River fisheries in Africa: their relationship to flow regimes

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Abstract

River fisheries in Africa are important because of their contribution of animal protein to human diets. Such fisheries are highly dependent on hydrological regimes and show considerable year-to-year variation in response to natural climatic events. River flow regimes are being increasingly altered by withdrawals by man, principally for agriculture. The modification of hydrological regimes is leading to diminishing catches of fish and changes in the number and size of the species caught. Given that the trend to remove water from rivers for agriculture and power generation will continue, better appraisals of the impacts of such withdrawals are urgently needed so the policies for water allocation can be better defined. The development of tools to aid in such decision-making is equally important.

Introduction

Inland fisheries are fundamental to the livelihood of many African peoples. Freshwater fish contribute a considerable proportion of the animal protein in their diet, especially in areas close to streams and rivers. For example average fish consumption in Cameroon rainforests is around 47 kg/person/year, compared to 10 kg/person/year for the general population (Obam 1992) and in the Central Delta of the Niger fish consumption is about 10.5 kg/person/year versus to 7.8 kg/person/year for meat (Breuil and Quensière 1995). In 2000, the nominal catch of edible products on the continent, including fish from inland waters, was 2.2 million t, which represents about 25 per cent of the total world nominal production. About half of this probably came from rivers and their associated wetlands. It has been argued that real catches are much greater than the official estimates recorded in the nominal statistics because of under-reporting of subsistence catches from the many smaller streams (Welcomme 1976). A realistic value is probably double the nominal catch, implying that African rivers and streams produce about 2 million t of fish per year.

Information on fish and fisheries from as early as the 1970s shows that catches of fish from rivers are highly sensitive to hydrological regimes and, hence, to the many natural and human influences on such regimes. Management of river fisheries has proved to be extremely difficult. The highly dispersed nature of the fisheries and the general lack of defined landings make a regular census problematic. They also hinder the regulation of fishers through the types of centralised management common until recently. More serious is the fact that the sensitivity of river fish populations to changes in the hydrological regime means that the fishery is effectively controlled by a number of users, other than the fishers, who impound, control and extract water for their own purposes. This has led to a situation where many fisheries have declined and, if unchecked, will lead to a more widespread impoverishment of river fish resources. Proper management of the river regime by providing for "environmental flows" requires a more thorough understanding of the ecology of the fish and their response to hydrological and fishing pressures.

Factors influencing fish production from rivers

Fish production from rivers is influenced by a number of factors, many of which are related. This paper focus on three key factors: hydrological regimes, fishing pressure, environmental degration.

Hydrological regimes

Flood waters are important for most species of fish because the flooding of lateral plains increases the area of food rich habitat and shelter from predators, and provides ideal sites for fish to develop and grow (Welcomme 1979, 1985). The annual hydrological cycle influences the migrations of many species of fish between floodplain and main channel habitats. The abundance and biomass of floodplain dependant species, and the fish catches that depend on them, fluctuate from year to year depending on the strength of flooding. Correlations between catches in a particular year and the intensity of flooding (usually represented by an index of flooding) in the same or preceding years have been found in a number of African rivers (University of Michigan (1971) for the Kafue River; Welcomme (1979) for the Shire River; Moses (1987) for the Cross River; Welcomme (1979) and Lae (1992, 1995) for the Niger River).

The delay between any flood event and the response in a fish community depends on the degree to which it is being exploited. Thus, the relationships between flood strength and catch in subsequent years for the Shire, Kafue and Niger Rivers (Welcomme 1985) showed the main correlations to be with floods in one to two previous years. Lae's 1992 data for the Niger show that in the late 1980s catches were more closely correlated with floods in the same year and that 69 per cent of the catch consisted of young-of-the-year fish, indicating a general increase in fishing pressure. Some authors have also found correlations between catches and the amount of water persisting in the system over the low water period, notably the University of Michigan (1971) for the Kafue flats, although the best correlations were usually with the indices of flooding.

The situation in arid rivers has been less well described although, even during the drought years of the Niger River when the system was in an arid phase, good correlations with the strength of flooding were obtained (Lae 1992). All of this argues that in normal, humid African rivers the flood component of the hydrological regime is the most important factor affecting fish production, although the dry season component of the hydrograph cannot be ignored.

The effects of declining water levels on fish populations and catches were illustrated by the impact of the Sahelian drought from 1970 to 1985 when rainfall declined steadily in the Senegal, Niger and Chad basins. In this case there was no constraint to longitudinal migration, but flooding was much reduced or failed over a number of successive years. Catches declined from 90 000 t/yr to 45 000 t/yr in the Niger basin (Lae 1995). Some rheophilic and floodplain spawning species that like swift flowing water were depleted whereas lenitic and main channel spawning species that prefer still water, such as in lakes and slack water areas of rivers, became more common. These findings closely parallel those of Neiland et al. 1990 on the Benue River. In the Senegal River, catches rose from a pre-drought level of about 15 000 t to about 25 000 t in 1975 and then fell to 10 000 t in 1979. Catches in the Chad basin rose from pre-drought levels of about 100 000 t to 220 000 t in 1974 and fell to only about 35 000 t in 1985 (VandenBossche and Bernascek 1990). Chad basin catches included those from the lake as well as from the Chari-Logone river system, whose contribution became insignificant as the drought progressed. In all three systems, the early stages of the drought were marked by initial increases in catches due to an increased vulnerability of the fisheries and because the existing stocks were concentrated into smaller volumes of water, but in the later stages catches fell as the drought impacted biological production.

Fishing pressure

Most fisheries in African rivers exploit a large number of fish species by using a range of fishing gear (consisting of lines, nets and traps), each adapted to particular species, life stages and habitats. Use of the gear varies from season to season in such a way that nearly all life stages of species are vulnerable to capture. This type of multi-species, multi-gear fishery is especially difficult to survey and does not yield readily to standard mesh-dependent methods of control.

The growing population densities and increasing shortage of land means that many people have been forced into fishing as a means of livelihood. As a result, pressure on inland fish resources has tended to increase over the whole continent over the last twenty years (Welcomme 2003). As fishing effort increases, fishing impacts fish assemblages by successively eliminating the larger individuals and species from the multi-species communities and replacing them with smaller species and individuals. This process does not result immediately in lower catches as the greater productivity and reproduction rate of the smaller species compensates for the lower biomass (Welcomme 1999), but it does change the nature and the value of the fishery. While such intensive fishing pressure is now widespread, the Second International Symposium on the Management of Large Rivers for Fisheries (Phnom Penh, 11-14 February 2003) concluded that there are no proven cases of a river fishery as a whole having collapsed from fishing pressure alone. Where collapses have occurred, they have always been linked to degradation in environmental quality, usually because of altered hydrological regimes caused by dams. The impact of increased fishing pressure exacerbates the effects of such changes in the hydrological regime, but it is the changes to the flows that are of greatest importance.

Unfortunately the history of management of inland fisheries worldwide shows a generally low success rate in containing the growing pressures on fish stocks. This was mainly because of the centralized nature of traditional management whereby all the national waters were regulated by the central governments with little attention to the differing biological and ecological needs of the fish stocks and the social and economic conditions of the fisheries. The recent trend to devolve management through co-management systems may prove more successful in that local communities will have more say in the management of their local resources. However, fisheries management is not only a question of managing the fishery, but also the environment on which the fishery depends and for this different approaches to management at the basin level have to be developed.

Environmental degradation

Most large rivers of Africa have at least one mainstem dam and some, such as the Nile and the Zambezi, have more. There are also a large number of medium-sized dams (reservoir sizes 10 - 100 km^2) for irrigation, urban water supply and small-scale power generation. The larger dams are the major causes of degradation of the aquatic environment and disruption of the livelihoods of communities dependent upon farming, fishing and grazing along the river valley.

Although there have been attempts to develop large irrigated areas such as the Gezira in the Sudan and the *perimetre irrigée du Niger* in Mali, smaller irrigation projects are more common. As a result there are thousands of small dams (less than 10 km^2) spread about the continent, particularly in the northern and southern semi-arid/arid Sahelian zones, that are installed for irrigation, drinking water for cattle and as a reserve for human use. Individually these small dams will have only minor effects on the watercourses downstream, which often dry out completely for part of the year. However, their cumulative effect is likely to be massive as they influence the hydrograph in many watercourses. They also alter stretches of rapids in smaller streams to form bodies of standing water for which resident fish species are ill equipped.

Dams have a major effect on fisheries downstream. They act as a barrier to upstream and downstream migration. They also regulate water flow so as to change the amount and timing of discharge and can prevent the regular inundation of downriver floodplains. The loss of floodplains below major dams has been observed and recorded in a few cases. About 100 km^2 of the Phongolo River flats and associated lakes disappeared after the closure of the Phongolo-poort reservoir (Coke and Pott 1970). Much of the floodplain of the Senegal River has disappeared following the closure of the Manantali dam and a persistent failure of flooding has also been recorded below the Kainji dam on the Niger River (Sagua 1978). Post-impoundment flow values from the Benue River below the Lagdo reservoir show that peak river discharges have decreased by 44 per cent from 3 330 m^3 to 1 870 m^3, limiting the extent and duration of the flood (Neiland et al. 1990). Lae (1995) estimated the loss in catch caused by the Selingue and Markala dams at about 5 500 t at flood level, corresponding to catches of between 45 000 and 85 000 t/yr. The effect becomes more marked in systems already stressed by low water levels. Catches in the Niger River below the Kainji dam fell by about 50 per cent in three years (1967-69) in the Jebba - Lokoja reach (Otobo 1968) and by 60 per cent in the lower Anambra basin downstream.

The reduction in the catch is usually accompanied by changes in species composition, whereby flow loving and floodplain spawning rheophilic species are replaced by lenitic species that favor still waters and those that breed in the main channel. This change also often results in local loss of species.

Conclusion

Rivers in Africa are used for a number of human functions other than fisheries. The needs of high economic profile activities, such as power generation and irrigated agriculture, frequently result in conflicts of interest between extractive industries and the water requirements of the fish and the fisher communities. In such conflicts the interests of agriculture and power generation have invariably prevailed. Apart from the greater financial and political power of the agriculture and power sectors, an important reason for this is that the water requirements for power generation and agriculture are relatively well understood, whereas the requirements of fisheries are less clearly defined. It is, therefore, essential to better refine our understanding of the ways in which fisheries respond to altered flow regimes in order to represent fishery interests more effectively in negotiations for the allocation of water to fish.

Much of the existing information and knowledge on the impact of changes in water flows on fisheries comes from the response of the Niger River to the Sahelian drought and to fisheries in such rivers as the Niger and the Senegal to dam building. Studies and experience in South Africa also give some indication of the costs of remedial activities in already modified systems. Here Heeg et al. (1980) estimated that the Phongolo floodplain [10 265 ha at peak flood and 2 700 ha of river and lakes at mean retention level] required 26 million m^3/yr to maintain the mean retention level of its floodplain lakes and a further 100 million m^3/yr to flood the whole plain. However, a model developed by Weldrick (1996) showed that the part of the floodplain could be submerged and the lakes could be filled by a discharge of 100 $m^3 s^{-1}$ for five days (equivalent to a total discharge volume of 216 million m^3/yr). However, this limited information is insufficient to describe the complex impacts that follow changes in the volume, form and timing of floods (Welcomme and Halls 2001; Bunn and Arthington 2002 for an analysis of impacts).

The various methodologies available for the assessment of impacts on fish and fisheries due to changes in river flows have been reviewed through the Comprehensive Assessment of Water Management in Agriculture. Two methodologies have emerged that provide a potential for analyzing impacts and projecting scenarios of environmental flows for the conservation of fish stocks and fish biodiversity in African rivers. The first is a generalized tool called DRIFT (Downstream Response to Imposed Flow Transformations) that has been developed in South Africa (King et al. In press) to analyse the impacts of a range of altered flows on river ecology and the social setting associated with it. The second is a model of fish populations alone, originally developed by Welcomme and Hagborg (1977), that was elaborated by Halls (2001) to describe the response of fish communities to various hydrological regimes and fishing pressures.

Such initiatives represent only the start of an important process. With the increasing demand for water across the African continent and the proposals to meet local deficits by exerting greater control of river flows and water abstractions, it is inevitable that the living aquatic resources that provide such an important source of protein to the people will be put under increasing stress. It is urgent to study further and improve the understanding of the response of these resources to altered flows so that informed decisions can be made about a better allocation of water. One initiative currently getting underway that should help achieve this is the CGIAR Challenge Program on Water and Food which is fostering research on environmental water flows (Box 1).

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The CGIAR Challenge Program on Water and Food is launching an ambitious research, extension and capacity building program designed to significantly increase the productivity of water used for agriculture. The immediate objectives of the Program are to achieve:

- Food security for all at household level.
- Poverty alleviation, through increased sustainable livelihoods in rural and peri-urban areas.
- Improved health, through better nutrition, lower agriculture-related pollution and reduced water-related diseases.
- Environmental security through improved water quality as well as the maintenance of water related ecosystem service, including biodiversity.

Focusing geographically on nine river systems referred to as Benchmark Basins (Nile, Limpopo, Volta, Karkeh, Indo-Gangetic plains, Mekong, Yellow, Sao Fransisco and a group of Andean basins) the Program will address five principal inter-related research themes: crop water productivity improvement, multiple use of upper catchments, aquatic ecosystems and fisheries, integrated basin water management systems, and the global and national food and water systems. The WorldFish Center will coordinate the aquatic ecosystems and fisheries theme on behalf of the Challenge Program.

The Aquatic Ecosystems and Fisheries theme has identified four main areas of research that will be given priority under the Program: Policies, Institutions and Governance; Valuation of Ecosystem Goods and Services, and the Costs of Degradation; Environmental Water Requirements; and Improving Water Productivity. Expected outputs from research in these areas will include:

1. Assessment of the factors determining access to aquatic resources by target communities and social groups and how these can be managed in each focal basin.

2. Specific guidance on the form of governance systems, policies and institutions, that foster equitable and sustainable management of aquatic ecosystems and their resources in each focal basin, and generic guidance on approaches that can be used in other basins.

3. Improved technical capacity and information systems that will support the development and application of such governance systems, policies and institutions.

4. Assessments of the ecological functions of key aquatic ecosystems, and valuations of the goods and services provided by these and the costs of ecosystem degradation.

5. Improved tools and methodologies for generating such information rapidly and in an accessible manner.

6. Projections of the impacts of specific degrees of hydrological change on the ecological functions of different aquatic ecosystems in selected basins and of the different goods and services they provide.

7. Improved methodologies for assessment of environmental water requirements of different aquatic ecosystems.

8. Quantification of the freshwater requirements of coastal ecosystems in selected basins.

9. River fisheries production models developed and applied in selected basins.

10. Assessment of the current and potential contribution of aquatic resources to water productivity in different farming systems, notably irrigated and flood-prone systems.

11. Quantification of the benefits that can be obtained by integrating fish production and harvest of other aquatic animals and plants into farming systems.

12. Improved technologies for integrating aquaculture and fisheries into different farming systems.

Those wishing to know more about or contribute to this program should visit www.waterforfood.org

Box 1. Water and food challenge program

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