 pp.

Deceuninck V., 1989. Etudes nationales pour l'aquaculture en Afrique. 24. Mali. *FAO Fisheries Circular*. 770.24. Rome, FAO.

Dembele 1994. La jacinthe d'eau, un nouveau fléau pour les cours d'eau du Mali. *Sahel Pvinfo CILSS/UCTR/PV No. 63*, Juillet 1994: 12-14.

Doray M., Mikolasek O., Boureima A. & Oswald M. Savoir-faire paysan et exploitation piscicole de mares temporaires en zone sahélienne: cas du village de Tafouka Niger. *In* D. Orange, R. Arfi, M. Kuper, P. Morand & Y. Poncet, eds. *Gestion Intégrée des Ressources Naturelles en Zone Inondables Tropicales*. Paris: IRD. (forthcoming)

Dublin-Green C.O. 1990. The foraminiferal fauna of the Bonny Estuary. A baseline study. *Technical paper of the Nigerian Institute of Oceanography and Marine Research*, N 64: 1-27.

Durand J.R. 1983. The exploitation of fish stocks in the Lake Chad region, Lake Chad: Ecology and productivity of a shallow tropical ecosystem. *In* C.J.P., D.J.R. & L.C. eds. *Monographiae Biologicae*, 53: 425-481.

Egborge A.B.M. 1998. *Some solutions to water problems in the Niger Delta*. Paper presented at the First Urhobo Economic Summit on Oil, Gas and Sustainable Development, Nov. 27-28 1998.

Fagade S.O. & Olaniyan C.I.O. 1972. The biology of the West African shad, *Ethmalosa fimbriata* Bowdich in the Lagos lagoon. *Journal of Fish Biology,* 4: 519-533.

Fagade S.O. & Olaniyan C.I.O. 1973. The food and feeding interrelationship of the fishes in the Lagos lagoon. *Journal of Fish Biology*, 5: 205-227.

Fagade S.O. & Olaniyan C.I.O. 1974. Seasonal distribution of the fish fauna of the Lagos lagoon. *Bulletin de l'IFAN 34 A*. pp. 244-252.

Fay C. 1989. Systèmes halieutiques et espaces de pouvoir: Transformation des droits et des pratiques de pêche dans le Delta Central du Niger Mali, 1972-1982. *Cah. Sci. Hum.*, 251-2: 213-236.

Federal Department of Fisheries FDF 2000. Fisheries statistics of Nigeria. Victoria Islands, Lagos, Nigeria.

Gallais J. 1967. Le Delta intérieur du Niger, étude de géographie régionale. *Mém. IFAN*, Dakar-Paris, Larose, Vol. I & II. 621 pp.

Harley K.L.S. 1994. *Eichhornia crassipes* Mart. Solms-Laubach. *In* R. Labrada & J.C. Parker, eds. *Weeds management for developing countries*. pp. 123-124. *FAO Plant Production and Protection Paper No. 120*. Rome, FAO. 384 pp.

Hughes R.H. & Hughes J.S. 1992. *A Directory of African Wetlands*. IUCN, Gland, Switzerland and Cambridge, UNEP, Nairobi, Kenya, WCMC, Cambridge, UK. 820 pp.

Ita E.O. 1978. An analysis of fish distribution on Kainji Lake, Nigeria. *Hydrobiologia*, 58: 233-244.

Ita E.O. 1984. Lake Kainji, Nigeria. *In* J.M. Kapetsky & T. Petr, eds. Status of African reservoir fisheries. *FAO CIFA Technical Paper No. 10.* pp. 44-104.

Ita E.O. 1993. Inland fisheries resources of Nigeria. *CIFA Occasional Paper No. 20.* Rome, FAO. 120 pp.

Kassibo B. 1990. L'organisation sociale de la pêche dans le Delta Central du Niger. Genèse et évolution des systèmes de production halieutique. *In Études halieutiques du Delta Central du Niger.* ORSTOM-IER, actes de l'atelier de Bamako, 20-23 Novembre 1990. 38 pp.

Kodio A., Morand P., Dienepo K. & Laë R. 2002. La dynamique de la pêcherie du Delta Intérieur du Niger revisitée à la lumière des données récentes. Implications en termes de gestion. *In* D. Orange, R. Arfi, M. Kuper, P. Morand & Y. Poncet, eds. *Gestion intégrée des Ressources Naturelles en zone inondable tropicale.* IRD éditions, Colloques et Séminaires. (sous presse)

Koné M. 1991. Pêches collectives et aménagement des mares dans le Delta Central du Niger. Rapport de stage, Montpellier, USTL-CREUFOP. 44 pp.

Laë R. 1992a. Impact des barrages sur les pêcheries artisanales du Delta Central du Niger. *Cahiers d'Agricultures*, 2: 14-21.

Laë R. 1992b. Influence de l'hydrologie sur l'évolution des pêcheries du Delta Central du Niger de 1966 à 1989. *Aquatic Living Resources*, 52: 115-126.

Laë R. 1994. Effects of drought, dams and fishing pressure on the fisheries of the Central Delta of the Niger River. *International Journal of Ecology and Environmental Sciences*, 20: 119-128.

Laë R. 1995. Climatic and anthropogenic effects on fish diversity and fish yields in the Central Delta of the Niger River. *Aquatic Living Resources*, 81: 45-58.

Laë R. 1997. Does overfishing lead to a decrease in catches and yields? An example of two West African coastal lagoons. *Fish. Manag. Ecol.*, 3: 101-116.

Laë R., Maiga M., Raffray J. & Troubat J.J. 1994. Évolution de la pêche. *In* J. Quensière, eds. *La pêche dans le Delta Central du Niger*, IER-ORSTOM-KARTHALA. pp. 143-163.

Laë R. & Morand P. 1994. Typologie des cycles d'activités halieutiques: ménages sédentaires et petits migrants du secteur de Mopti. *In* J. Quensière ed. *La pêche dans le Delta Central du Niger*, IER-ORSTOM-KARTHALA. pp. 287-294.

Laë R. & Weigel J.Y. 1994. Adaptabilité des pêcheurs aux changements environnementaux et économiques. *In* J. Quensière ed. *La pêche dans le Delta Central du Niger*, IER-ORSTOM-KARTHALA. pp. 295-310.

Laë R. & Weigel J.Y. 1995. Diagnostic halieutique et propositions d'aménagement: l'exemple de la retenue de Selengue Mali. FAO-PAMOS. 73 pp.

Laë R. & Mahé G. 2002. Crue, inondation et production halieutique: Un modèle prédictif des captures dans le Delta Intérieur du Niger. *In* D. Orange, R. Arfi, M. Kuper, P. Morand & Y. Poncet, eds. *Gestion intégrée des Ressources Naturelles en zone inondable tropicale.* Paris: Éditions de l'IRD, Colloques et séminaires, à paraître.

Lelek A. & El Zarka S. 1973. Ecological comparison of the preimpoundment and postimpoundment fish faunas of the Niger River and Kainji lake, Nigeria. *Geophys. Monogr.*, 17, 655-660.

Lévêque C. 1995. River and stream ecosystems of north-western Africa. *In* C.E. Cushing, K.W. Cumins, G.W. Minshall, eds. *Ecosystems of the world*: *River and stream ecosystems*. Amsterdam NDL, Elsevier; Lausanne, CHE. pp. 519-536.

Lévêque C., Paugy D. & Teugels G. 1990. La faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest, tome I et II, ORSTOM/MRAC, *Collection Faune Tropicale*, No. XXVIII. Paris, France.

Lobet H. & Abdoulkadry D. 1993. *Enquête sur la Structure de consommation du poisson et le comportement d'achat et de motivation du consommateur*. Niamey, Ministère de l'Hydraulique et de l'Environnement de la République du Niger Action de Développement de l'Aquaculture au Niger. 56 pp.

Lowe-McConnell R.H. 1975. *Fish communities in tropical freshwaters: Their distribution ecology and evolution*. London and New York, Longman. 337 pp.

Mahé G., Bamba F., Orange D., Fofana L., Kuper L., Marieu B., Soumaguel A. & Cissé 2002. Dynamique hydrologique du Delta Intérieur du Niger Mali. *In* D. Orange, R. Arfi, M. Kuper, P. Morand & Y. Poncet. eds. *Colloques et séminaires*, Éditions de l'IRD, Paris. (à paraître)

Malvestuto S.P. & Meredith E.K. 1989. Assessment of the Niger River fishery in Niger 1983-85 with implications for management. *In* D.P. Dodge ed. *Proceedings of the international large rivers symposium. Can. J. Fish. Aquat. Sci. Spec. Publ.*, 106: 533-544.

Marie J. & Témé B. 2002. *Gestion des ressources et aménagement du fleuve Niger. Des connaissances scientifiques pour la décision publique*. Paris, IRD Éditions. 11 pp.

Matthes H. 1993. *Rapport de la mission d'évaluation de la pêche continentale et de l'Aquaculture en République de Guinée*. Rome, FAO. 94 pp.

Mikolasek O., Patout O., Lazard J. & Massou M. 1997. Le développement à l'épreuve du concret: l'exemple de l'aquaculture en cages flottantes sur le fleuve Niger. *In* K. Fitzsimmons ed. *Tilapia aquaculture, proceedings from the fourth international symposium on Tilapia in aquaculture volume 2*. pp. 483-498. Orlando, Florida, November 9-12, 1997. Northeast Regional Agriculture Engineering Service.

Mikolasek O., Massou M. & Allagdaba E. 2000. Appropriation et gestion des espaces piscicoles nigériens par les populations villageoises riveraines. In: D. Gascuel, P. Chavance, N. Bez & A. Biseau, eds. *Les espaces de l'halieutique*. Paris, IRD. pp. 517-526.

Mikolasek O., Oswald M., Boureima A. & Massou A.M. Savoir-faire paysan et pisciculture au Niger. Communication in Colloque International sociétés rurales au Sahel, quel avenir Niamey, Niger, 18 et 19 Novembre 1999. Co-organisé par l'Université de Lausanne Suisse et l'Université Abdou Moumouni de Niamey. (sous presse)

Morand P., Quensière J. & Herry C. 1990. Enquête pluridisciplinaire auprès des pêcheurs du Delta Central du Niger: plan de sondage et estimateurs associés. *ORSTOM ed. SEMINFOR,* 4: 195-211.

Morand P. & Bousquet F. 1994. Modélisation de la ressource: Relations entre l'effort de pêche, la dynamique du peuplement ichtyologique et le niveau des captures dans un système fleuve-plaine. *In* J. Quensière ed. *La pêche dans le Delta Central du Niger*. IER-ORSTOM-KARTHALA. pp. 267-281.

Ministere des Ressources Naturelle et de L'Elevage. 1975. Direction nationale des eaux et forêts. Opération Pêche Mopti, Rapport Annuel. Mopti, Mali.

NEDECO Netherlands Engineering Consultants. 1959. *River studies and recommendations on improvement of Niger and Benue*. Amsterdam, The Netherlands, North Holland Publishing Company.

NEDECO Netherlands Engineering Consultants. 1961. *The waters of the Niger Delta*. The Hague, Netherlands Engineering Company.

Obot E.A. 1984. Studies on the productivity of *Echinochloa stagnina* beauv. *In* The Kainji Lake Basin of northern Nigeria. University of Ife, Nigeria. (Doctoral dissertation)

Okaeme A.N., Stopford G., Haliru M. & Wari M. 1989. Survey of aquatic birds and their contribution to Lake Kainji fisheries. *In* National Institute for Freshwater Fisheries Research, Annual Report. pp. 28-30.

Olaleye V.F. & Akinyemiju O.A. 1996. Effect of glyphosate N-Phosphonomenthyl glycine application to control *Eichornia crassipes* Mart. on fish composition and abundance in Abiala Creek, Niger Delta, Nigeria. *J. of Environmental Management,* 47: 115-122.

Olaleye, V.F. & Akinyemiju O.A. 1999. Flora and fauna of Abiala Creek, Niger Delta, Nigeria. *J. of Aquatic Sciences,* 14: 61-65.

Olaleye, V.F. & Akinyemiju O.A. 2002. Planktonic community regeration in a post-herbicidal water hyacinth *Eichhornia crasssipes* Mart. *J. of Aquatic Sciences,* 17: 21-26.

Oswald M., Mikolasek O. & Kodako Y. 1998. *Projet de développement de la pisciculture en milieu rural, Marché n 91/005/MHE/DFPP - Rapport final*. Niamey, Ministère de l'Hydraulique et de l'Environnement du Niger Direction de la Faune de la Pêche et de la Pisciculture DFPP / CIRAD-EMVT, Juillet 1998. 97 pp.

Otobo F.O. 1978. Commercial fishery in the middle Niger, Nigeria. *CIFA Tech. Pap./Doc. Tech. CPCA, N5*. pp. 185-208.

Peters R.H. 1983. *The ecological implications of body size*. Cambridge, UK, Cambridge University Press. 329 pp.

Petts G.E., Imhof J.G., Manny B.A., Maher J.F.B. & Weisberg S.B. 1989. Management of fish populations in large rivers: A review of tools and approaches. *In* D.P. Dodge ed. *Proceedings of the international river symposium. Can. J. Fish. Aquat. Sci. Spec. Publ.*, 106: 578-588.

Price T.L. 1991. Gestion "scientifique" et connaissances locales: Le projet pêches au Niger. *In* G. Dupré ed. *Savoirs paysans et développement*. Paris, Editions Karthala. pp. 473-487.

Quensière J. ed. 1988. Études halieutiques du Delta Central du Niger. Premiers résultats. *In* ORSTOM-INRZFH *Enquête statistique auprès des pêcheurs*. Actes de l'atelier de Bamako, 7-9 Juin 1985. 5 pp.

Quensière J. ed. 1994. La pêche dans le Delta Central du Niger, approche pluridisciplinaire d'un système de production halieutique, IER/ORSTOM/KARTHALA, Paris, France.

Raimondo P. 1975. Monograph on operation fisheries, Mopti, in consultation on fisheries problems in the Sahelian Zone, Bamako, Mali 13-20 Nov. 1974. *CIFA Occas. Pap.*, 4: 294-311.

Reed W. 1967. *Fish and fisheries of Northern Nigeria*. Ministry of Agriculture, Northern Nigeria.

Roberts T.R. 1975. Geographical distribution of African freshwater fishes. *Zool. J. Linn. Soc.*, 57: 249-319.

Robinson D., 1997. *Ogoni: The Struggle Continues*. World Council of Churches, Nigeria. 106 p.

Ryder R.A. 1965. A model for estimating the potential fish production of north temperate lakes. *Transactions of the American Fisheries Society,* 94: 214-218.

Sagua N.O. 1978. The effect of Kainji Dam, Nigeria on the fish production in the River Niger below the dam at Faku. *CIFA Tech. Pap./Doc. Tech. CPCA No. 5*. pp. 209-294.

Scott, J.S., 1966. Report on the fisheries of the Niger Delta special area. Harcourt. Niger Delta Dev. Board Port. 109 pp.

Sheves G. 1981. *Établissement de centres communautaires de pêche artisanale au Niger, analyse économique.* FAO/UNDP, Document de Travail No. 4. 37 pp.

Stauch A. 1966. Le bassin Camerounais de la Bénué et sa pêche. *Mém. ORSTOM 15*. 152 pp.

Talatou H. 1995. Synthèse des activités de pêche de 1974 à 1990. *In Atelier national sur la pisciculture et la pêche au Niger, Kollo du 26 au 30 Décembre 1994*. pp. 54-58. Kollo: Ministère de l'Hydraulique et de l'Environnement de la République du Niger & Mission Française de Coopération et d'Action Culturelle Action de Développement de l 'Aquaculture au Niger.

Van der Knaap M., Malam A., Bouba G., Pala A. & Zourmba P. 1991. Résultats du recensement des pêcheurs autour du lac Lagdo, Février 1990, MEAVSB, Rapport NEB/PECHE/TECH/91/01.

Van den Bossche, J.P. & Bernacsek G.M., 1990. Source book for the inland fishery resources of Africa, *CIFA Technical Paper*, 182. Rome, FAO. 411 p.

Welcomme R.L. 1972. The inland waters of Africa, *CIFA Tech. Pap.* 1: 117 pp.

Welcomme R.L. 1979. *Fisheries ecology of floodplain rivers*. London, New York, Longman. 317 pp.

Welcomme R.L. 1985. River fisheries. *FAO Fisheries Technical Paper*, *No. 262*. 330 pp.

Welcomme R.L. 1986. The effects of the sahelian drought on the fishery of the central delta of the Niger River. *Aquaculture and Fisheries Management*, 17: 147-154.

Welcomme R.L. 1989. Review of the present state of knowledge of fish stocks and fisheries of African Rivers. *In* D.P. Dodge ed. *Proeedings of the International River Symposium, Canadian Special Publication on Fisheries and Aquatic Sciences,* 106: 515-532.

Welcomme R.L. & Hagborg D. 1977. Towards a model of a floodplain fish population and its fishery. *Environmental Biology of Fishes*, 2: 7-24.

Welman J.B. 1948. Preliminary survey of the freshwater fisheries of Nigeria. Lagos, Nigeria, Government Printer,.

Wetlands International 1999. Atelier sur la conservation de la biodiversité des poissons en Afrique de l'Ouest, région de Mopti Mopti du 24 au 27 août 1999.

White E., ed., 1965. The first scientific report of the Kainji biological research team. 88 pp.