Chapitre 20

FISHERIES SCIENCE IN AFRICA

LA SCIENCE DES PÊCHES EN AFRIQUE

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1 - INTRODUCTION

In most African countries, fisheries are among the important renewable natural resources. A large part of Africa is well-watered, harbouring many of the world's greatest rivers and lakes and smaller streams. This favours the rapid growth of fish, leading to high yields of valuable animal protein for most countries. Even in the more arid areas, fish production is of considerable importance because yield in very large rivers and dams is often not seriously affected during drought periods.

Such are the roots of the great importance that the fish resource has traditionally always had in the African diet. In the past certain tribes, particularly those with a cattle-owning tradition, have not eaten fish for reasons of customs or taboo. But such prejudices are rapidly disappearing, so that there are now very few parts of the continent where the capture or cultivation of fish, its preservation, processing and marketing, are not major occupations. The rapidly increasing human populations make this food source of even greater value, while the construction of the huge man-made lakes on most of Africa's largest rivers have greatly increased the biomass of commercially important freshwater fish. Fisheries science, covering fishing and fish technology, regulation and management of fishery resources, is therefore of great significance in enabling the best advantage to be gained from this asset.

African freshwater fisheries started with the use of locally fabricated materials such as baskets, spears, etc. initially mainly for subsistence. Yield was greatly increased by the introduction of seine nets braided from twine which was originally hand-spun, while trade in products preserved by drying, salting and smoking began to encourage fish consumption from centres far removed from the water'edge. A very great impetus came with the introduction of the gillnet by the Norwegian Aarup in 1905 in Lake Victoria (Worthington & Worthington, 1933). This gear has advantages in catching fish which are scattered fairly widely and not concentrated in dense shoals, because it is stationary. Once set the only energy expended is by the fish which catches itself while the fisherman is otherwise occupied, in contrast to the costly and time-consuming effort required to operate moving gear such as seines and trawls. This characteristic, together with its relative cheapness, has ensured the gillnet's pre-eminence over all other gears in most African inland fisheries.

Most of the increase in the exploitation has taken place within the last half century and has coincided with very great increases in human populations. Today the demand for fish in all parts of the continent is high, requiring the best possible management. But those aspects of fisheries science which deal with capture, processing, transporting and marketing techniques have made better progress in the African freshwater fisheries than management and regulatory aspects. Most of the originally profitable species show ominous signs of overfishing and many fisheries neither yield the quantity nor the quality that they once did. In many waters the population structure and relative abundance of the species has changed, often for the worse. Hence, fisheries science in Africa is presented with great challenges both in promoting fisheries of man-made lakes and aquaculture systems as well as in overcoming the management problems of a usually complex fishing industry.

2 - FRESHWATER FISHERY RESOURCE ASSESSMENT

2.1 - Centres of production.

In Africa there are few areas where fishing is not practised, even if it is merely a basket trap in a small stream or hook and line in a small irrigation or cattle watering dam. Since in most cases it is difficult to keep records of such simple fishing, yields cannot be accurately estimated, but they nevertheless contribute significantly to the fishing effort in many countries. Welcomme (1979a) has estimated that the catch from 35 African countries is about 1400 000t (Table 1), of which some 40% comes from rivers and floodplains (Welcomme, 1979b), showing that the present total annual catch is near the potential level for many countries.

Ssentongo (1979) gives fish production data for some selected natural and man-made lakes in Africa, and productive inland waters in the world. (Table 2).

2.1.1 - River and floodplain fisheries. These are considered together since few large rivers (except the Zaire) have a large production without significant contributions from their floodplains. In general, the yield of river and floodplain systems depends very largely on the extent and duration of seasonal floods, on which both the ichthyomass and the catches for a particular year depend (Welcomme & Hagborg, 1977; Welcomme, 1979c). In the last two decades, severe environmental constraints have been placed on these systems by the construction of large dams, usually for the provision of hydroelectric power. One important implication of dam construction is that the retention of large quantities of water in man-made lakes usually, if not always, has very deleterious effects on the downstream floodplain environment, including the fisheries. The general question is reviewed by Davies (1979). In the case of Kainji the loss of fish catches from the downstream floodplains is only just balanced by increased fishing from the reservoir (Welcomme, 1979b), while Bowmaker *et al.* (1978) show the effects of the two Zambezi dams (Kariba and Cahora Bassa) on the downstream and delta regime.

a) The Niger river, tributaries and associated floodplains. These provide the bulk of the inland fisheries yield in Nigeria, Mali and Niger. De Vos (1979) deals with the importance of large river regimes which are buffered against drought, particularly applicable to Mali and Niger, while management problems with particular reference to the Niger are treated by Awachie (1979), who stresses the undesirability of catching gravid, pre-spawning fish at the beginning of the flooding season.

b) The Kafue river and floodplain. Zambia is a well-watered country with important fisheries on more than a dozen lakes, rivers and swamps. Nevertheless, though subject to the usual fluctuations associated with riverine regimes, some 20% of the total national catch has often in recent years been contributed in a single year by this fishery (Lagler *et al.*, 1971).

c) The Shire river and floodplain. This system is of great importance in Malawi relative to other natural fisheries (Willoughby & Walker, 1978) producing a catch of 13 300t in 1976, or over 30% of the nominal total for Malawi that year. This system is characterized by having in it a large swamp, the Elephant Marsh, which contributes significantly to the catches.

Table 1 : Estimated total inland fish catches and potential by some African countries (Welcomme, 1979a).

COUNTRY	CATCH (t)	POTENTIAL (t)
Angola	10 000	10 000
Benin	20 000	25 000
Botswana	1 600	15 000
Burundi	20 330	20 000
Cameroon	40 000	40 000
Central African Republic	10 000	15 000
Chad	115 000	up to 20 000 depending on rainfall
Congo	1 000	60 000
Egypt	80 000	80 000
Ethiopia	1 000	59 100
Gabon	1 800	2 000
Gambia	800	8 000
Ghana	41 950	40 000
Guinea	1 000	5 000
Ivory Coast	17 000	17 000
Kenya	37 000	37 000
Liberia	4 000	at least 4 000
Madagascar	41 000	41 500
Malawi	78 500	78 500
Mali	100 000	up to 115 000 depending on rainfall
Mauritania	13 000	very low due to environment changes in Senegal River
Mozambique	3 000	15 000
Niger	8 000	15 000
Nigeria	200 000	200 000
Rwanda	600	12 000
Senegal	25 000	much reduced due to hydro-agricultural management of Senegal River
Sierra Leone	1 100	5 000
Sudan	22 000	125 000
Tanzania	150 000	250 000
Togo	3 000	3 000
Uganda	174 000	240 000
Burkina Faso	3 500	6 000
Zaire	114 000	280 000
Zambia	49 000	70 000
Zimbabwe	14 000	15 000
Total	1 404 030	2 108 100

Table 2 : Fish production data for some selected natural and man-made lakes in Africa (Ssentengo, 1979).

LAKE	AREA (km^2)	MEAN (m)	CATCH (t)	PRODUCTION (kg/ha)
Bangweulu (open water)	2 800	4	9 000	32.1
Chisi (open water)	35	-	280	80.0
Chilwa (open water)	750	2	9 800	130.7
George	270	3	4 200	155.6
Kainji	1 270	11	7 200	56.7
Kariba	5 364	29	4 080	7.6
Kioga	2 700	6	105 000	388.9
Kitangiri	1 200	3	5 180	43.2
Malawi	30 000	426	28 000	9.1
Mweru Wa-Ntipa (open water)	300	7	3 000	100.0
Tanganyika	32 000	700	73 300	22.3
Turkana (= Rudolf)	7 200	-	16 000	22.2
Victoria	68 800	40	101 082	14.7
Volta	8 482	19	37 300	44.0

2.1.2 - Wetlands. An accepted classification of wetlands is that proposed by Cowardin *et al.* (1979) : various classes of waters less than about 3 m deep. While rivers and floodplains are included, many important fisheries occur in other categories, eg. on the shallow lakes such as Chad, Chilwa in Malawi and Mweru Wa'Ntipa in Zambia. The Bangweulu Swamps in Zambia are among the biggest in area in the world. The Niger Inland Delta and the Okavango Swamps also support important fisheries. Wetland fisheries are characteristically variable in response to rhythmic water level fluctuations (Bruton & Jackson, 1983) : thus in Lake Chad the fishery increased very rapidly from 30 000t in 1962 to 220 000t in 1974, then dropped drastically to less than 100 000t in 1977 (Durand, 1980, 1983).

2.1.3 - Natural lakes. Africa has large water masses. While the Great Lakes are the huge water bodies of Victoria, Malawi, Tanganyika and Turkana, there are very many others, from larger open water areas such as Mweru to endorheic wetlands which, though large, are swampy and impermanent. Many are major centres of production; details of their fisheries vary in detail though most are now near the optimum level of exploitation. It is on the Great Lakes that the use of gillnets and later of mechanised fishing was first developed. These have had much effect on the population structure of exploited fish stocks and the consequent management measures.

2.1.4 - Man-made lakes (see also Chapter 15). The first really large African impoundment, Lake Kariba, was also the first on which a pre-impoundment survey was undertaken (Jackson, 1960, 1961). After Kariba, man-made lakes have proliferated and no river in Africa, however large, is now without at least one. A sole exception is the River Zaire, but even here very large dams are contemplated (Olivier, 1979). Present-day, and projected dams in Africa are listed in Chapter 27.

Most large impoundments are built for the purpose of providing hydro-electric power, a reflection of mankind's energy crisis, and, provided that this was economically feasible, few other considerations have prevailed. Fisheries are usually an unplanned benefit which was incidental to the main purpose of the dam. Nevertheless fisheries can readily be established (Jackson, 1966) which in many cases have proved a major fish producer such as in Lakes Volta (Welcomme, 1979a) and Kariba (Marshall, 1979). Adverse effects have long been appreciated (Ellis, 1941; Jackson, 1963), and recent experience has again shown many dams to be somewhat of a mixed blessing (Davies, 1979; Scudder, 1979; Welcomme, 1979b), with increased fish production offset by adverse developmental and downstream effects.

2.1.5 - Estuaries and brackish water. The African continent is relatively poorly endowed with coastal lagoons although comparatively extensive ones exist in West Africa, Mozambique, Zululand and Madagascar. Estuarine fishing is therefore limited in extent except in areas such as the Ivory Coast where extensive lagoons occur (Durand *et al.*, 1978). Purse seines are used in such areas, but otherwise beach seines, traps (especially in tidally influenced areas) and cast nets in shallow areas are the most important gear. However, all around the coast, estuaries are important nursery areas for many commercially valuable fish (Day, 1981). Several sea-spawned fishes such as the eels (Anguillidae) and mullets (Mugilidae) migrate far up most river systems and these fishes are important elements of the inland water biota (Kiener, 1959; Bok, 1979).

2.2 - Resource monitoring.

Monitoring of the fishery resources is an urgent necessity in all African inlands waters. Virtually without exception all of the major fisheries have been intensively exploited, so that the older year-classes of most fish populations have been taken out and what remains are the young which are annually recruited. But successful recruitment depends largely on the abundance of older fish that spawn each year and when this breeding stock becomes too small to yield enough recruits to the fishery, catches decline. In cases when natural mortality occurs through food shortages or winter kill, the harvesting of younger age-groups before these die naturally is desirable (Allanson & Jackson, 1983). A useful resume of inland fishery management, dealing with monitoring, decision-making and techniques, is given by Welcomme & Henderson (1976), while population dynamics and biomass estimated are briefly treated by Lévêque & Bruton (1981).

Studies on some exploited fish stocks have provided fairly reliable information on the state of the stocks and fishing trends. Some have been on rivers and smaller lakes, e.g. the study by Loubens (1964) on the Ogoue and that of Durand (1978) on *Alestes* in Lake Chad. On the Great Lakes the classical study is that of Garrod (1961a, 1961b, 1963) on the gillnet fishery for tilapias on Lake Victoria. In Lake Tanganyika the fishery resources are considered by Coulter (1970, 1976). Production to biomass ratios of present stocks will be higher than in the previous populations when more predatory and older fish were present (Coulter, 1981; Coulter & Jackson, 1981). Such populations can withstand greater exploitation than they receive at present, at the price of the loss of older and larger fish. The introduced sardine *Limnothrissa miodon* has made the open waters of Lake Kariba very highly productive (Marshall, 1979). An important resource monitoring activity is the study of the trawl fishery on Lake Malawi by Turner (1977, 1978) who gives a clear picture of the effects of demersal trawling, the yield which is possible and the regulation which is necessary. Lake Malawi pelagic stocks have been examined by FAO 1982.

2.3 - Resource potential.

It is clear from the fore-going that the resource potential which exists is not easily defined since it varies so much from place to place, though it is often large, and also that development possibilities have to a large extent already been fully implemented, in so far as natural fisheries are concerned, excepting in some offshore fisheries in the larger lakes. The first three-quarters of the present century have seen the advent of large-scale fishing by twine netting, a great increase in fishing techniques which have resulted in the depletion of accumulated stocks. By 1975 the older year-classes of most of the larger and slower growing species had been fished up, as indicated by Coulter (1981) for Lake Tanganyika, Turner (1977) for Lake Malawi, and Benda (1979) for Lake Victoria, with similar situations occuring for most of the other of the older established fisheries. Since an accumulated resource was being exploited, it is inevitable that fish catches should decline.

This process has often been obscured by a change in the potential of some other fish species, e.g. the various tilapias, the Nile perch and catfishes, which have been displaced by smaller and more abundant fishes which can reach maturity in one year, or two at most, leaving very numerous descendants. Such responses to fishing pressure are well-known elsewhere in the world, such as in the North American lakes (Smith, 1968).

This process has been clearly shown in major African fisheries, e.g. the Nyanza Gulf fishery of Lake Victoria, traditionally a «tilapia» fishery but later dominated by smaller, faster growing species (Benda, 1979; Marten, 1979) and now by the Nile Perch (Hughes, 1983). The small, quick-growing highly fecund resources, the freshwater sardines *Pellonula afzeliusi* and *Limnothrissa miodon*, are responsible for the high catches of some man-made lakes such as Volta and Kariba. In immature communities, such as those created by extreme fishing pressure, there is a fast turnover and high fecundity (Lowe-McConnell, 1975). To the fishery manager, the importance lies in the production being high in relation to ichthyomass, giving high yields relative to standing stock (Coulter & Jackson, 1981) but with the loss of the more desirable, larger and slower-growing species.

While the first three-quarters of the century have seen a «mining out» of an accumulated fishery resource which took many centuries to develop, it is hoped that the last quarter will be characterized by an emphasis on management for optimum yields and rehabilitation of fished-out stocks. It is undeniable that there has been considerable over-fishing in the past and that the effect of this has in many cases been to remove favourite and preferred fish such as the larger and older fishes like tilapias and catfishes as well as the important migratory cyprinids such as *Labeo* spp., and partially to replace them with smaller and fast-growing species. *Labeo* are particularly vulnerable to uncontrolled exploitation through having few though having individually numerous year classes due to irregular breeding success (Tomasson *et al.*, 1984). This is the most important future task for fisheries science in Africa : to manage the fisheries resources in such a way that its optimum potential can be maintained, not only in tonnage yielded but in the maintenance of species diversity. In order to do this, fishery managers need to gain the cooperation of the governing authorities, of the fishermen and the consumers in general, so that the needs for and benefits arising from wise resource use are fully understood. In addition, much attention is now being paid to aquaculture and this should remain an important aspect of fisheries science in the years to come.

2.4 - Estimation of resource potential from other parameters.

No fishery can be effectively managed without some understanding of its potential fish production. In this regard the productivity of a waterbody as a whole is important and several attempts have been made to equate this with independent limnological variables. Some are summarised here and the question is treated further in Chapter 21.

Experience has shown that depth is one of the most important of such parameters and Rawson (1955) showed an inverse relationship (the shallower the more productive) to exist between mean depth and fish production in large Canadian lakes. In Africa, Jackson (1960) applied the principle by recommending clearing of vegetation at Kariba to facilitate fishing down to 9 m below minimum water level only, because of the higher productivity in shallower areas. In 1972 Fryer & Iles showed the relationship in African lakes to be generally similar to that in Canada (Fig. 1). Bowen (1978) demonstrated the importance of shallow water to fish. Previously a correlation between productivity and water chemistry had been shown in North America by Moyle (1956) and Northcote & Larkin (1956). These indexes were combined by Ryder (1965) to form his Morpho-Edaphic Index (MEI), which proposed a relationship between the total dissolved solids (tds) and depth. Since data on water conductivity are more readily obtained and more widely available they are often substituted for tds to enable the expression to read :

$$MEI = \frac{\text{Conductivity } (\mu \text{ mhos/cm})}{\text{Mean depth (metres)}}$$

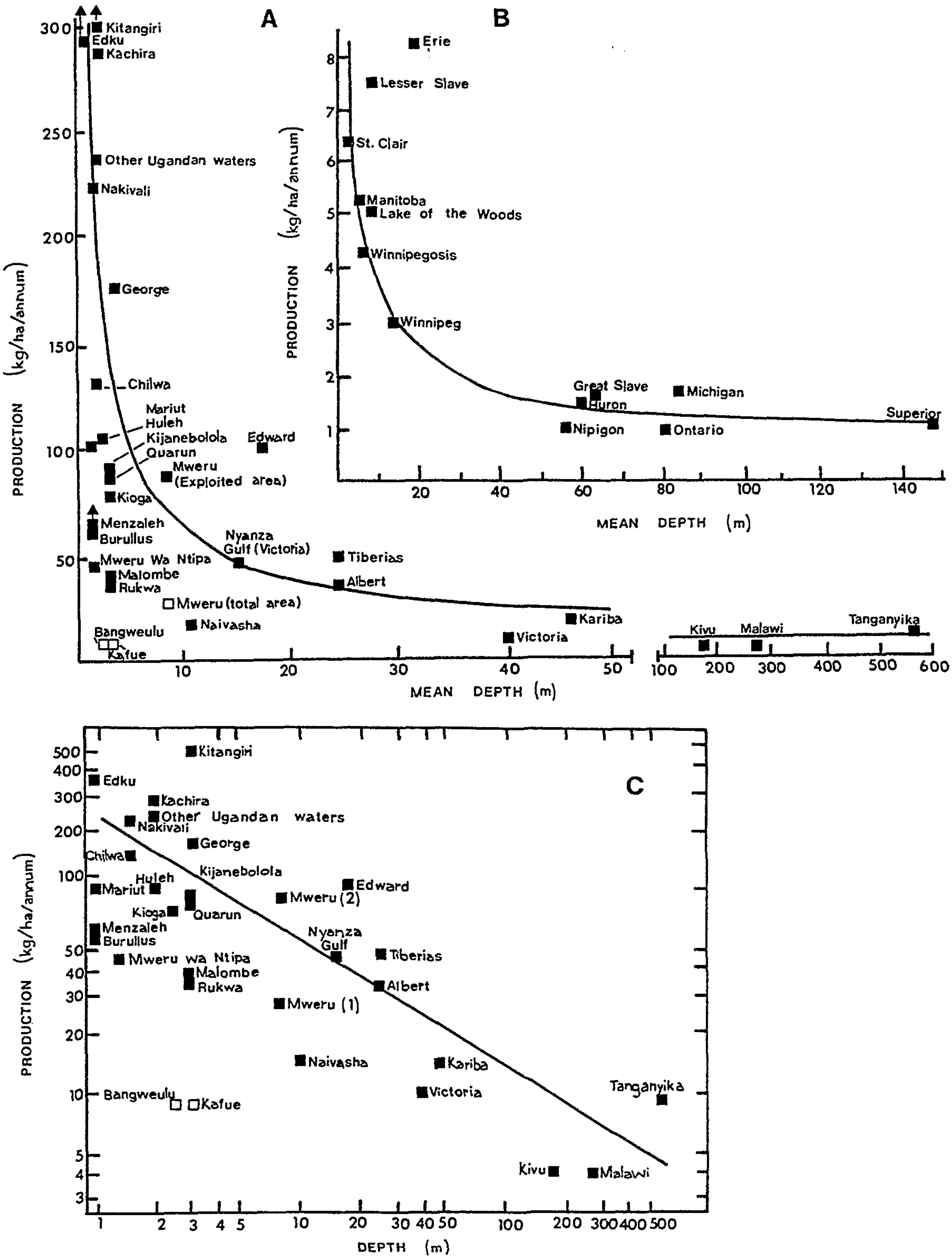


Fig. 1 : Relationship between depth and fish yield in African inland waters (A) and as a logarithmic plot (C), and in Canadian lakes (B). From Fryer & Iles (1972).

For Africa, the application of the MEI was first considered by Regier, Cordone & Ryder (1971) for seven African lakes, and the principles underlying the use of the index in Africa were dealt with in greater detail by Henderson, Ryder & Kundhongania (1975). A relationship between increasing MEI and catch in kg/ha (c) was found to exist by Henderson & Welcomme (1974), with the expressions :

$$C = 14.3136 = \mathrm{MEI}^{\,0.4681}$$

describing the relationship for lakes near their maximum level of exploitation. Catch per fisherman, as well, increased with increasing value of MEI (Figs. 2, 3). Bruwer & Claasens (1978) related MEI to potential fish production in temperate or subtropical southern African dams and, while actual fish yield is mostly unknown, potential may often be over-estimated because of the very turbid water of most impoundments. But in spite of such limitations, Morpho-Edaphic Indices and variations in catch per fisherman density are valuable tools in fishery resource managements. Another attempt to correlate fish yields to other parameters is that of Melack. Henderson *et al.* (1973) had earlier suggested that fish yields may increase as a power function of primary productivity, but Melack (1976) first analysed such relationships. In eight African lakes he found that commercial fish yields increase logarithmically as primary productivity increases arithmetically. The regression equation describing the relation between fish yields (FY) and gross photosynthesis (PG) was

$$\log \mathrm{FY} = 0.91 + 0.113\ \mathrm{PG}$$

Correlations between fish yield and gross photosynthesis by phytoplankton in China was also found by Liang *et al.* (1981), but the authors concur with McConnell *et al.* (1977) that one universal regression equation suitable for predictive application to all fisheries is unlikely. Gross photosynthesis must be calculated, including respiration by heterotrophic (bacterial) as well as autotrophic plankton. The implications of this in Lake Tanganyika, where primary production is not high relative to fish yield, is discussed by Hecky *et al.* (1981) and Eccles (1985). Further work is required especially on the deep Rift Valley lakes with their huge bacterial stocks in poorly lit and oxygenated profundal zones, but in general there is little doubt that measurements of primary productivity can improve the assessment of fish yields from tropical lakes.

Finally, one may by contrast consider the attempt by Welcomme (1978) to provide preliminary estimates of the catch from rivers and their floodplains by analysing the fish yield patterns from a number of water bodies (Table 3). A fairly good relationship was found between the drainage basin area (A) and the catch obtained from it (C). Rivers with average sized fringing floodplains conform to the relationship

$$C = 0.12\,A^{0.85}$$

Basin area and length of longest channel are themselves related; also a relationship exists for yield in t as a function of main channel length in km (L) :

$$Ct = 0.0033\,L^{1.95}$$

or, approximately, the catch in kg equals 3.33 times the square of the river length (L) from its source,

$$C\mathrm{kg} = 3.33\,L^2$$

These simple models work in general, though deviations occur for individual rivers, due mainly to edaphic factors; e.g. if conductivities, which usually average 50-150 mhos for larger rivers, are widely different, such as in «black water», nutrient-poor rivers (e.g. the Zaire). Conductivity differences account for about 60% of variations from the predicted values of catches in African rivers. Other deviations examined by Welcomme (1978) are caused by morphological factors, especially by exceptionally large floodplain development such as in the Senegal, Niger and Oueme rivers, and the influence of fishermen (N) according to the relationship (Fig. 4) :

$$C = 3.922\ (0.91\ \text{number of fisherman/km}^2)\ (r = -0.89)$$

Finally, variations in flood intensity result in year-to-year variations in catch. To sum up, considerable progress has been made in the estimation of fish yields from other environmental parameters, which are of great value in African fishery management. Virtually all the authors involved, however, stress the need for further and more adequate information on the various fisheries. The provision of more extensive accurate catch data on African fisheries is therefore an important priority in African fisheries management.

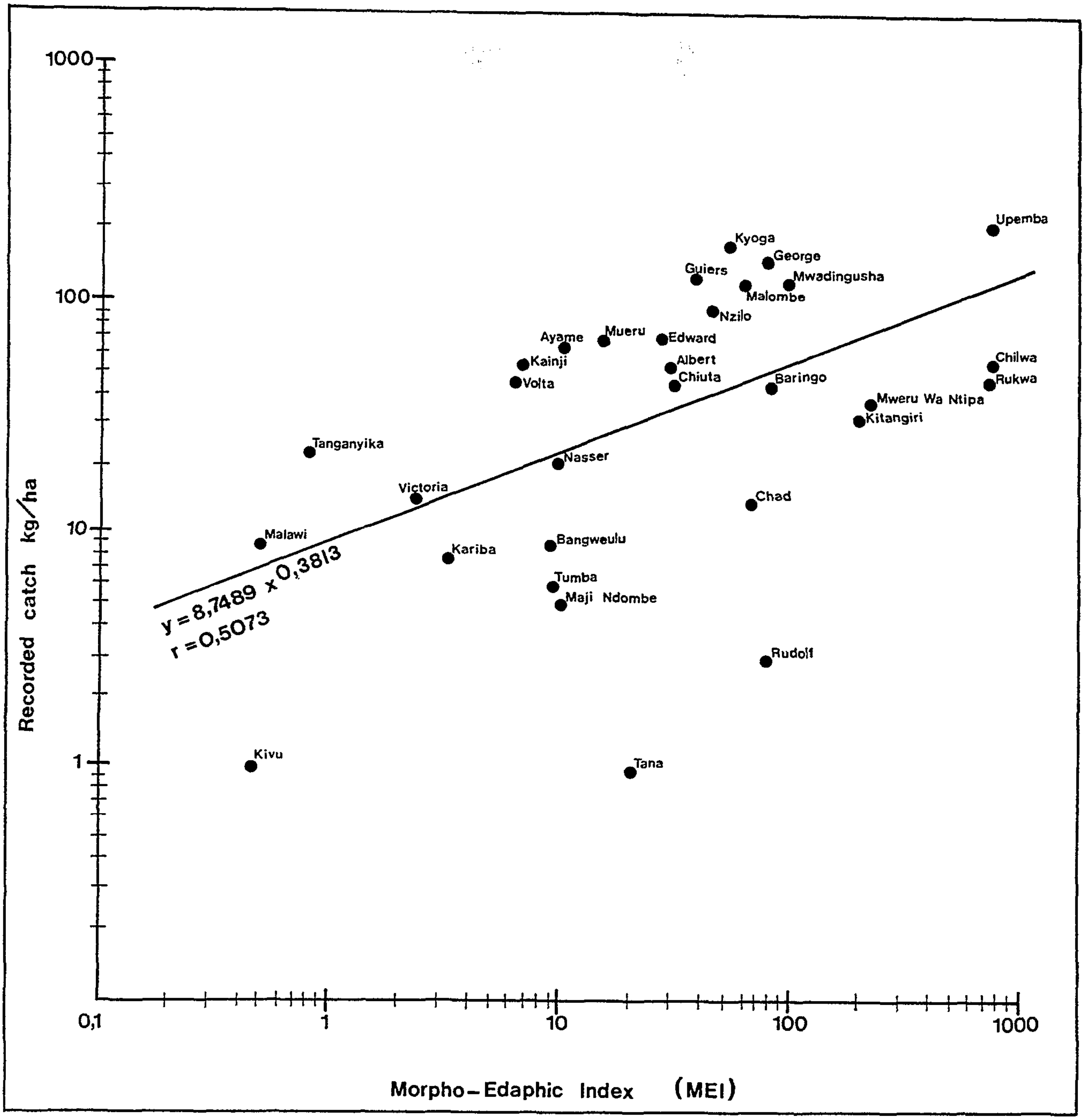


Fig. 2 : The relationship between Morpho-Edaphic Index and recorded catch in 31 tropical African lakes. From Henderson & Welcomme (1974).

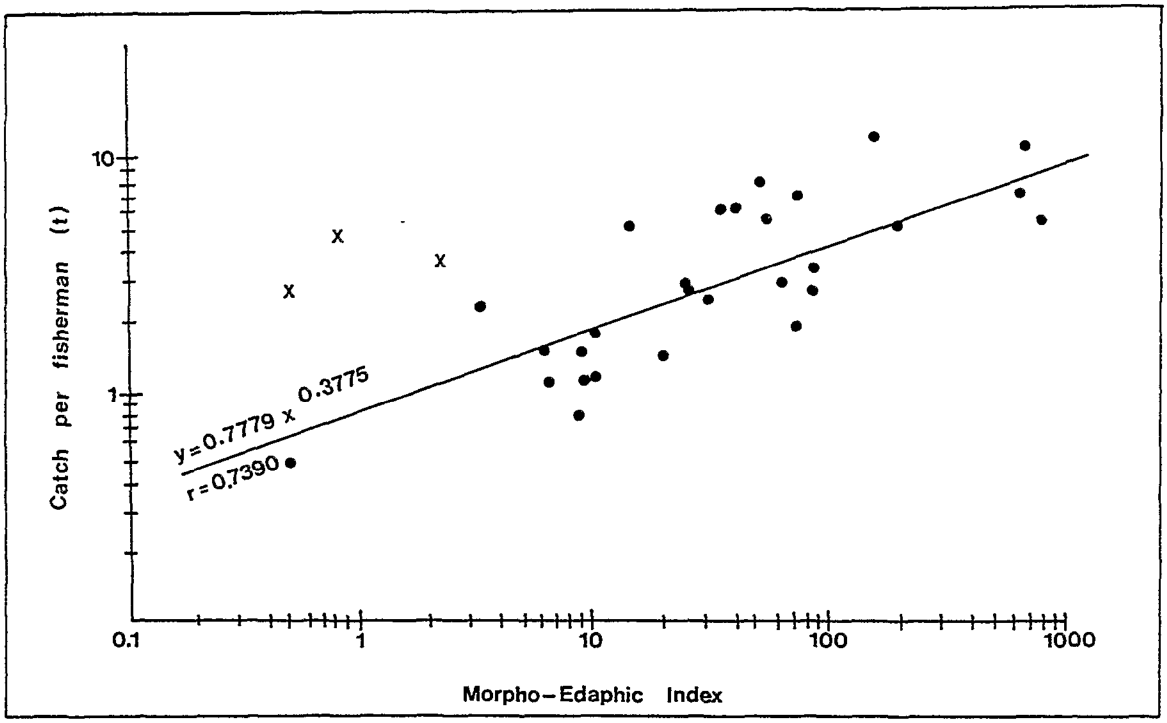
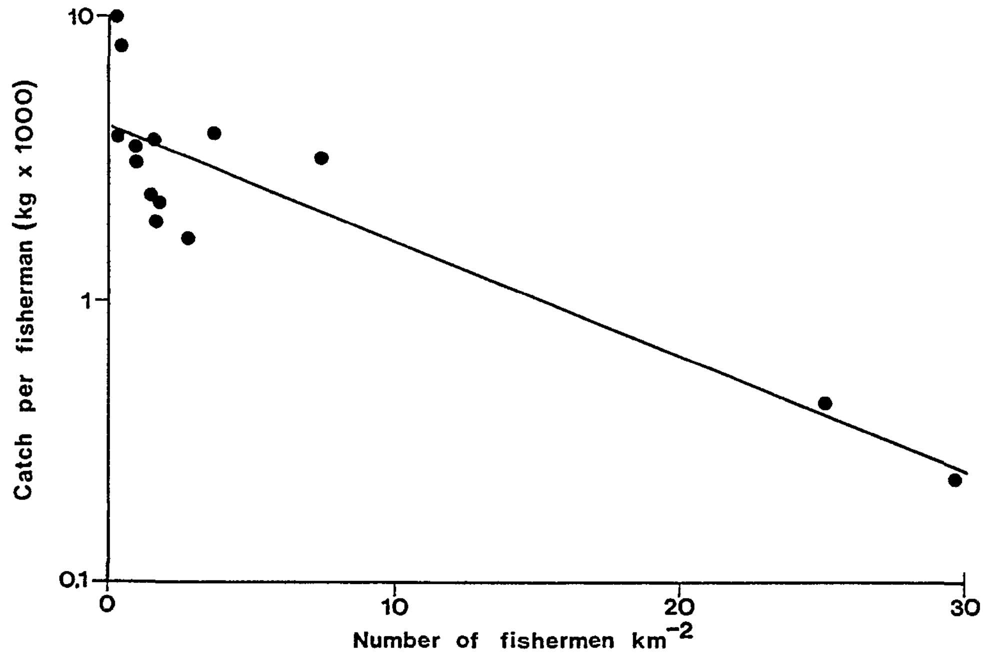


Fig. 3 : The relationship between Morpho-Edaphic Index and catch per fisherman in 31 African lakes. Lakes Victoria, Malawi and Tanganyika are shown by crosses and all other lakes by dots. From Henderson & Welcomme (1974).

Table 3 : Number of fishermen, catch and maximum flooded area of some tropical rivers (from Welcomme, 1978).

River	Number of Fishermen (f)	Catch in Tons (c)	Areas in km² (a)	$\frac{f}{a}$	$\frac{c}{f}$	$\frac{c}{a}$ (kg/ha)
Shire (1972)	2445	9039	665	3.68	3.70	135.9
(1976)	4433	13300	665	6.65	3.00	200.0
Kafue (1963)	1112	8554	4340	0.26	7.69	19.7
(1970)	670	6747	4340	0.15	10.06	15.5
Sénégal	10000	36000	12970	0.80	3.46	27.8
Central Delta, Niger	54112	90000	20000	2.71	1.66	45.0
Pendjari	65	140	40	1.65	2.15	35.0
Ouémé (1975)	25000	104000	1000	25.00	0.42	104.0
(1968/69)	29852	6.500	1000	29.85	0.22	65.0
Niger, Niger	1314	4.700	907	1.45	3.58	51.8
Niger, Nigeria	4600	14350	4800	0.96	3.12	29.9
Benue, Nigeria	5140	9570	3100	1.66	1.86	30.9
Barotse	912	3500	5120	0.18	3.84	6.8
Magdalena	30000	65000	20000	1.50	2.17	32.5



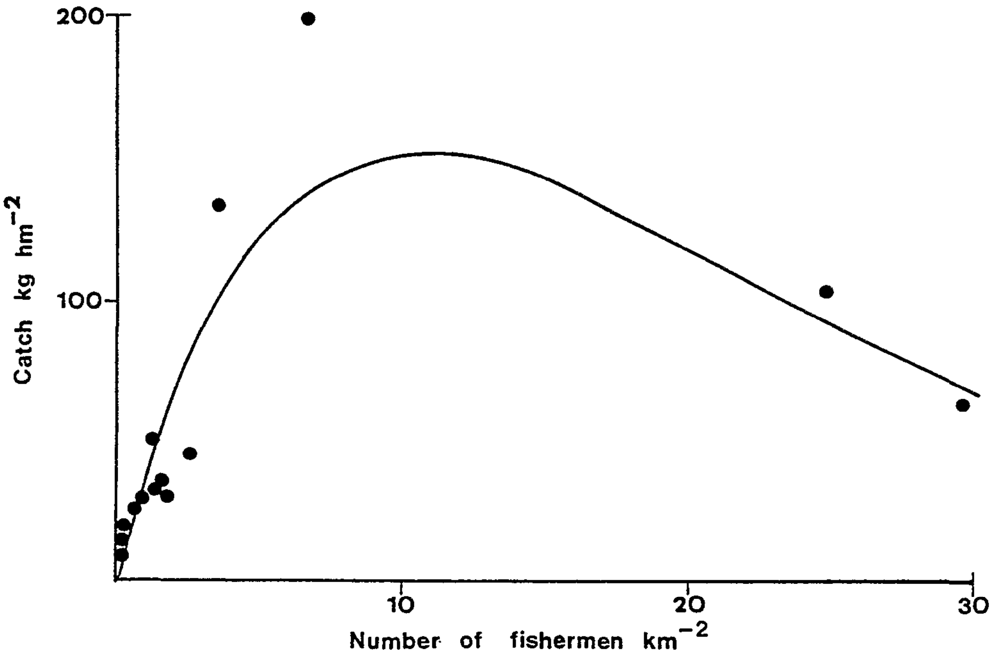


Fig. 4 : Above : Catch per fisherman as a function of number of fishermen km^{-2} with calculated regression line C = 3.955 (.910N).

Below : Theoretical relationship between number of fishermen and catch from tropical rivers derived from the regression equation plotted above. Also plotted are actual values from Table 3.

3 - FISHERY MANAGEMENT AND DEVELOPMENT

3.1 - Evolution of fisheries and trends in technology.

The past 75 years have, for inland fisheries throughout the world, been a period of rapid evolution of the fishing industry with advances in fishing technology, fish processing and distribution. By the turn of the century the African fishery, though still strongly orientated towards the traditional capture methods of woven baskets etc., was beginning to use seine nets of woven twine. Fishery products were disseminated to inland centres from the shores of lakes and rivers (see Jackson, 1971, for review). The early descriptions by Stanley (1878) of markets and Boulenger (1901) of fishing methods in Zaire, are of particular interest in this regard. As an example : Malawi in the 19th century was thinly populated and abounding with game, and fishing was comparatively little practised. Livingstone (1865) observed seine netting on Lake Malawi in 1859 and also commented on the weir fishery for large cyprinids (*Opsaridium*, *Labeo* and *Barbus*) ascending rivers from the lake on their breeding migration. Johnston (1898), in an exhaustive treatise on the country, briefly mentions fishing, saying only that it was practised with baskets, hooks and lines and large seines made of netting. However, by 1939 a nutrition survey had found fish to be a major part of the diet so that a separate fish survey was made. Traditional methods were mainly in use, and it was recommended that gillnets should be introduced into the artisanal fisheries in the same way as in Lake Victoria (Bertram *et al.*, 1942). By this time fishermen from Greece had begun to have a strong effect on the lake fisheries (Jackson, 1971) and by 1947 their gillnetting for *Labeo mesops* using powered boats was very extensive, though such nets were little used in the artisanal fishery (Lowe, 1952). In the northern, deeper parts of the lake gillnets set as deep as 100 m were successfully pioneered in 1954 (Jackson *et al.*, 1963).

Previously, the first-ever use of open-water gear from mechanized boats on an African lake had commenced in southern Lake Malawi in 1943 by Greek fishermen using purse-seines (Lowe, 1952; Nielsen, 1959). This was for the Malawi tilapias of the *O. squamipinnis* group with a surface shoaling habit that enabled the use of this gear. Otter trawling with the gear hauled by a power winch started experimentally in 1965 and by 1968 was in commercial operation in depths down to 90 m in the shallow southern lake (Tarbit, 1972). The species mainly caught were a group of bottom-dwelling cichlids of the genus *Lethrinops* and collectively known as Chisawasawa. Catches in the south east arm of Lake Malawi rose from 1000 t to over 9000 t in 1972 (Tarbit, 1974). In 1973 a midwater trawl fishery commenced, aiming mainly at pelagic species of cichlids (Turner, 1976).

This brief sketch shows that, though some innovations in technique started earlier, the expansion of the Malawi fishery to its maximum production with sophisticated gear has been a matter of a mere 35 years from the time of the first introduction of mechanized fishing during World War II. During this time the yield of fish had increased more than ten-fold, from 5800 t in 1960 to 68 300 t in 1977. Of special interest is firstly that there has been no increase in the total Malawi catch for over 10 years, the record catch being in fact 84 000 t in 1972, and secondly, despite this enormous increase, the amount of fish exported has not increased in the same proportion. Relatively more of the fish are consumed locally, an indication of the increasing human populations of African countries.

Fishing vessels originally consisted of dug-out canoes, many of which are still in use especially in shallow-water fisheries such as Lake Chilwa. Variations occured, such as the very effective canoes made of papyrus which are used on Lake Chad. In some places, the Arab influence is seen in the planked sailboats of the dhow type, especially on Lake Victoria (Jackson, 1971). On Lake Victoria also are the graceful Ssese Island canoes, one of the most beautiful African watercraft, which retain as a keel a hollowed plank, being a vestige of the original dug-out boat but having above the «keel» two or three flared strakes in the Arab style (Hunter, 1969). The next foreign influence was that of the Greeks especially in Lakes Mweru, Bangweulu, Tanganyika and Malawi from the early 1930s, where the first boats to be powered by internal combustion motors and propellors appeared. Large steam-powered vessels were in use on most large waters from the latter half of the 19th century, mainly for transportation.

Fishing boats were originally all built of wood, using the fine indigenous timbers of tropical Africa. Partly because of the growing scarcity of suitable wood and partly because of an often comparatively short life caused by dry rot, sheet metal, rivetted or welded, was later increasingly used. With the advent of synthetic materials, boats built of resins reinforced with glass fibre have become more popular. Today all three methods are used in boat-building. A few experimental vessels have been built in concrete reinforced by wire netting, such as the trawler «Tilapia» built for the Uganda Fisheries Department, but this type of boat has not yet become popular.

3.2 - Fish processing.

Since fish is such a highly perishable commodity, the processing of fish for storage and transport to the consumer has been practised from ancient times. The most popular method is splitting the fish open by cutting along the dorsal surface and opening the two sides away from each other, using the abdominal skin as a hinge, and then sun-drying, smoking or salting by soaking in brine. The type of processing depends on what is feasible and also on the taste preference of the consumer. For example, it can not use smoke in an area which is short of fuel, such as the arid area surrounding Lake Kitangiri (Tanzania) where sun-drying alone is practised. There is usually an abundance of sunshine in most areas but during the rainy season in high-rainfall areas, fish must be smoked, often by partly roasting the product over a slow fire. A salted product is popular only in certain areas, e.g. Zaire, Angola and Mozambique. Managers wishing to supply such areas should salt their product to the degree acceptable to the customer, e.g. in the case of the Lake Turkana (Rudolf) fishery which exports to Zaire.

However, fishery must guard against the use of expensive processing techniques which are not economically viable. Many customers, particularly city-dwellers, prefer fish to be fresh and will pay a relatively higher price for this commodity. Appreciating this, Zambian traders in the 1950s began purchasing blocks of ice in the Copperbelt towns and driving it, insulated with sawdust, to the Lake Mweru fishery. Here fresh fish were purchased on the lake shore, chilled in the ice and transported back to the Copperbelt where a good price was obtained. This was economical and profitable, partly because the ice was not primarily produced for the fishery but also for the cooling or preservation of other commodities such as dairy products, beverages, etc. Whenever the cost must be borne entirely by the fishery, the operation can become uneconomical because customers are unwilling to pay the high price which must be charged for the enterprise to be profitable. Thus some of the flake ice plants which have been erected in some fish production centres in Africa, have, with rising operation costs, become uneconomical and now disused. Such problems are the more acute because of the need to avoid spoilage of fish products. The urgent necessity to feed more and more people has led to an increase in fishing pressure, to the point of severe overfishing, so as little as possible of this valuable resource must be wasted. In comparison with traditional processing techniques, better methods, such as chilling, freezing, or canning the product may exist, but the factor of cost, in the modern context of high oil prices and lessening availability of local energy such as firewood, mean that the use of direct solar energy will still remain a very viable processing method in many areas. Here it is especially important to guard against damage by Dermestes beetles.

3.3 - Promotion of fishery development.

A most important future task for fisheries science in Africa is the assessment of socio-economic factors affecting the industry, identifying constraints in its administration and development, and also endeavouring to obtain for it the planning and other national and international assistance necessary for its most advantageous use. This is a most complex task which calls for a very high order of problem identification, decision-making and the setting of objectives.

Promotion of fishery development is very largely political. Good examples may be found in the fields of resource appraisal. The situation has often existed where an appraisal has been made, particularly of mature lake ecosystems, of the amount of fish which may be removed without damage, but that when this limit has been reached the assessment has been ignored.

For example, the tilapia fishery of Lake Victoria continued successfully for many years while the scientific requirement of gillnets of fairly large mesh was met. However, pressures of more fisherman wishing to enter the fishery, and economics of wishing for a higher return from the yield combined progressively to reduce mesh size. We consider that the consequent decline in catches was one of the factors instrumental in the introduction of various non-endemic tilapias though these were less desirable by both fisherman and consumer. Nevertheless, catches continued to decline so that the once valuable 'tilapias' became of secondary importance and displaced by smaller, less desirable but rapidly growing fish species (Benda, 1979).

Such disregard for assessments is largely due to political considerations, an administrative constraint which the fisheries manager finds most difficult to overcome. Regulatory legislation is unpopular among fishermen, so its abrogation is more popular. Besides, it is politically expedient to allow more people into a fishery in rural areas of high unemployment. In these circumstances, the manager must try to persuade politicians to assist the financing of alternatives such as fishing a less accessible stock and producing the boats to do it, or the promotion of aquaculture in intensive agriculture schemes. Compromise on both sides is required, the politician appreciating that the scientist has a basis to recommend an optimum yield and the manager recognizing the politician's difficulties in alleviating unemployment and food shortages.

Many such administrative constraints are extremely complex. Some fisheries are undervalued because, in an effort to combat inflation, floor price controls are instituted, limiting the price at which a fisherman might sell his catch. The fisherman nevetheless has to pay current prices for his gear replacements, engine spares, etc., and therefore in these circumstances he is in effect subsidizing the fish-buying public. Another adverse effect of an artificially low floor price is that it also gives the entire fishery an unrealistically low value. Financial planners then tend to underestimate its value to the national economy and thus they award fishery departments and fishery projects a disproportionately low share of Government expenditure (Jackson, 1978).

People inexperienced in fishery management are often misled through not being able to monitor the resource properly because of the environment in which fish live. A most one observes the daily catch which is a very small proportion of the entire annual resource, because fish are cropped a little at a time. This is in contrast to agriculture, where the whole herd of cattle or the entire field of maize is harvested at once, and can readily be seen and its potential value assessed. This again has the effect of concealing the true value of the fishery to the national economy (Eccles, 1985).

In these circumstances, fishery departments are often small and understaffed in comparison with other natural resource departments, and receive a disproportionately small share of financial aid or development projects. Fishery scientists, in assessing available stocks, often measure this resource in weight. But the monetary value should whenever possible also be given so that national planners can have some measure of comparison with the worth of fishery resource assets. Therefore, fishery managers should say «this fishery yields so many tons worth so much money per annum».

4 - AQUATIC ECOSYSTEM MANIPULATIONS

4.1 - Fishery potential of man-made lakes.

The impoundment of large quantities of water behind a dam must be paid for the loss of that water to the floodplain and its fishery below. The fisheries scientist must therefore obtain the best possible benefit from the newly created resource, which consists primarily of greatly expanded numbers of certain species which were present in the river prior to impoundment. It may be augmented by deliberate or accidental introductions, such as of pelagic planktonivorous species to inhabit the newly created open-water niche, not used by the previous species which are adapted only to riverine conditions (Junor & Begg, 1971). By the same token, certain river-adaptated species may disappear from the new lake (Begg, 1974; Dadzie, 1980). The new fish resource is thus of great importance, but a number of social and political implications must also be considered by the manager.

4.1.1 - Provision of additional protein food.

All African man-made lakes have been found to yield more protein than that given by the same stretch of river before impoundment. However, in many areas the improved catches from man-made lakes barely compensate for the greatly reduced catches from the floodplains below which are not as well supplied with water (Welcomme, 1979a).

4.1.2 - Provision of employment. Due to the human population explosion most countries have problems of unemployment, and the industries connected with the exploitation of fish in the new man-made lake offer valuable employment opportunities. These activities include catching of the fish, and related activities such as netmaking, boatbuilding, engine repair and maintenance, processing, marketing, trading and shopkeeping.

4.1.3 - Resettlement. Arising from the employment question is the need to resttle and rehabilitate people who have has to be removed from their homes. Such people need new employment and the exploitation of fisheries can be a great help here (Chambers, 1970; Butcher, 1973). Psychologically the fisheries are most valuable in the rapid re-ajustment of uprooted people to normal life (Jackson, 1975), while the Volta lake fishery soon provided work for many people previously unconnected with the dam (Kalitsi, 1973).

4.1.4 - Recreation. This is an important exploitation activity, especially but not entirely in industrialized countries. Considerable sums are spent annually on recreational fishing in many African countries (Cadieux, 1980). Recreational fishing is an «intangible asset» in that it does not produce the tangible asset of a unit weight of fish with a definite monetary value, but is psychologically and aesthetically beneficial as relaxation for workers in cities. Besides, it facilitates the distribution of funds since some of the money earned by workers in cities is spent in the purchase of fishing tackle, boats, outboard motors, etc., which creates employment in the manufacture and sale of such items while other jobs are directly created, especially in rural areas, in the employment of roadmakers, guides, gillies, sellers of bait, motor and outboard fuel, etc., as well as in the local hotel and catering trades. These can be very real benefits provided by dams in areas where there are few natural fisheries.

4.2 - Fishery potential from aquaculture systems.

4.2.1 - The potential benefit from aquaculture. At first sight the cultivation of fish and other aquatic organisms may appear to be very attractive. Much of Africa is well watered and lies within the tropics, offering a favourable environment for fish culture. Excellent results were obtained in the past (de Bont, 1952), while Gruber (1960) showed that high yields may be obtained from ordinary household refuse such as banana skins, sweet potatoes and other foodstuffs which are spoiled, rice debris, etc. The high rate of unemployment in most African countries may be considerably alleviated by the integration of aquaculture into intensive agriculture, as shown by the experience of many Indo-Pacific countries. There has been ample encouragement of aquaculture in Africa by FAO in recent years; why then has aquaculture in Africa not reached anywhere near the levels attained in the Far East? Several constraints affect aquaculture productivity in Africa, discussed more fully in Chapter 22. The most important general factor is probably psychosocial; there is no tradition of fish culture handed down from father to son in Africa, because the increase in human populations to the point necessitating intensive land use is too recent for such a tradition to emerge. This contrasts with the Far East where this situation was reached many hundreds of years ago. The previous abundance of natural fish populations meant also that wild fish capture, akin to hunting, was a more acceptable occupation for the males of the community than fish culture (considered a form of land cultivation).

A very important constraint is the economic one. In many areas the economic infrastructure associated with aquaculture does not as yet exist in Africa (Shehadeh, 1976). As with the rearing of other animals for human consumption such as chickens or pigs, most expenses, usually over 70 percent, relate to the cost of the feed if this is purchased. The fish produced may then be too highly priced. But failure to provide such expensive food may cause low productivity, with consequent uneconomic yields. This economic dilemma may partly be resolved by the heavy fertilizing of ponds with animal manure or vegetable waste, thus cultivating micro-organisms which are of great value in protein production (Schroeder, 1977). But economically viable techniques usually require a high degree of skill and experience which are often lacking. Another cause of limited productivity is the great difficulty of visualizing the economic value of a fish crop. Fish populations cannot easily be assessed like a herd of cattle or field of maize. Cultivated fish stand in danger of receiving low priority from agricultural decision-makers who are more used to assessing terrestrial crops. Similarly, at the village level, fish in a pond are likely to receive less attention than goats, sheep or cattle. It is difficult to persuade the villager, who seldom or never feeds the chickens pecking around his door, that the invisible fish in the pond need to be fed. Besides, fish in ponds face risks of disease, predation by frogs, otters and birds, and losses by theft and flood. It can be seen that the promotion of aquaculture, though desirable, is a formidable task in Africa. It may certainly succeed in future years, but this will only be achieved through perseverance.

4.3 - Translocation of fish species.

Temptations exist for managers to introduce alien species in the hope of the fishery deriving increased yield or recreational benefits. Such have proved successful only in veru few cases, e.g., in man-made lakes where a new niche is colonised and existing riverins species unharmed, such as *Limnothrissa* in Lake Kariba. Most others have led to changes in species composition, e.g., the introduced Nile Perch in Lake Victoria drastically reducing the previous yield in both quantity and quality (Coulter *et al.*, in press), to the extent that a Code of Practice based on European models, severely regulating future introductions, is being formulated (FAO, 1985). No introductions should ever be contemplated without adherence to this Code.

5 - TRAINING AND EDUCATION IN FISHERIES SCIENCE

Most African countries are now taking the necessary steps to promote training and education in all branches of fisheries science, including fishery biology and economics, fish culture, fishing technology, ichthyology, limnology and oceanography. During the first half of the twentieth century, most fishery biologists working in Africa concentrated on systematic ichthyology and limnology. There were few studies on life histories, distributions, migrations and population dynamics of exploited stocks to assess the impact of fishing on fish population and formulate fishery management and development plans. But at present, in most African countries, training and education in fisheries science focuses mostly on those aspects that lead to fishery development, management and conservation.

Many African countries have benefitted from training courses in fisheries science organized by FAO, UNEP, the Intergovernmental Oceanographic Commission (IOC), etc. Such courses have been mainly designed for small groups of people. Under these schemes, consideration has mostly been given to stock assessment and population dynamics, acoustic surveys, fishing technology, fish processing and utilization. The only limitation to the frequency of such training has been the lack of adequate financing and the availability of time of leading experts. Fortunately, the United Nations Development Programme (UNDP) and development aid agencies from Britain, France, North America and Scandinavia have been helpful in providing assistance for training in fisheries.

FAO, IOC, UNEP and both Regional Fishery Bodies and non-fishery bodies have programmes of preparing and publishing manuals, books, etc., on various aspects of fishery science, e.g. a fairly elementary general introduction to fishery science is provided by Holden & Raitt (1974). Other manuals and handbooks dealing with particular aspects of fishery science are, e.g., Gulland (1969) and Ricker (1971, 1975). Additionally, there are a number of books and articles written on the biology and ecology of African fishes by leading experts.

All African countries are involved in the rational exploitation of their fishery resources, but most have not enough national experts in fishery science to advise on proper resource utilization. In these circumstances, regional collaboration in training and education in fisheries science is very desirable. There are already a number of fisheries training institutions in Africa to which couritires in the region can send their prospective trainees in various fields of fisheries.

RÉSUMÉ

Dans la plupart des pays africains sub-sahariens, la pêche est une importante ressource renouvelable et le poisson est un produit de haute valeur commerciale.en raison de la croissance démographique rapide et d'une demande sans cesse accrue. Dans le cas du développement rapide des pêcheries africaines, la science des pêches (qui comprend la technologie des engins, la préservation et le traitement du poisson, la réglementation et l'aménagement des ressources piscicoles) est par conséquent d'une grande importance dans la mesure où elle peut permettre d'améliorer la production.

La plupart des espèces économiquement intéressantes montrent des signes assez inquiétants de surexploitation et beaucoup de pêcheries sont en déclin. Dans beaucoup de cas, la structure de la population et l'abondance relative des espèces ont changé. De ce fait, on compte beaucoup sur la science des pêches pour résoudre les problèmes d'aménagement d'une pêcherie complexe et souvent fractionnée dans les milieux lacustres ou fluviaux, ainsi que pour promouvoir l'aquaculture ou la pêche dans les lacs artificiels.

Beaucoup de pays africains, qui se sont engagés dans l'exploitation rationnelle de leurs ressources piscicoles, n'ont pas encore suffisamment d'experts nationaux qui puissent les conseiller. En général, la pratique de translocations de poissons n'est pas désirable. Il en résulte que le développement et l'aménagement des pêches africaines dépendent d'une meilleure coopération bilatérale ou régionale, notamment pour la formation de personnel qualifié.

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