5 FISHERIES IN THE INNER NIGER DELTA

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5.1 Introduction

Old fishermen in the Inner Delta still tell stories about the past when they captured Nile Perches of 1.5 m and longer. This is certainly not a fisherman's yarn. All fishermen in the Inner Delta remember that during the last 30 to 40 years fish have significantly reduced in size. And the fishermen know about the causes of the decline in size. The fish stock in the Delta is almost the same as in the past, but fishing intensified continuously, visible in the increase of fish traps, hook lines and fishing nets. During the décrue, the fish are easy to catch because they become trapped in (temporary) lakes and concentrated in creeks and the riverbed. Nowadays, nearly all fish will be captured long before the next flood arrives. The catch of the following year now mainly depends on the young fish born in the preceding flooding period. Nile Perches in the Inner Delta no longer have the time to reach a size of over 1.5 meters.

A number of studies confirmed the conclusions drawn by the fishermen. Meanwhile, more data have become available. This allows us to extend former research and include additional data, to be used specifically for the purpose of this study. The objective of this chapter is to enhance the current knowledge with regard to the fish production in the Inner Niger Delta and to determine its relationship with fluctuations in the flood level of the Niger River. By determining this production function we will be able to estimate the impact of the management of Office du Niger, Sélingué reservoir and Fomi dam on the fish production in the Inner Niger Delta.

The chapter is structured as follows. Section 5.2 describes previous conducted work on fisheries in the Inner Niger Delta, with a focus on the relationship between flooding and fish catch. Section 5.3 aims to estimate fish production in the Delta by distinguishing between catch and trade of fresh and dried fish. This section also scrutinises existing estimates of the fish consumption in the Inner Niger Delta. The revised estimates of fish production of Inner Delta are compared to those in other African floodplains in Section 5.4. Special attention is paid to the biological upper limit of fish production in the Delta. Section 5.5 applies the production function for fish catch to four scenarios, central in this study. Conclusions are drawn in Section 5.6.

5.2 Literature on fisheries in the Delta

About one third of the 900,000 rural people in the Inner Delta (Table 4.2) depend for their living on fishery. Fish is not a secure food source in the Inner Delta, however. Welcomme (1986) compared the annual fish catch in the Inner Delta for the years 1967 – 1975 and found that in years with a high flood the catches were three times higher than in years with a low flood. Laë (1992a, b) analysed a longer time series (1966 – 1989) and concluded the same. He linked the annual catches with Niger discharge at Koulikoro of the previous year, as well as with maximally inundated area in the Inner Niger Delta.[1]

Since 1967, fish catches in the Inner Niger Delta have been registered by l'Opération Pêche de Mopti (OPM). Our analysis is based upon the same statistics. Fig. 5.1 shows the annual fish catch for the period 1966-2003 according to OPM. The annual catch is closely related to the maximum flood level. Because most fish is captured during falling water in the first half of the year, the catch in Fig. 5.1 is compared with the maximal flood level in October/November the previous year.

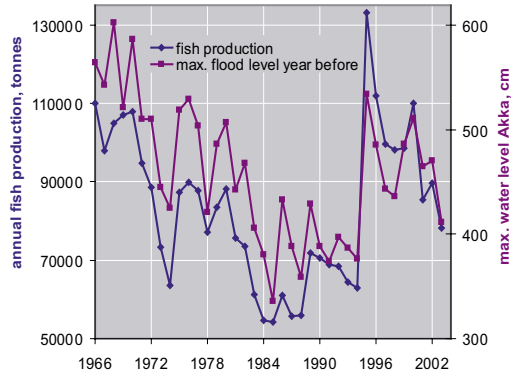


Fig. 5.1. The fluctuation in annual fish catch in the Inner Delta between 1966 and 2003 compared to the fluctuation in the flood level (Akka, cm) in the year before. Source: OPM (fish) and DNH (flood level).

As discussed in chapter 3.7, the annual fluctuation in flooding can be expressed in several ways: maximal flood level, maximal inundated surface and annual or maximal flow of the river entering the floodplains. These variables are highly interrelated, since the river flow determines the maximal flood level as well as the surface of the flooded area. The main question is what lies behind the dependency of fish on the flood volume, the flood level and/or the surface of the flooded area. Clearly, high flood levels allow fish to reproduce and to grow. The flood level is moreover closely related to the duration of the flooding period and thereby on the length of the period during which the fish can grow. In a year with a high peak flood level in the Inner Delta, the flood lasts four months longer than in a year with a low flood: the wave comes one month earlier and continues for an extra three months (Fig. 3.17).

In order to survive, fish have to leave the floodplains during falling water. During the dry period, they are concentrated in the riverbeds and small lakes, where the living conditions for fish are poor. The growth comes to a halt and fish may even lose body weight (Dansoko *et al.* 1976). Therefore, the duration of the flooding period determines the growth of the fish and hence the biological production in a given year. In the central Inner Delta, a surface area at a flood level of 300 cm relative to the gauge of Akka is covered by water for 41% of the year. Yet, due to variations in flood level the coverage by water varies between 15% and 65% of the year (Fig. 3.18). Fig. 3.18 shows that duration of flooding is closely correlated with the maximal water level, i.e. the reason to compare the annual fish catch and fish trade with the maximally inundated area.

[1] The surface of the inundated area was derived from the water loss between inflow and outflow of the Inner Delta (Olivry 1995; see also chapter 3).

After the pioneering work of Daget (1954), a large number of excellent studies have been conducted on fish and fisheries. Quensière (1994) summarised this research. Ten years later, his conclusions and recommendations are still valid. Laë was the first to quantify the effect of Sélingué and Office de Niger on the flooding and fish production of the Inner Delta (Laë1992a, 1992b, 1994, Laë *et al.* 1994, Laë & Levêque 1999, Laë & Mahé 2002).

In this chapter we produce a new estimate of the impact of Sélingué, Office du Niger and Fomi on the annual fish trade. First, however, we analyse and evaluate fish production and then discuss monitoring, production and consumption of fish in the Inner Delta.

5.3 Estimation of fish production and consumption

Since 1967, Operation Pêche Mopti (OPM) monitors the landing, export and price of fish brought from the Inner Niger Delta to the harbour of Mopti. A summary of these data is published in the annual reports of OPM. The original data, from the beginning carefully registered in hand-written books, were recently digitalised by OPM, with the aid of Wetlands International and RIZA. OPM also calculates the annual production of fish and forwards these data to the FAO.

Fish production can be studied from a biological and an economic perspective. In a biological context, annual fish production can be interpreted as the total biomass produced by fish populations, such as determined by natality, mortality and growth rate of different year classes. OPM and FAO use the word fish production in an economical sense: harvested biomass (i.e. the total amount of fish taken each year by fishermen). The economic estimate of the fish production depends on a large number of variables, which are applied as fixed multipliers by OPM. This section evaluates the annual production and examines the validity of some of the multipliers used. The amount of fish sold on the market of Mopti, either as dry fish ("*poissson transformé*" i.e smoked or dried) or as fresh fish ("*poisson frais*"), is recorded daily. The total fish production is evaluated separately for dry fish and fresh fish.

Dry fish according to OPM

OPM registers the trade in Mopti harbour but makes three corrections to arrive at the amount of dry fish actually traded in the Inner Delta. First, it is assumed that a certain proportion of the trade (i.e. 15% before 1985 and 20% after 1985) occurs outside the harbour of Mopti. Second, OPM assumes that not all trade is registered. OPM estimates that the total trade is 12% higher than the registered trade. Third, OPM estimates that 3% of the traded fish is lost due to packing and another 15% during storage. The loss during storage was 30% before 1985 and 20% in 1986. After these three corrections, the total amount of captured fish to be sold as dry fish is estimated to be 59% higher than the recorded trade in Mopti since 1986.

To estimate the consumption of dry fish by fishermen and local people in the Inner Delta, OPM uses the following variables:

- An estimate is made of the population of active fishermen (x), non-active fishermen (y) and non-fishermen (z); (see below);
- During 360 days a year, each fisherman and each member of its family daily consume on average 20 grams of dry fish;
- During 360 days a year, the other people in the Inner Niger Delta and its surroundings, who get fish directly from the fishermen, consume a daily ration of 15 grams of dry fish.

The sum of trade, auto-consumption and local consumption by non-fishing people gives the total production of dry fish. The calculation of the total production of dry fish is shown in Table 5.1.

Ten parameters are included in the calculation of the total production of dry fish. Only the registered trade in Mopti varies each year. The number of fisher-

Table 5.1. Calculation by OPM of the production of dry fish (kg) in 1987.

Dry fish variables	Multipliers	1987
Registered trade in Mopti	a	2,431,169
Registered trade outside Mopti	20% of a	486,234
Registered trade	c=a+b = 1.2*a	2,917,403
Non-registered trade in Mopti	10% of c	291,170
Non-registered trade outside Mopti	20% of c	58,348
Total trade	d=1.12*c = 1.344*a	3,267,491
Loss at packing	3% of d	98,025
Loss during the trade period	15% of d	490,124
Total production to be traded	e=1.18*d = 1.586*a	3,855,640
Auto-consumption by fishermen (225,000)	f=20*360*(x+y)	1,620,000
Local consumption by non-fishermen (540,000)	g=15*360*z	2,916,000
Total production	h=e+f+g	8,391,640
Total trade as % of total production	e as % of h	46.0%

Note: x+y = number of fishermen (x) + number of their family members (y); z = number of non-fishermen.

Table 5.2. Calculation by OPM of the production of fresh fish (kg) for 1987.

Fresh fish variables	Multipliers	1987
Registered trade in Mopti	i	219.986
Local consumption by active fishermen (62,000)	j=150*360*x	3348.000
Local consumption by non-active fishermen (163,000)	k=50*360*y	2934.000
Local consumption by non-fishermen (540,000)	l=40*360*z	7776.000
Total production	m=i+j+k+l	14277.986
Total trade as % of total production	i as % of m	1.5%

Note: x= number of active fishermen, y family of active fishermen, z = number of non-fishermen.

men and the number of non-fishermen increase at a constant rate. Seven parameters are multipliers relative either to the registered trade (registered trade outside Mopti, non-registered trade in Mopti, non-registered trade outside Mopti, loss at packing, loss during trade) or to population size (daily consumption by fishermen, daily consumption by non-fishermen).

Fresh fish according to OPM

Compared to dry fish, the estimated production of fresh fish is straightforward for trade, but slightly more complex for local consumption. OPM assumes that all registered fish trade takes place in Mopti. The trade in fresh fish was small in the past, so although this figure was known since 1967, was not taken into account in the calculation of the fish production until 1995.

To estimate the consumption of fresh fish by fishermen and local people in the Inner Delta, OPM uses the following variables:

- An estimate is made of the population of active fishermen (x), non-active fishermen (y) and non-fishermen (z);
- During 360 days a year each active fisherman daily consumes on average 150 grams of fresh fish.
- During 360 days a year, the non-active members of fisherman's family daily consume on average 50 grams of fresh fish.
- During 360 days a year, the other people in the Inner Niger Delta are assumed to eat a daily ration of 39 grams (before 1994) or 40 grams of fresh fish (1995 and later).

The sum of trade, auto-consumption and consumption by other people in the Inner Niger Delta who get the fish directly from the fishermen, gives the total production of fresh fish. Table 5.2 illustrates how the production of fresh fish is calculated.

Eight parameters are included in the calculation of the total production. The registered trade in Mopti varies each year. The number of fishermen and the number of non-fishermen increase at a constant rate. Four parameters are multipliers (non-registered trade, daily consumption by active fishermen, daily consumption by non-active fishermen and daily consumption by non-fishermen).

Total production according to OPM

To calculate the total production of dry and fresh fish, the amount of dry fish has to be converted into total amount of fresh fish. During the years 1977-1997, dry fish consisted of smoked fish (75%) and dried fish (25%). Since 1998 the ratio is 83% smoked fish and 17% dried fish. Fresh fish loses 2/3 of its weight after smoking and 3/4 ditto after drying. To express dry fish production in terms of fresh weight equivalents, the following multipliers are used:

(0.75 * 3 + 0.25 * 4) = 3.25 for 1977-1997, and

(0.83 * 3 + 0.17 * 4) = 3.17 for 1998 onwards.

Number of fish consumers in the Inner Niger Delta according to OPM

Most yearbooks of OPM present tables such as our Table 5.1 and Table 5.2.The various multipliers are extracted from these yearbooks. Total fish production is not very sensitive to the assumptions regarding unregistered trade. The use of different estimates of the population size, however, has a dominant effect on calculations of the total production. Throughout the years, various estimates of the population size have been applied by OPM:

- OPM estimated that there were 54,112 active and 26,246 non-active fishermen from 1980 to 1987.
- These numbers changed in 1988 to 196,952 and 84,408, respectively. As a result of this sudden increase, the total production increased by 21% from one year to the next. These numbers remained then the same from 1988 to 1994.
- The OPM-annuals did not report the number of fishermen between 1995 and 2000.
- In 2001 and 2002 the number of active fishermen was 84,255 and 85,928, respectively and the number of non-active fishermen 187,534 and 191,304. This implies an increase of 2.01%. An annual increase of 2.01% is found in several documents and originates from Nadio (1984) who estimated that this was the rate of increase of fishermen in the 1970s and early 1980s (see also Weigel & Stomal 1994).

According to the OPM-annuals, the number of non-fishermen buying fish directly from the fishermen was assumed to be 1.2 million from 1981 to 1988 and about the same (1,166,582) in the period 1989-1994. No data were found in the OPM-annuals for 1995 - 2000, but in 2001 and 2002 the number of non-fishing people was estimated to be 1,496,265 and 1,530,529, respectively. The increase was 2.29%. This figure was first mentioned by the Ministère du Plan (1987) and based upon a comparison of the National Census of 1976 and 1987.

Comparison of the National Census of 1976, 1987 and 1998

A comparison of the National Census of 1976, 1987, and 1998 shows that the population living in and around the Inner Niger Delta increased by only 0.7% per year between 1986 and 1998 (Table 3.1). Since part of the population within the area moved to the cities, the rural population even slightly decreased. This decrease is due to depopulation of the northern delta. The rural population in the southern part of

the Delta has increased with 1% (Table 3.2). These findings imply that the population growth rates as applied by OPM lead to an overestimation of the group of fish consumers in the Inner Delta.

Herry (1994) analysed the census of 1976 and 1987. He used additional data from 1987 to divide the population for all 'arrondissements' within the Inner Delta into fishermen, farmers and cattle breeders. He found that hardly any fishermen lived in the northern Delta in 1987. The area had been dry for several years and most fishermen had moved to the south. The comparison of population change per arrondissement led to similar conclusions. The population increased in the central part of the Delta, where more than 25% of the population are fishermen. Comparable data are not available for the 1998 census. Most fishermen live within the region of Mopti, where the population increase has been 1% per year.

Several independent researchers provided estimates of the number of fishermen in the Inner Delta. Gallais (1967) estimated their number at 70,000. This number increased to over 80,000 in 1975 and 225,000 in 1987 (Morand *et al.* 1991). Nadio (1984) and Laë *et al.* (1994) concluded that the increase of fishermen was 2.01% per year between 1966 and 1976 and 1.5% between 1976 and 1989. The increase of the non-fishing people in the Inner Niger Delta was estimated at 2.29% between 1966 and 1976 and 1% between 1976 and 1989.

Laë *et al.* (1994) and Weigel & Stomal (1994) used these figures to recalculate the total fish production.

They used the results of the National Census of 1987 and the work of Morand *et al.* (1991) to arrive for 1987 at an estimate of 62,000 active and 163,000 non-active fishermen and 540,000 non-fishermen living in the Inner Niger Delta. Now that the results of the National Census of 1998 are available, we can conclude that their estimate of the population increase has been too high.

In our calculation we assume that the population increase of the rural people in the Inner Niger Delta, fishing or non-fishing, has been 1% per year between 1977 and 2003. On the basis of this assumption, the number of active, non-active fishermen and non-fishermen has increased from 56,128, 147,562 and 488,855 in 1977 to 72,700, 191,130 and 633,192 in 2003, respectively. Because these estimates of the population size differ from the estimate applied by OPM, our estimation of total fish production also deviates from the one reported in the OPM-annuals and therefore also by FAO.

The annual fish production in the Inner Niger Delta

By combining the OPM statistics and multipliers on registered trade of dry and of fresh fish in Mopti and our findings on population size in the Inner Delta, new estimates of fish production in the Inner Niger Delta have been made (see Fig. 5.2 and Fig. 5.3). The underlying data are reported in Appendix 6.

Fig. 5.2 shows the annual production (tonnes) of dry and fresh fish, sub-divided into the amount consumed by fishermen, by non-fishermen in the Inner Delta, and the amount sold on the market. Total production is expressed as fresh weight, using a multiplier of 3.25 (or 3.17 in recent years) to convert the weight of dry (= dried + smoked) fish into fresh weight.

Fig. 5.2 clearly shows that at present about half of the dry fish is brought to the Mopti harbour to be traded. Yet, only a small proportion of the fresh fish is marketed. For both fresh and dry fish, these proportions have not been stable over time. In the 1970s 75% of production of dry fish was sold, then decreased to 50-60% in recent years. The relative significance of

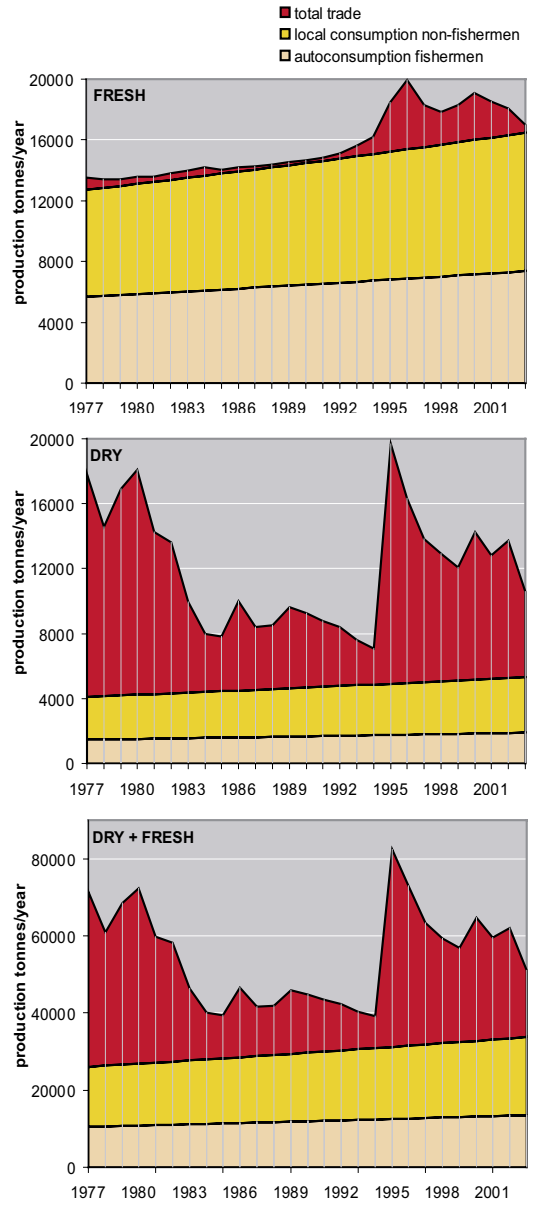


Fig. 5.2. Annual fish production for the Inner Delta, split for trade, informal trade within the Inner Delta and auto-consumption by fishermen.

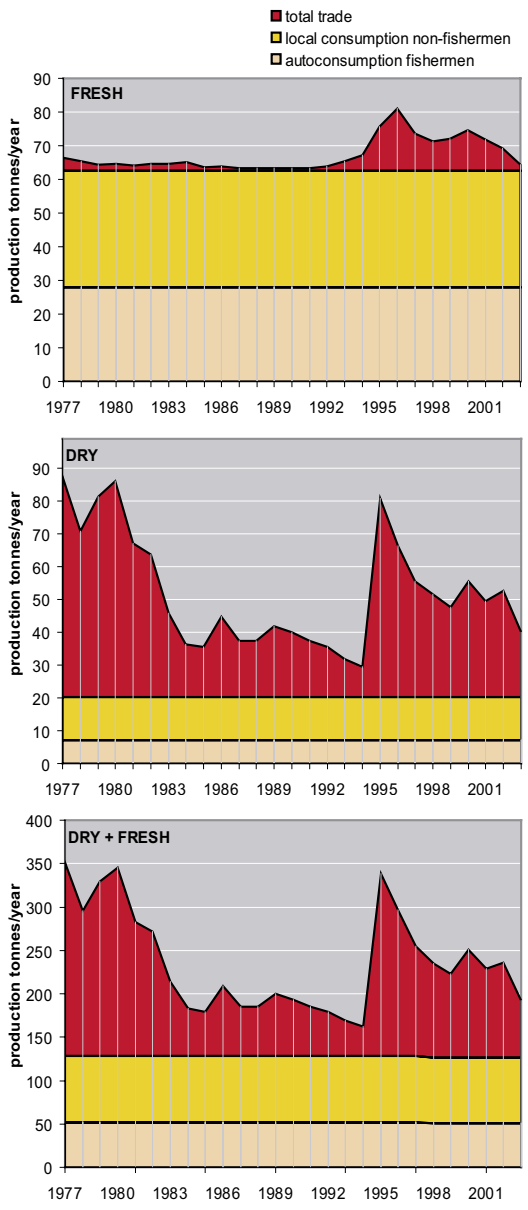


Fig. 5.3. Annual fish production per fisherman in the Inner Delta, split for trade, informal trade within the Inner Delta and auto-consumption.

trade of fresh fish was less than 5% until 1993. Fresh fish trade increased to 10-25% of the total catch between 1995 and 2002. The main reason for this shift might be the presence of an ice factory in Mopti from 1974 until 1984, again from 1986 until 1988 and finally since 2000. It is remarkable, however, that the absolute peak in trade of fresh fish was reached in 1995 when there was no ice factory.

Fig. 5.3 shows the total average annual production per fisherman (either active or non-active) of dry and fresh fish. The total production is the sum of the amount sold on the market, auto-consumption and local trade. The auto-consumption of dry fish is estimated at 7.20 kg/year/fisherman and local trade at 12.96 kg/year/fisherman. Auto-consumption of fresh fish is estimated at 27.92 kg/year and local trade at 34.56 kg/year/fisherman. The estimates are obtained by dividing the total production by the adjusted number of fishermen. To convert the data to production per active fisherman or per family, all production estimates have to be multiplied by 3.57 or by 10.

5.4 Revised estimates

According to the statistics obtained by OPM, total fish production in the Inner Niger Delta during the last 34 years has varied between 54,000 and 133,000 tonnes. More than half of the total production is consumed in the Inner Delta (auto-consumption plus local trade). After adjusting the OPM data for the smaller population increase that we found in the National Census in the Inner Delta (see chapter 4), total fish production is also smaller. Based on a smaller population, our estimate of fish production in 1977 is 17% smaller than provided by OPM; this discrepancy increased over the years to 35% in 2003 (see Fig. 5.4). Note that the data published in the annuals of OPM are also reported by the FAO-site.

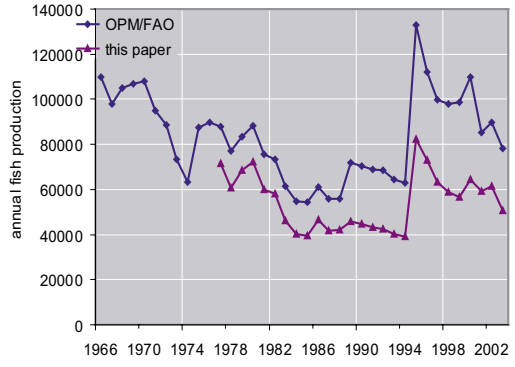
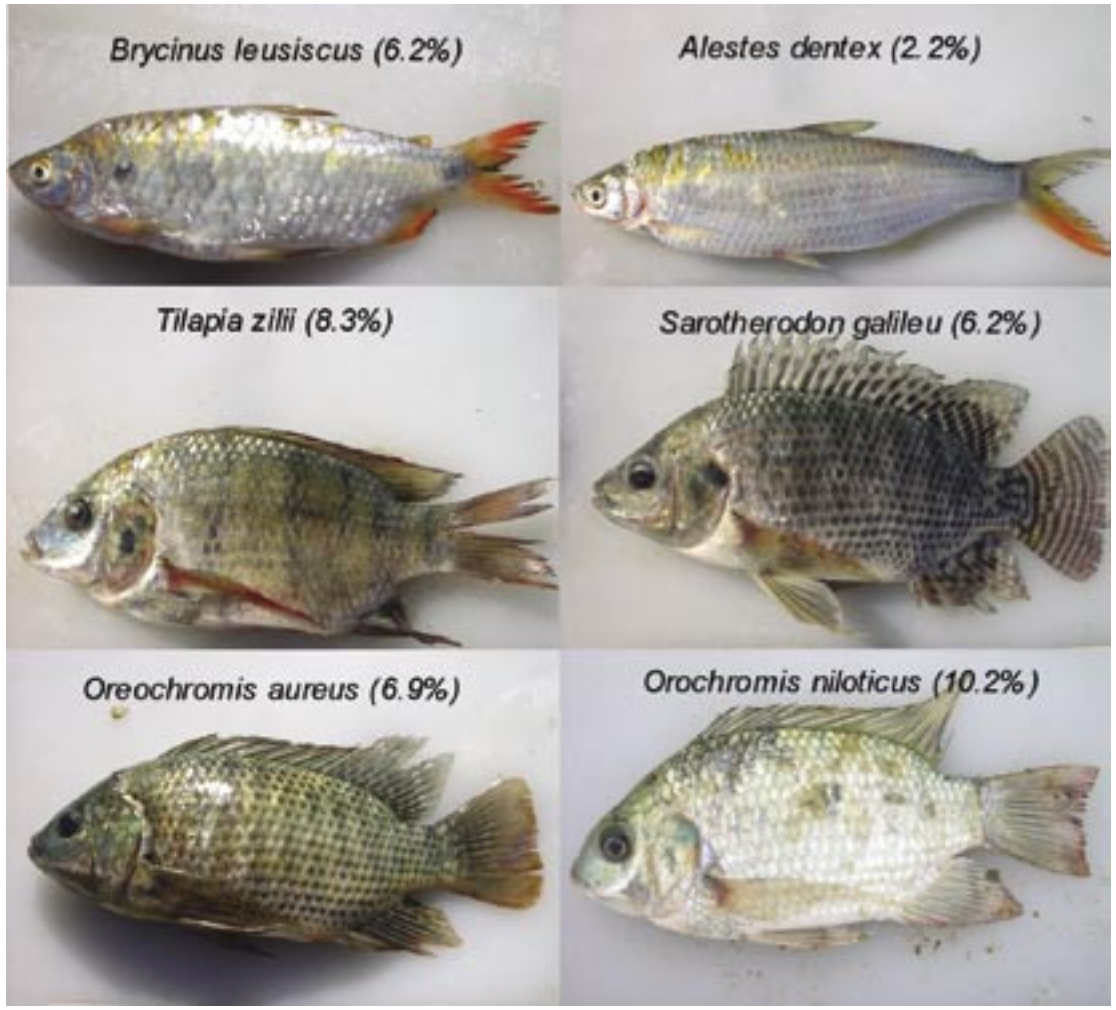


Fig. 5.4. Annual fish production equivalents in the Inner Niger Delta in tonnes fresh weight according to OPM and our estimate that assumes a smaller population growth.

Fish production in the Inner Niger Delta and other African floodplains

That annual fish catches in a floodplain vary in accordance with the intensity of flooding is generally recognised in the literature. Before Welcomme published his paper about the annual catches in the Inner Delta, he had already described a similar relationship between annual catch and flood level in the Kafue River (Zambia) (Welcomme 1979). A similar effect of flood level on fish catch has been found in the rivers Amur, Cross, Danube and Nile (Laë 1992a, Laë & Levêque 1999) and also in Lake Tchad (Durand & Levêque 1978). Laë & Levêque (1999) combined the various case studies to draw a more general picture of the relationship between annual fish catches and variations in the size of floodplain. Their findings are shown in Fig. 5.5.

From an ecological perspective it is obvious that the catches depend predominantly on the size of the inundation area. Welcomme (1986a, b) concludes that fish production of African floodplains amounts to 3.83 tonnes per km^2 floodplain, or 38.3 kg/ha. Fig. 5.5 shows that the relation between fish production and floodplain area is exponential, the exponent of this relationship being 0.63. Note that, if fish catch and floodplain area are independent, the exponent is equal to 1. The exponent is lower than 1 because the catch per hectare declines with floodplain area. For the large floodplains, the catch per hectare varies between 6.5 kg/ha for the Yaérés floodplain in the Logone River (Cameroon) and 40 - 50 kg/ha for the Inner Niger Delta. Two estimates are given for the Inner Delta: 40,000 tonnes at an inundation of 8,000 km^2 and 80,000 ton at an inundation of 20,000 km^2. The only area that is more productive than the Inner Niger Delta is the Sénégal floodplain with a catch of 56 kg/ha. Yet, this estimate refers to the situation before dams and dikes delimited this inundation area. The catches in the Sudd floodplains, southern Soudan (8.8 kg/ha), and the Cross floodplains, southeast Nigeria (25 kg/ha) are much smaller than the Inner Delta.



Economically most important fish species in the Inner Niger Delta. Proportional share of total catches is indicated between brackets. Source: Laë *et al.* (1994).

Production function for fish catch in the Inner Delta

The available data on traded fish and the variation in inundation zone over time allow for the estimation of a production function for fish catch. The main variable that determines the variation in fish trade and catch is the biological production of fish, which in turn is determined by the maximum water level, reached the preceding year in Akka. This relationship has already been described for the total production and over a shorter period: Welcomme (1986a) for 1967 – 1975 and Laë (1992a) for 1966 - 1989. An updated analysis is shown in Fig. 5.6.

The earlier work by Welcomme and Laë concluded that the fish production not only depends on the flood level in the previous year but also on the flood level

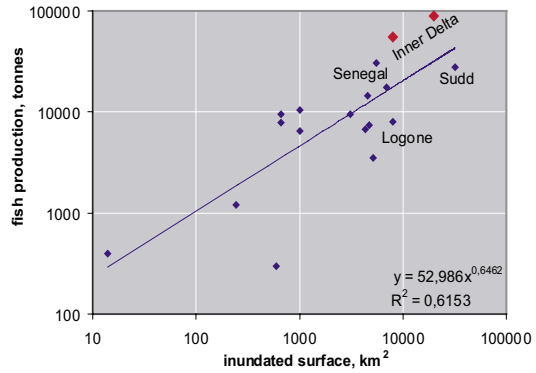


Fig. 5.5. The relationship between annual fish production in different African floodplains and the maximum surface of the inundation zone. Both scales are logarithmic. Source: Laë & Levêque (1999). Two revised estimates are given for the Inner Delta: one for a low and one for a high flood.

two years earlier. To analyse the effect of the flood two years before, the deviation between observed trade and predicted trade, given by the curvilinear regression in Fig.5.6, was plotted against the water level in Akka two years earlier. Although, a curvilinear relationship was again found, the level of correlation was weak ($R^2 = 0.17$) and not significant. The explanation for this weak relationship is that fisheries have intensified so much in recent years that the share of mature fish in the overall fish catches (i.e. fish that is older than one year) declined substantially. More than 30 years ago, the catch of fish in the Inner Delta still comprised several year classes. Since fish catches in the last one or two decades increasingly consists of immature fish (i.e. fish being less than half a year old), there is no reason to expect that the water level of two years ago determine fish catches today (in accordance with the regression analysis).

Since the number of fishermen has increased with 1% per year, one would expect that the trade would have increased over the years at the same rate. In fact, there was, on average, no increase at all. Fig. 5.6 shows the trade separately for two periods, before and after 1990. The relationship between total trade and maximal water level in the previous year is the same for the two periods, hence one common regression line.

That the trade per individual fishermen has not increased over the past 27 years could already be seen in Fig. 5.3. Data from Fig. 5.3 were used to generate Fig. 5.7, showing traded fish as a proportion of total production in relation to the maximally inundated area in the foregoing year. Similar to Fig. 5.6, the data are separately analysed for the period before and after 1990. The positive slope of both curves indicates that higher flood levels lead to more fish trade. Yet, the relative proportion of traded fish is structurally higher in the period before 1990 than after 1990. Therefore, if the flood level is taken into account, each fisherman sold more fish in the past than in more recent years. This may be the first sign of a depletion of fish stocks.

Upper limit of fish production is reached

If it were true that a larger population of fishermen is not able to bring more fish to the market, this suggests that fish production is constrained by an absolute ceiling level in the biological production. This far-reaching conclusion is supported by the work of Amaga Kodio and co-authors (Kodio *et al.* 2002). During a series of years (1994-95 till 1998-99), they measured the daily catch of individual fishermen in the period February - June. There is a substantial fluctuation in the daily individual capture, varying between 1 and 400 kilogram. Poor catches mostly occurred in June while nearly all large catches took place in February and March. On average, there was a decrease in the daily catch from 35 kg/day in early February to 7 kg/day end of June. Kodio *et al.* (2002) concluded that this decrease must be due to depletion of available fish stock and that nearly all fish had been captured by the end of the fish campaign.

Fish older than one year has become increasingly scarce in the Inner Niger Delta (Laë 1994). The only way for a species to survive is to reproduce as early as possible. The reproduction for most species is restricted to the high water period (Bénech & Dansoko 1994). Therefore, the fish stock of a year depends

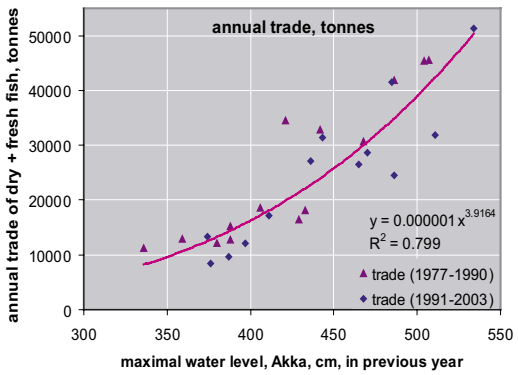


Fig. 5.6. Annual trade (ton fresh fish equivalents) of dry and fresh fish in the Inner Niger Delta as a function of the maximal inundation in the previous year.

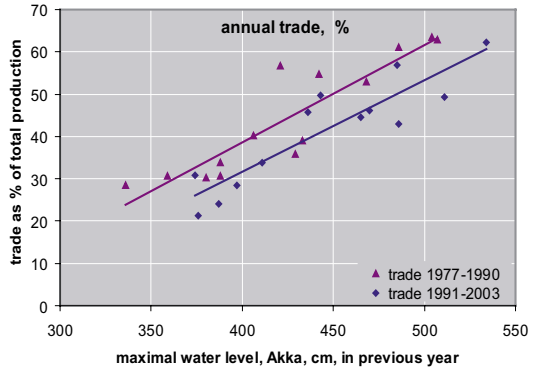


Fig. 5.7. Annual trade as percentage of the total production (dry and fresh fish combined) as a function of the maximal inundation in the foregoing year.

on the spawn and fry produced by the few fish still alive at the end of their first year and the very few fish older than one year. Bénech & Dansoko (1994) found that the fish species in the Inner Niger Delta have adapted to this extreme predation pressure by advancing their age of reproduction.

The depletion of fish stock in the Inner Niger Delta is mainly caused by the introduction of nylon nets in the 1960s. Since then, the exploitation system has changed significantly. In parallel to the continuous decline of the size of captured fish, mesh sizes of the nylon nets have decreased simultaneously. Mesh sizes were less than 50 mm before 1975, 41-50 mm between 1976 and 1983 and 33-41 mm between 1984 and 1989 (Laë *et al.* 1994). By using nets with smaller mesh width, only very small fish can escape. At the same time, since the average fish gets smaller, nets with a wide mesh width become increasingly useless. As described by Laë *et al.* (1994) fishermen have consequently adapted their fishing technique.

The conclusion that the amount of fish being captured has reached a ceiling casts doubts on the earlier conclusions drawn in this section. For example, it would mean that the data on the total production as presented in Fig. 5.2 increasingly overestimated in recent years. If the fishermen are not able to catch more fish than they do now, one may doubt whether the daily consumption by the local population is still at the same level as 20 or 30 years ago. The estimation of the total production is based upon the assumption that fishing people consume daily 30 grams dry fish and the other people in the Inner Niger Delta 15 grams.

Is auto-consumption and local trade constant over the years?

Two studies are available on the average daily fish consumption by a fisherman's family (10 persons, on average). The daily consumption was 1,183 grams in 1961 and 1,365 grams in 1989 (Laë 1994). It is remarkable that these estimates do not differ more from each other, since the flood in the foregoing year was high in 1960 (580 cm at a maximum in Akka) and low in 1988 (439 cm at a maximum in 1980). Apparently, low food supply does not immediately affect daily rations of fish eaten by fishermen themselves.

There are also two estimates of the daily ration of fish by non-fishermen in the Inner Niger Delta: one from a period when the flood levels were extremely high (1957-58) and one from a year with a very low flood (1991) (Weigel & Stomal 1994). Again, the estimates of the daily rations do not deviate much from each other. It is clear from the study of Weigel & Stomal that it is difficult to estimate the daily fish ration. It is too simple to make a distinction between fishermen and non-fishermen. An average migrant fisherman consumes more fish than a sedentary fisherman and much more than an agro-fisherman. In 1991, 19% of the fishermen were migrants, 48% sedentary and 33% combined fishing with agriculture. It is likely that the latter category has increased in the last few years. As a consequence, the overall auto-consumption would have decreased over the years.

Although the study of Weigel & Stomal (1994) found no difference between the individual fish consumption by local people, it remains unlikely that this ration would not vary between years. Each fisherman has to decide which part of its capture would be sold locally and which part on the market. Fig. 5.6 shows that the annual trade in Mopti varies between 10,000 and 50,000 tonnes. It is likely that the local, informal trade would vary more or less simultaneously with the annual trade in Mopti. In any case, it seems very unlikely that the local trade in a year with a low flood would be the same as in a year with a good flood.

The estimate of the total production changes significantly if the local trade for local consumption varies simultaneously with the trade in Mopti. First, the total production would be much lower in years with a low flood, since the amount of traded fish is low in those years. Second, the total production would be lower in recent years, since the contribution of the local consumption to the total production has increased due to the increase of the population size. Hence, the recalculated production data as presented in Fig. 5.6 would be even lower if one assumes that the local trade varies in accordance with trade in Mopti. Because the evidence for the suggested decrease in the local, informal trade and auto-consumption is missing, the statistics presented in Appendix 6 are applied instead. Still, one should keep in mind that the shown decrease in fish catch per fisherman during the last 30 years is possibly even larger than indicated.

5.5 Production function for fish catch under the four scenarios

The annual fish production presented in Fig. 5.1 and Fig. 5.5 as well as the trade Fig. 5.6 reveal a strong correlation with the flood level. Therefore, a production function for fish trade and fish production in relation to the flood level can be estimated on the basis of fish trade data for the period 1976 – 2003. For reasons of comparison, the functions presenting the relationship between trade and production versus flood level are estimated. Both production functions are presented below:

Fish trade

$Ht = 0.00003x^{2.1728}$ **5.1**

($R^2 = 0.801$)

Fish production

$HP = 7.404x^{0.9459}$ **5.2**

($R^2 = 0.847$)

where:

T = total fish trade (in tons)

P = total fish catch or production (in tons)

x = maximal flooding surface in the previous year (in km^2)

Next, equations (5.1) and (5.2) are used to evaluate the impact of the irrigation by Office du Niger and the withheld water in the Sélingué and planned Fomi reservoirs. The subsequent variation in flooded area for these scenarios has been substantiated in chapter 3 and Appendix 6. As mentioned, fish trade is known for the period 1976 – 2003. Still, we run the scenarios for the years since 1982 because this is the period for which the effect of irrigation and reservoirs is manifest.

Fig. 5.8 shows the four scenarios for the period 1982-2003 on the basis of the production functions estimated in equations (5.1) and (5.2) for both fish trade (left) and fish production (right). The yellow regression line represents the calibrated present situation (scenario 2). The derived regression functions also simulate the fish catch and production under conditions for higher (scenario 1 and 2) and lower flood levels (scenario 3). The top of Fig. 5.8 shows the difference between scenario 0, 1 and 3 with the baseline scenario (i.e. present situation). By adding these curves to the present situation curve, the absolute levels of fish trade and production are generated (see bottom half of Fig. 5.8).

Compared to the present situation, fish trade would have been 630–2200 tonnes higher without Office de Niger, which is on average 6% of the total fish trade. In a situation in which neither Office de Niger nor Sélingué operates, fish trade would have increased to 1150-7200 tonnes (i.e. approximately 12%). With the reduced river flow due to the planned Fomi dam, the fish trade will decline further with 34%.

According to the above calculations, the relative effect of irrigation and reservoirs is smaller for production than for fish trade. Compared to the present situation, fish production will be, on average 2,7 tonnes higher without Sélingué, which is on average 5% of the total fish production. In a situation with neither Sélingué nor Office de Niger, fish production would increase to 4,100 tonnes (i.e. 8%). The Fomi dam will reduce fish production by 8,500 tonnes per year (16%) compared to the present situation.

Our estimate does not differ much from the previous estimates. Laë (1994) concludes that without Office de Niger and Sélingué the total fish production would have been 4,500 to 5,000 tonnes higher or 9 - 10% of the total production. Two further remarks need to be made with regard to our analysis. First, we assume that auto-consumption and local trade within the Inner Delta are constant and is thus not related to flood level. The main reason for this assumption is the fact that daily fish consumption per family is supposed to remain constant over time. The validity of the implicit assumption is uncertain. It is quite plausible that the daily consumption by local people varies in relation to the total annual

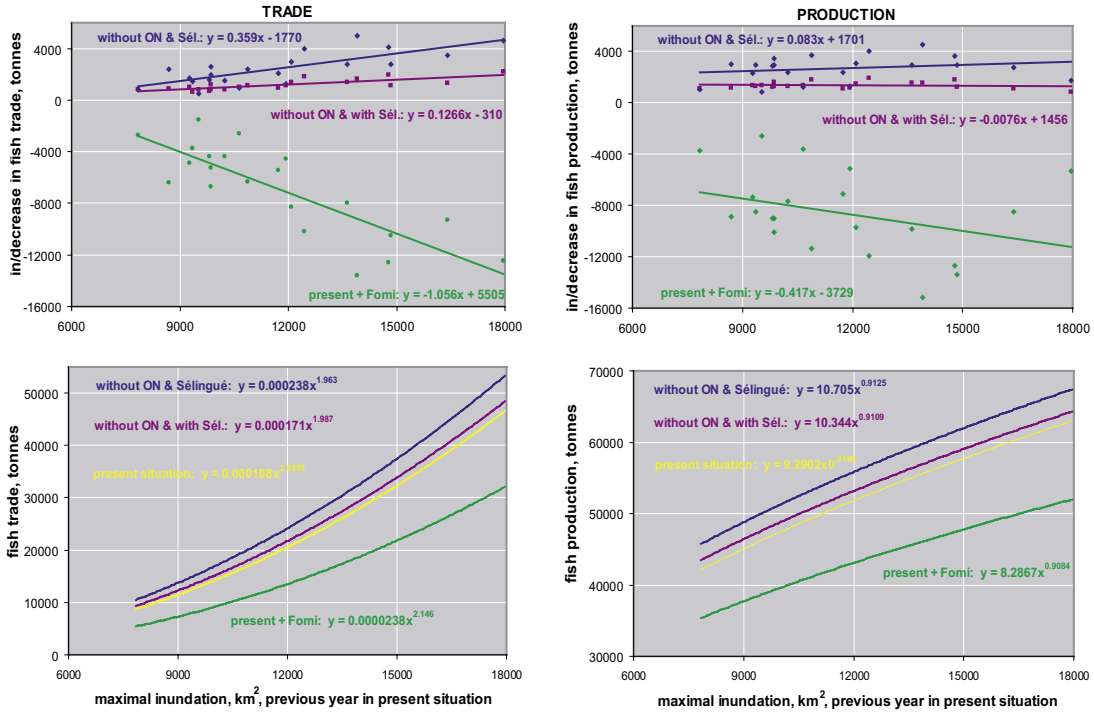


Fig. 5.8 The absolute (bottom) and change in (top) annual fish trade (left) and production catch (right) in ton in the Inner Delta in the present situation compared to three scenarios (0) without Office de Niger & Sélingué, (1) without Office de Niger & with Sélingué, and (3) present plus Fomi.

catch and thus to the flood level. Unfortunately, no evidence of such relationship is available. Second, our as well as Laë's estimate contain an element of underestimation because both analyses ignored the fact that, in the first three years of its existence, the effect of the Sélingué reservoir on fish trade was less extensive (i.e. reduction of 500-1,200 ton). The explanation for this exception is that, in the beginning, Sélingué withheld less water because the reservoir was not completely drained in the dry period and not fully filled during the crue (see Fig. 2.10 and Appendix 2).