

13. The exploitation of fish stocks in the Lake Chad region

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Fishing exploits a major resource in the Sahel because the potential yield of continental fisheries is estimated to be several hundred thousand tons, most of which originates from the central Niger delta in Mali and the Lake Chad region. This tonnage represents a similar quantity of protein to that produced by cattle and also has significant export value. Only recently has the value of this resource been recognized and so the wide range of knowledge required for proper management has not been acquired. The development of fisheries in the Lake Chad region can be examined initially from data collected since 1963, mostly on total catches. But the optimization of the fishing industry still requires a considerable amount of biological and socio-economic research.

The fisheries of Lake Chad cannot be considered in isolation as has generally been done for the other disciplines in this book. There is remarkable agreement between the permanent as well as the temporary river and lake environments. The climatic variations associated with the very flat morphology of the center of the Chad basin, cause the seasonal existence of large flood zones, fed by rivers and then drained towards the permanent environments. These flooded zones offer shelter and food to the young of several species and thus they constitute a considerable portion of total lake production.

The life cycle of several commercially important species can be described in three phases: an upstream reproductive migration of adults in the rivers at the beginning of the flood, growth of the fry in the flooded zones and the major river beds and finally a return to the lake where both adults and juveniles remain. The life cycle stages of *Alestes baremoze*, whose biology and dynamics were particularly studied (Section 6) are summarized in Fig. 1 (Chapter 10). They occurred in the fishing zone studied, above 10°50' latitude north which included most of the fishing activities of the Chad basin.

The fishing industry of Cameroon was first described by Monod (1928). This study only deals with the northern course of the Logone and the Shari in the Chad basin. A complete list of traditional techniques and their usage until 1955 was provided by Blache and Miton (1962). Recently, more specialized studies have been done on some fisheries of Lake Chad and the lower Shari and

Logone streams: Durand (1970a, b, 1971, 1973, 1980); A. J. Hopson (1968); J. Hopson (1969, 1972); Loubens (1973); Quensière (1976) and Vidy (1982).

Blache and Miton showed that the traditional fishing techniques were well adapted to the many situations encountered in a complex and varied aquatic network. Therefore the very large variety of fishing gear in use resulted from the local differences in hydrography and seasonal rhythms:

- low water fishing during which the best yields are obtained;
- river fishing with drift nets during the flood;
- fishing in flooded zones during high waters;
- exploitation of lateral migrations during subsidence.

No systematic surveys were made which allow a precise comparison to be made 20 years later but it is certain that many traditional techniques are not used anymore. This is the case with 'zemys' fishing practised by the Kotokos at the Logone-Shari confluence and downstream. These collective fisheries have disappeared since the sixties when Monod counted 68 large pirogues in 1925 and Blache and Miton 169 in 1955.

13.1 The fisheries

The recent fishing history of the Lake Chad region has been marked by a combination of two phenomena: the Sahel drought and an accelerated development of fishing activities. Two periods can be distinguished: pre-1971, with little or moderate exploitation and a post-1971 period of drought with an increase in human predation on the aquatic environments.

13.1.1 *Before the lake contraction*

13.1.1.1 *The rivers and their tributaries.* From the delta to the confluence, the Shari is characterized by the absence of adjacent flooded zones. Therefore it is the only possible route for species which migrate from the lake to the rivers and whose migrations are related to the flood patterns upon which fisheries activity depends. This latter was very important and the four major fishing methods were organized around it: fixed gill nets, drifting gill nets of small mesh (28.5 mm in general), nets of large mesh (60 to 70 mm), unbaited multiple hook lines (Loubens 1973).*

Unlike fishing in the lake, the bulk of the catch came from small mesh nets in this area, where most of the *Alestes baremoze* catches were made between 1965 and 1970.

* All the mesh sizes cited refer to the edge of the mesh (in mm) measured from knot to knot, being thus half the classical 'stretched' mesh. The abbreviation 'GNx' is used for 'gill net of size x mm'.



Photo 16 View of a traditional fishing on the El Beid River, during the dry season.

— In the rivers, above the Logone and Shari confluence, the seasonal fishing techniques often remained the most diversified. The total yield was still less in the Logone than in the Shari. This was doubtless due to the very extensive flooded zones on the right and left banks of the Logone which did not really have an equivalent in the Shari.

Small or large mesh fixed or drifting gill nets, unbaited multiple hook lines were again found as well as triangular nets (sakamas) used from the pirogues, casting-nets (introduced by the fishermen of the Benoué basin etc. ... The major outflow of the flooded zones on the right bank of the Logone drained the north and south Ba-Illi region (cf. Fig. 22, Chapter 2). When fishing, the Kotokos install a screen dam made from the stems of *Echinochloa*, supported by solid plant beams driven in the river bed.

Stick seines, which are 20 to 23 mm gill nets were found in this region. The nets, about 0.5 m high and 15 to 20 m long are fixed on some small sticks which support the net opening. The fishermen draw several attached sheets that scrape the sandy bottom up to the shore. Large sized fishes like *Tilapia* and *Citharinus* were caught but most of the catch consisted of *Alestes baremoze*, *A. dentex* and *Hydrocynus forskalii*. These fisheries operated at low waters on the uncovered sand banks and their importance has become reduced over these last few years.

— There were two flooded zones south of the lake: the triangle between Logone

and Shari, south of Logone-Gana, dependent on the river system, and 'yaéré' of North Cameroon, whose main exit, the El Beid, directly rejoins Lake Chad. The first of these zones provided the recruitment of the great traditional fishery of Logone-Gana which only caught adult fishes returning to the Logone during their anadromous migration when the subsidence begins. In the yaéré of North Cameroon however, the fishing took place in the subsidence outlets, catching fingerlings aged from about two to five months.

In the region of the Logomatia which drained the southern waters of the North Cameroon floodplain (Fig. 1, Chapter 10), little fish traps built with small spaced wicker blocked many hand-made channels dug in the river bank. These fisheries only caught fingerlings and the yields were relatively low as most of the flood waters passed through the El Beid. This river is barred by many permanent fish dams from Tildé up to the lake (Fig. 1, Chapter 10) and about 270 were counted in January 1969 (Durand 1970a). Nets with triangular frames similar to the sakamas mentioned earlier were used for fishing. Young fishes constituted the bulk of the catch.

13.1.1.2 *The lake.* Before 1972, the south basin was characterized by a general weakness of fisheries, that were practically absent from the southeastern archipelago and the south and southeastern open water (Fig. 1, Chapter 2). Only on the southern border and especially in the Shari delta, was activity notable with two types of gear being used: large mesh nets, as in the north basin, and the non-baited multiple hook lines, simply placed on the bottom or hung horizontally between surface and bottom.

Fishing was more active in the north basin with a large predominance of large mesh nets (GN 60 to 130 with a trend towards GN 90). Limited at first to the zones in contact with the reed islands and the western coast with the northern open water, they slowly expanded throughout the basin, due to the increased use of outboard motors. The northeastern archipelago however was hardly exploited, corresponding to a relative scarcity of large sized fishes.

The bulk of the catch of average sized fishes, of little importance before 1970, was caught by seines on the Yobé river (Fig. 1, Chapter 10). Seasonally, these fisheries used locally made nets, of 20 mm mesh, placed right up-stream of the mouth of the Yobé and used between September and February (J. Hopson 1972). Some gill nets were used along the western coast, near the Yobé. The use of the new boats and outboard motors allowed the extension of this fishery, which was installed in 1969 in the northeastern reed islands with GN 25 to 30 (J. Hopson 1972).

The diversity of fishing activity in the above description shows that the gill nets dominated, and that the fisheries corresponding to the lower bed of the rivers, to the delta and to Lake Chad were the ones that provided practically all the production for the past ten years.

This situation was quite different of that described by Blache and Miton as



Photo 17 General view of a traditional fishery occurring once a year at Logone Gana during the annual drying up of the North Cameroon flood plain.

the gill nets then only appeared as one technique among others and being fairly specialized allowed either the capture of a particular species, or allowed fishing at certain times. It appears however that this technique of fishing is very old since it was cited by Monod (1928) for the Shari delta and Boyd Alexander (1907, in A. J. Hopson 1968) for the mouth of the Yobé. The increase in total fishing effort corresponded to the introduction of nylon for making the gill nets. A. J. Hopson (1968) placed its appearance at about 1958 but Mann (1962) noted that during 1961 most of the nets used on the lake were still locally made by the fishermen. Thus it is possible to the start of gill net fishing from 1961–63 as being due to the introduction of nylon and most especially to the industrial production of net material at accessible prices. According to our estimates, the total fishing effort in the north basin was multiplied by about 50 between 1967 and 1971–72 when in the same time the total production multiplied by 5 (Durand 1973b).

13.1.2 *Changes in fishing during the drought*

The intensification of gill net fishing was accompanied by a progressive displacement of fisheries towards the lake and by their establishment there. In



Photo 18 A fisherman and air-dried fish.

these last years, it supplied most of the fish production of the Chad basin (Durand 1973). To show the change in fishing habits, Blache and Miton can be quoted (1962, p. 19): 'Le lac reste très peu exploité et ne l'est que dans sa bordure sud-ouest et dans la région des îlots-bancs de la bordure nord-est' whereas the north basin of the lake provided between 50% and 80% of the total production between 1967 and 1975 (Stauch 1977). This change in the fisheries of the northern Chad basin had already begun in the fifties since Blache and Miton had already noted the tendency to 'des implantations de plus en plus denses de groupements d'émigrés venus du sud dans les zones nord' ... It is thus possible to say that the search for fishes and for increased yields pushed the fishermen increasingly closer to Lake Chad, a tendency that was favoured by the introduction of nylon which allowed the generalized use of gill nets. To this must be added the proximity of Nigeria whose protein needs opened up a large market which easily absorbed the increased fish production.

Until 1971, the progressive displacement of fishing areas towards the delta region was accomplished independently of the lowering of the lake. Starting in 1972 and 1973, the in-between years, the catches in the river diminished very noticeably and the fishermen increased in number by the border of the lake or sometimes fished in the lake from the Delta encampment. During 1973, river fishing was practically negligible and the lowering of the lake helped in exploiting the whole lake. This almost depleted the stocks before the drought of the north began in 1974. After being displaced massively towards the north, the

fishermen fell back again toward the south basin, starting in 1975. It was the south basin which supplied the essential catches although significant ones were made in the marshy zones of the north basin temporarily flooded each year for several months.

The fishing techniques did not change particularly between 1965 and 1977* and the gill nets still supplied most of the fishing effort in the lake region. The meshes on the other hand changed a lot. There were initially two principal types of nets: (a) gill nets of large mesh (GN 80 to 130) used especially as fixed nets in the rivers at low water and in the north basin throughout the year. These nets caught most of the large sized fishes: *Lates niloticus*, *Labeo* spp., *Citharinus* spp., *Hydrocynus brevis*, *Bagrus* spp., *Heterotis niloticus*, *Hemisynodontis membrana-ceus* ... (Durand 1973); (b) Salanga gill nets (GN 25 to 30): the salanga represent all the *Alestes baremoze* and *A. dentex* fished in abundance until 1972. Average sized fishes (25 to 30 cm standard length) were taken including *Hydrocynus forskalii*, *Brachysynodontis batensoda*, various Schilbeidae, Mormyridae. ...

The apparent absence of meshes lower than GN 25 on the one hand and those between GN 40 and 70 on the other guaranteed that most of the fish caught were adults.

Since 1971 the fishing of *Alestes* almost ceased with the disappearance of the stock that earlier supplied 8000 to 10 000 tons of fish a year (cf. Section 6.2). The large meshes were slowly been replaced by smaller meshes: GN 70 then 60 and 50. Observations made during November 1977 in the Shari delta showed that the meshes ranged from 40 to 75 mm with a dominance of GN 55.

The environmental changes have evidently involved some modifications of the fish populations and the major features of this change were given in Chapter 10. It should simply be noted there that the initially common fishes were slowly replaced by better adapted species, particularly tolerant of temporary or permanent deoxygenation of the environment (*Clarias* for example).

13.2 Processing and commercialization

Ideally one would like to assess total fish catches from effort and yield data for the principal fisheries and the most important commercial species. This would avoid sometimes erroneous extrapolations and would permit the actual change in the fisheries to be extensively analyzed. This is impossible in the Lake Chad region, except for some data as those shown in Section 4, and we have to

* Seine fishing had developed in the Shari above the confluence after 1975 (Franc and Vidy, personal communication). During May 1977 these nets (GN 14 to 25) only caught small sized fish.

evaluate here the fresh fish production from the statistics of circulation of smoked and/or dried fish.

The consumption of fresh fish occurred immediately around the lake and rivers (in particular by the two large urban centers, N'Djamena and Maïduguri). All of the remaining catch was preserved by smoking/drying or by drying alone. Sun-drying was used for the small sized fishes (for example, fishery of the El Beid) and certain fishes of average size sold commercially under the name 'salanga'. This category corresponded almost solely to *Alestes baremoze* and *A. dentex*, which were always dried whole (Nigerian side of lake), or eviscerated and placed flat (Logone and Shari). For most of the large sized fishes (*Lates niloticus*, *Heterotis niloticus*, *Citharinus* spp., *Distichodus rostratus*, *Bagrus bayad*, *Hemisynodontis membranaceus*, *Labeo senegalensis* and *L. coubie*, *Gymnarchus niloticus*, *Hydrocynus brevis*, *Clarotes laticeps*, *Mormyrus rume* etc. ... in order of approximate importance), the most common processing was marketed under the name 'banda' prepared for the south Nigerian markets.* The fishes were scaled, eviscerated and cut in pieces. Only some of the bony pieces (heads of some species, spines ...) were thrown away. After smoking (or often only superficial burning), the fishes were again dried for one week. After this they were packed and forwarded to the south via Maïduguri.

The major objective of processing was to obtain good quality drying. A well-dried fish is much less attractive to fish eating insects, which were very abundant. Although average losses were ignored, up to 50 or 60% of the initial dry weight could be lost during transport between production and marketing sites. The insufficient drying resulted from a very hasty process or from poor climatic conditions (increased humidity from May to October).

13.2.1 Conversion coefficients

To obtain estimates of actual catches of fresh fish, it was necessary to consider the many factors operating on the dry weight or the smoked weight. This is, among others, an area where the absence of serious studies was particularly felt. Three factors had to be taken into consideration: the auto consumption (feeding of fishermen's families), the weight losses in the processing of fresh fish, the losses caused by ichthyophagous insects during storage and transport.

13.2.1.1 *The banda.* Outside of so-called auto-consumption, a considerable amount of fish is consumed fresh around the lake and in the urban centers. Not

* In the following text these two vernacular names will be retained; 'salanga' corresponds to *Alestes* caught with gill nets of average mesh (25 to 30 GN) then dried, and 'banda' includes the many species smoked after being caught with large mesh gill nets (50 to 130 GN but usually 80 to 100 GN).



Photo 19 Dried fish (*Alestes*) commonly called 'Salanga'.

all the rest was converted to banda (e.g. smoked *Gymnarchus* sold separately; *Lates* that reached a certain weight and which were dried and sold on the markets around the lake ...); failing precise data, we suggest that 20% of the large sized fishes were not converted to banda.

The transformation coefficient of fresh fish by smoking/drying is also subject to controversy. It actually varies with species, time of drying and seasonal humidity. Mann (1962) recorded it as 2 and 3 on two smoked fish samples after only one day of drying; Hopson (1964) estimated that 70% of fresh weight was lost at the end of the drying. Here the value 3 will be used considering that it is a minimum value and that a better calculation would be closer to 3.5 or even 4. According to the literature, the weight losses during transport by insect attacks range from 30 to 70%. On average, we estimated that 25% of the banda weight was lost between the end of drying and the inspection at Maïduguri. In total, the combination of these three coefficients, gives a coefficient of conversion between fresh fish and banda of $0.8 \times 0.33 \times 0.75 = 0.2$. In other words, there would have to be about five tons of fresh fish for one ton of banda recorded at Maïduguri.

13.2.1.2 *The salanga.* We started from some direct calculations of conversion coefficients for the salanga. Fish processing in the traditional way, drying, was carried out at the end of March, beginning of April and was very quick. The dry

weight/fresh weight ratio was almost identical for the two species: 3.49 for *Alestes dentex* and 3.53 for *Alestes baremoze*, thus 3.5 will be adopted for the salanga.

Theoretically, the auto-consumption (here this term includes all the production that had not appeared in the general circuit of commercialization of dry fish) should also be considered. There was also a lack of quantitative estimates and any precise numbers cannot be projected. It is however certain that the auto-consumption quantity should be considerably less for the salanga than for the banda, because it was a rather expensive product.* Considering the other causes of loss (transport, attack by insects like *Dermestes* between the site of fishing and Maïduguri), we estimate the difference between the fresh production and the commercial production (that was 10% of the fresh production).

From the various corrections one can say that a ton of commercial salanga corresponded to 1110 dry kg on the site of production and thus to a fresh production of 3900 kg of fish (Durand 1978).

13.2.2 *The marketing network*

The banda and salanga took quite different routes from the production site. The only thorough description that has been made was for the years 1963–64 (Couty and Duran 1968).

The configuration of the lake basin and the enormous demand for fish in the Nigerian market resulted in a relatively simple scheme for moving dried smoked fish (banda) which nearly all travelled through the city of Maïduguri in northern Nigeria (Fig. 1). The trucks loaded with bags of banda arrived in Maïduguri by the route of N'Djamena, which attracted the production of the low river system of the delta and of the south basin, by the route of Baga-Kawa which corresponded to the catches of the north basin. The traffic of 'banda' corresponded mostly to the fishing by large mesh nets (thus the larger fishes) which represented 80 to 90% of the total lake production.

As the salanga were then fished in the rivers, especially in the Logone upstream of the confluence, the total production was sent directly to North Cameroon or southern Chad. With the displacement of the fishing downstream, the route from N'Djamena to Maïduguri became important. However, in general the fish were unloaded in Cameroon in the southern region of the lake or even at Woulgo directly in Nigeria. Thus chadian taxes in N'Djamena could be avoided. From about 1967 the north basin of the lake became a new producing area for salanga which travelled by the route Baga-Kawa/Maïduguri.

* Like a number of other Charicidae, the *Alestes* have appreciable seasonal fat reserves that can be converted to oil. On the other hand, the dried meat is used like a seasoning in the sauces for millet and rice.

Cameroon remains the major center of dried fish whether directly by Maltam and Maroua or through northern Nigeria (Fig. 1). No recent data exist to

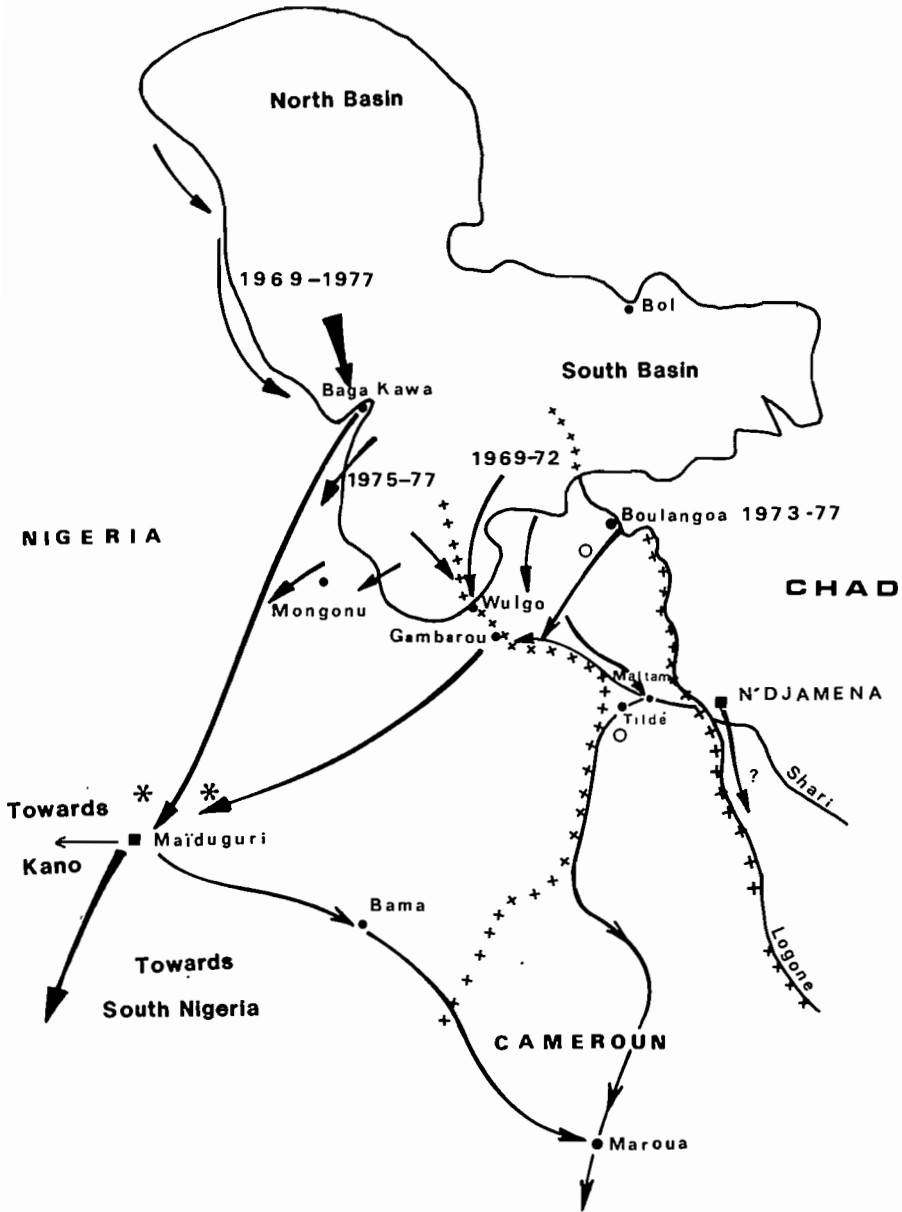


Fig. 1 Main routes for the traffic of the dried fish in the Lake Chad region; xxxx = boundaries; * = existing check-points; o = projected check-points.

permit theories to be proposed about the eventual Chad routes. From mid-1975, the salanga trade stopped completely with the depletion of *Alestes* stocks.

There was thus a convergence towards Maïduguri of the two major routes for the fish and an interesting possibility existed to control the commercial quantities entering this city. Beyond, the fish were sent to southern Nigeria via Jos and Kaduna: Lagos, Enugu, Benin-city, Onitsha and Kano, these representing on average the destination of 60 to 80% of the total tonnage (Stauch 1977).

The recent change in the environment involved some modifications in the routes between the fishing grounds and Maïduguri:

- after 1975, the route of Baga-Kawa did not exclusively correspond to the number of fish caught in the north basin. Production there diminished very markedly but was partially taken over by fishing in the Nigerian region of the south basin. The banda rejoined the Baga-Kawa route, especially from the south via Mongonu;
- the development of a very dense population of immersed macrophytes in the south basin forced the fishermen to stay in the open water and the delta. Otherwise, the density of the vegetation was such that the traditional channels of Woulgo and the Cameroon coast could not be taken. This explains the development of the center of Boulangoa that was established since 1973 and by which most of the fish caught in south basin of the lake passed in 1977 (Fig. 1).

13.3 Exploitation of lake stocks: the banda

The major fishing effort in the Lake Chad region was based on large mesh gill nets. They could also be used in the riverine environments (fixed and drifting nets) and in the lake as well as in the main routing ways of banda (Section 2.1.1).

Actually, the analysis that we are going to make here deals particularly with the lake stocks (as shown in the title) because they supplied most of the bulk of total catches since 1969 (between 70 and 95%). In addition, the only useful data on catch per unit effort from the point of view of the exploitation of stocks came from the north basin of the lake.

13.3.1 Changes in total catches

The first statistics on the movement of banda allowing the calculation of total catches in the fisheries by large sized gill nets were obtained from 1961 to 1963 (Mann 1962; Hopson 1964). After an interruption of more than five years, the collection of statistics on fishing was resumed in 1969 and continued until 1977 (Stauch 1977). We have described above (Section 2.2) the recent observations

made at the entry to Maïduguri; but from 1961 to 1963 the traffic inspection was done at the city exit, thus preventing us from estimating from old data the respective supplies of the rivers and the lake. On the other hand, it is likely that the total tonnages recorded on entry and exit at Maïduguri were comparable because this city was only a transit site of a product bound for southern and western Nigeria. Table 1 shows the half-yearly tonnages of fresh fish and their equivalents to the quantity of banda inspected on the two routes. The corresponding change is shown in Fig. 2.

The total catches constantly increased between 1969 and 1974, at first very quickly, more than 75% between 1970 and 1971 and over 44% between 1971 and 1972, then more slowly between 1972 and 1973 (over 16%) and from 1973 to 1974 (over 15%). The 220 000 tons caught during 1974 represented a maximum that was followed at first by a very rapid initial lowering of catches (41% less between 1974 and 1975), later slowed down (lower than 16% between

Table 1 Half-yearly tonnage of fresh fish corresponding to the tonnage of 'banda' inspected at the entry to Maïduguri: Baga (BG) and N'Djamena (NDJ) roads from July 1969 to June 1977 in thousands of fresh tons (after Stauch 1977).

	BG	NDJ	Total	
1969 II	20.0	8.8	28.8	
1970 I	23.6	8.1	31.7	} 65.5
1970 II	23.2	10.6	33.8	
1971 I	36.0	14.4	50.4	} 115.0
1971 II	50.3	14.3	64.6	
1972 I	55.3	19.4	74.7	} 165.7
1972 II	68.1	22.9	91.0	
1973 I	73.1	17.3	90.4	} 191.5
1973 II	80.5	20.6	101.1	
1974 I	89.7	28.0	117.7	} 220.0
1974 II	82.9	19.4	102.3	
1975 I	50.7	18.5	69.2	} 128.9
1975 II	33.8	25.9	59.7	
1976 I	38.6	20.3	58.9	} 108.2
1976 II	29.9	19.4	49.3	
1977 I	37.2	14.8	52.0	

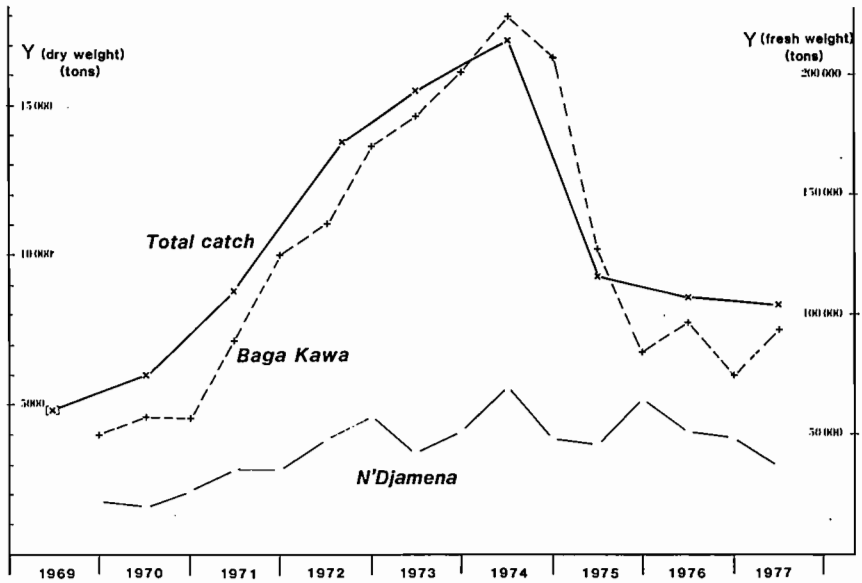


Fig. 2 Half-yearly statistics for the traffic of the Banda (tons); o—o = N'Djamena Road; x---x = Baga Kawa Road; x—x = total fresh weight (after conversion).

1975 and 1976). The partial data of 1977 give the impression of a stabilization of total catches between 100 000 and 110 000 tons. This change was explained by the increased fishing effort coincident with the lowering of the lake and by the increase of drying between 1972 and 1974. The maximum catch of 1973 and 1974 was due to a partial depletion of stocks, whose living space was considerably reduced within a few months. After the transition phase of 1976 when the lake returned to a certain stability, the permanent environment was limited to the south basin only. The total catches of 1976 and 1977 were thus the result of sustained exploitation of stocks but on almost half the aquatic space.

During 1969–70 the fish arriving by the N'Djamena route were caught in the rivers or in the delta; from the beginning of 1972, the proportion of catches in the south basin of the lake became appreciable then predominant. Between 1973 and 1977 the lake is estimated to have supplied 90 to 95% of the total catches.

From 1961 to 1963, the annual tonnage estimated at the exit of Maïduguri stayed the same: 6 to 7000 tons of banda or 30 to 35 000 tons of equivalent fresh fish. It therefore appears that the increase in production was relatively slow between 1963 and 1970 (Fig. 4). It will be seen later that it was however probable that the fishing activities had a remarkable development during the same period (Section 3.3).

13.3.2 The catch per unit effort

Some systematic studies were carried out from 1968 to 1971 on the landings from large mesh gill nets operating in the north basin. The observations were made in particular in two villages of the west coast, Baga-Kawa and Malamfatori, that were already the object of a detailed study (Durand 1973). Some experimental fishing GN 95 was done from 1963 to 1967 in the open water of the north basin of the lake (Hopson 1968).

Table 2 shows the mean catch per unit effort reconstructed for various periods between August 1963 and June 1971. The lowering of yields was very rapid from 1963 to 1966: from 18.3 to 4.6 kg. It was followed by a relatively stable period between 1967 and 1969 then the yields again showed a significant lowering during 1971, the average catch per unit effort for over 16 000 nights of fishing being less than 0.8 kg. Although the direct comparison of experimental catch per unit effort obtained during 1963–67 with that obtained for the local fisheries (1968–71) is not really valid it is necessary to emphasize that the average values were 25 to 30 times less from January to June 1971 than from August to December 1963.

Such a lowering of yield of course affected all the important species (Table 2). There appear to have been two different phases: a general lowering until 1967, when the catch composition had a tendency to simplify with a progressive dominance of *Lates*, a continued reduction in the number of *Citharinus* and *Heterotis* and an almost total disappearance of *Labeo coubie*.

Figure 3 shows two specific types of change: that of *Labeo coubie* which

Table 2 Average catch per unit effort (kg 100 m⁻² night⁻¹) for the large mesh nets (90 and 95 mm) between August 1963 and June 1971 in the open water of the north basin of Lake Chad. N is the number of effort units on which the observations were made. The main species of fish caught are shown by the abbreviations: LN = *Lates niloticus*; HN = *Heterotis niloticus*; CI = *Citharinus citharus* and *C. distichodoides*; DR = *Distichodus rostratus*; LC = *Labeo coubie* (*: c.p.u.e. lower than 0.05 kg).

	LN	HN	CI	DR	LC	Others	Total	N
1963: August–December	7.4	1.8	0.9	0.4	7.2	0.6	18.3	47
1964: April and June and 1965: August–December	3.0	0.7	1.7	0.3	3.0	*	8.7	94
1966: January–July	1.3	0.5	1.6	0.1	0.8	0.3	4.6	90
1967: January–December	0.4	0.3	0.5	*	0.1	0.1	1.4	183
1968: January–December	0.6	0.3	0.4	0.1	0.1	*	1.5	20 123
1969: January–November	0.6	0.2	0.3	0.1	*	*	1.2	38 522
1971: January–June	0.5	*	0.1	*	*	0.1	0.7	16 467

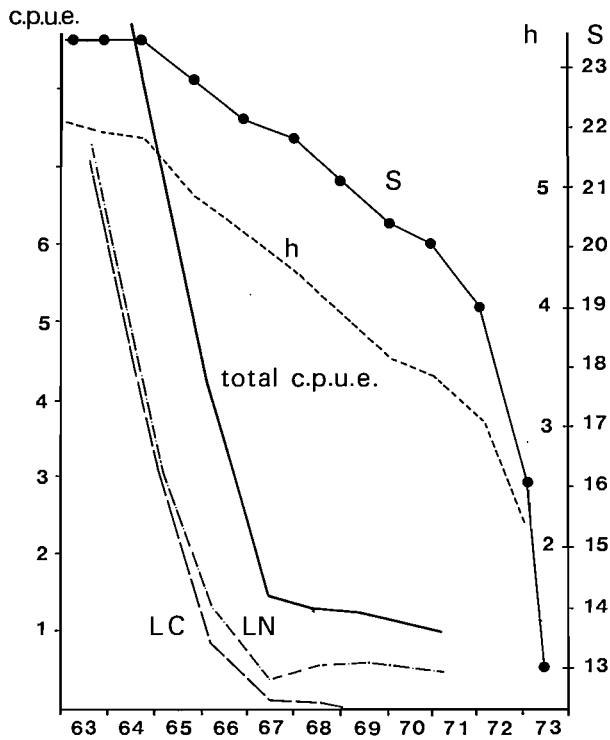


Fig. 3 C.p.u.e. evolution (GN 90 and 100; in kg 100 m⁻² night⁻¹) between 1963 and 1971 in the Open Water of the Lake Chad northern basin; LC = *Labeo coubie*; LN = *Lates niloticus*; h = water level gauge at Bol (in meters); S = lake area (in 10³ km²).

dominated the catches during 1963 and then showed a negligible c.p.u.e. in 1967; that of *Lates niloticus*, which after following a similar change to that of *Labeo*, stabilized in 1966 and has since maintained itself at about 0.5 kg 100 m⁻² night⁻¹.

Unfortunately no systematic observations of the local catches were made after 1971. Some scattered observations provide qualitative information on the change in the populations (Bénech 1975): *Lates* had become very rare by the end of catches with *Clarias*. Species more or less adapted to the conditions of the particular environments that were frequently hypoxic were present, namely: *Gymnarchus niloticus*, *Heterotis niloticus*, *Polypterus senegalus* and *Protopterus annectens* (Bénech et al. 1976; Bénech and Lek 1981).

The recent change in species composition of the catches corresponded of course to the considerable lowering of the lake since 1972; but during the preceding years the very rapid lowering of the catch per unit effort between 1963 and 1968 and the modification of relative abundance before 1971 are

explained on the one hand by the slow but already considerable change in the environment and changes in the fishing effort on the other hand.

Figure 3 also shows the height of the maximum annual lake level between 1963 and 1973 and the corresponding area of water (after Carmouze 1976). The morphology of the lake basin intervenes below the 4 m level which corresponds to a lake area of about 20 000 km². For the period of our study, after passing a maximum from 1962 to 1965, the lake area decreased regularly and the rate of lowering did not really accelerate as it did after 1971. Between 1963 and 1967, the change was not considerable (23 500 to 22 000 km²) whereas the catch per unit effort dropped from about 15 to 1.5 kg 100 m⁻². Therefore it was the change in the fishing effort which explained the change which was particularly spectacular for *Labeo coubie*: its stocks were almost unexploited during 1963 but disappeared 4 years later (Fig. 3). Such a phenomenon must be related to the resilience of a species that was not under human predation before.

13.3.3 *The fishing effort*

The increase of total fishing effort has been shown to correspond to the introduction of nylon to make the gill nets. Thus the development of gill net fishing can be placed from about 1961–1963, a period corresponding to the first observations on catch per unit effort. No estimates of total fishing effort have been made since. However, based on a few observations, the total fishing effort can be evaluated from the accompanying data on total catches and the total catches per unit effort. This change can be estimated for the north basin of the lake between 1963 and 1971. Supposing that the c.p.u.e. of large mesh nets (GN 90 to 100) were well represented throughout the fisheries where the banda originated and also that the later experimental observations (1963–1967) can be put on the same basis as those obtained from the fisheries. We see that these assumptions are all the more acceptable because the extent of the phenomena was well marked.

Table 3 summarizes the most characteristic values for the total catches (in tons of fresh fish) and the catch per unit effort (in kg 100m⁻² night⁻¹ in the north basin of Lake Chad between 1963 and 1972. These values were transferred onto Fig. 4 with the estimates of the total effort obtained; the latter, shown as *f*, thus represented an hypothetical number of fishing nights for gill nets of 90/100 mm mesh. The total catches for 1967 were calculated by supposing a regular growth between 1963 and 1967. Other data (Durand 1973) however suggest that the c.p.u.e. during 1971 was higher than the value shown here, hence the hypothetical values, 1 and 1.5 kg. Finally, to cover the absence of c.p.u.e. data for 1972, they may be considered to have increased, given the lowering of lake volume, and are estimated at 1.5 and 2.0 kg.

The fishing effort multiplied by 20 between 1963 and 1969 (Fig. 4) and its

Table 3 Assessment of the total fishing effort (f) for the fisheries of the north basin of Lake Chad between 1963 and 1972. the catch per unit effort ($\text{kg } 100 \text{ m}^{-2}$) data are those of GN 90 to 100 and T is the annual tonnage of fresh fish corresponding to smoke-dried fish inspected on the Baga-Kawa route at the entrance of Maiduguri. The values in parentheses are hypothetical.

Year	T (tons)	c.p.u.e.	$f (10^{-7})$
1963	30 000	18.3	0.17
1967	(35 000)	1.4	2.50
1969	40 000	1.2	3.33
1970	46 800	(1.0)	4.68
1971	86 300	0.7	12.33
		(1.0)	8.63
		(1.5)	5.75
1972	123 400	(1.0)	12.34
		(1.5)	8.23
		(2.0)	6.17

annual increase during this period would have been 5×10^6 . The latter essentially corresponds to the very rapid lowering of c.p.u.e. whereas the total catches increased only by about 30% in six years. Between 1969 and 1970, the c.p.u.e. stabilized at about $1 \text{ kg } 100 \text{ m}^{-2}$ and f increased by 10^7 . During 1971, f increased again by 4×10^7 for the same value of c.p.u.e., and, supposing that the c.p.u.e. increased during 1971 and 1972, f stabilized between 6 and 8×10^7 .

From the foregoing, it can be concluded that *between 1963 and 1972 the total fishing effort was multiplied by about 40 in the fisheries of the north basin of Lake Chad while at the same time, the total catches quadrupled.*

Starting in 1972, the environment changed profoundly, causing higher vulnerabilities, and the use of the catch per unit effort data is no longer valid. The maximum catches of 1973 and 1974 corresponded to the depletion of the stocks and one may simply say that the apparent stability of the total catches of 1975 to 1977 actually concealed a very important species variability corresponding to a succession imposed by a very rapid change of environmental conditions.

In conclusion, two major phenomena played a role in the changes in the fisheries between 1960 and 1977. At first, there was a very pronounced development of human predation on the stocks and this intensification of fishing will doubtless continue with the introduction of new methods (nylon,

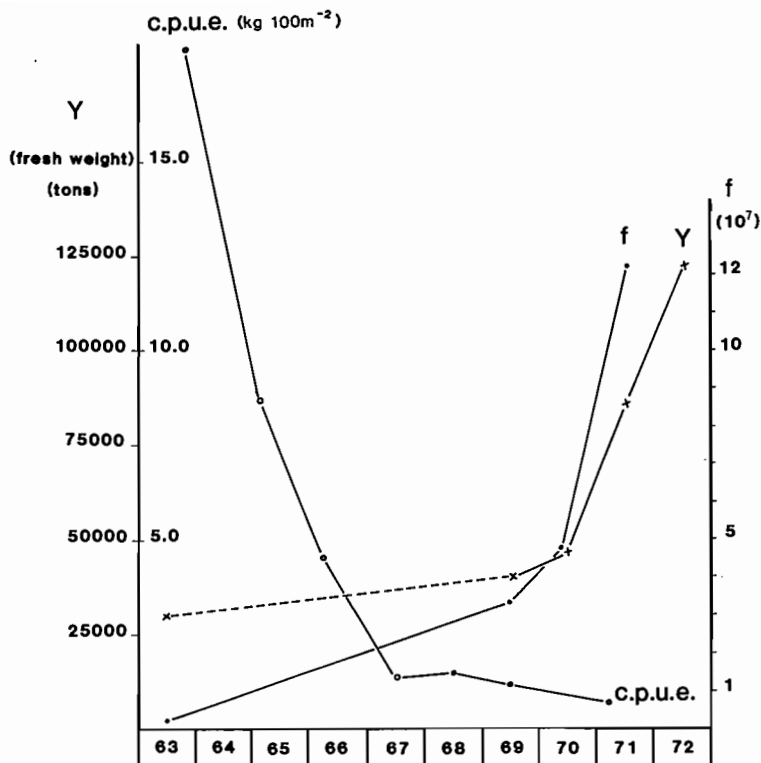


Fig. 4 Data for large mesh gill nets in Lake Chad northern basin (GN 90 and 100): yearly tonnage (Y), c.p.u.e. (kg 100 m⁻² night⁻¹) and corresponding fishing effort (f in night × 100 m²); cf. Table 3.

outboard motors). The second factor was the fall in lake level with the drought which at first accentuated the increase in fishing effort (1973–1974) and then reduced the available stocks (since 1975).

The prospects for fisheries can be examined by considering these two factors: (a) large variability of the environment involving parallel variations of potential catches; (b) increased level of fishing effort.

The latter will take place in the present small lake, and also if there is a future return to the maximum extension of the large Lake Chad, a point that will be developed later in our conclusions.

13.4 Riverine fisheries: the Shari delta

The riverine fisheries were very active before 1970 on the Shari between the lake and the confluence and on the mid-reach of the Logone and the Shari up-river

from N'Djamena. There was then a progressive movement of fishermen towards the lake, with a tendency to look for increased catches by going down the rivers and concentrating progressively on the delta. This movement reached its maximum by 1971–72, a time when the rivers above N'Djamena were not fished any more, and when the fishermen still did not dare to really venture into the lake, fearing very difficult navigation conditions. At this time, the study of deltaic fisheries was undertaken by Loubens (1973) and extended later by Quensière (1976). These observations lasted two and a half years and corresponded to the end of the normal period (1971–72) and the beginning of the drought (1972–73).

The Shari is connected to the lake by a delta with two branches of similar importance; the area studied extended to 12 km on the northern arm, with a width of 150 to 450 m (Fig. 1, Chapter 10). In this zone, 275 pirogues operated three types of fishing gear, resulting in four types of fishing: gill nets of small mesh used as fixing or drifting, drift nets of large mesh and nonbaited multiple hook lines.

The principal period of activity depended on the hydrological cycle and on the fish migrations. Small mesh drifting GN have a considerably reduced activity in very high waters (October) and during low waters (March to May). Fixed GN of small mesh were used during the lowering (February to July); drifting GN of large mesh during high waters from August to December and finally lines were used during low waters from April to July.

There was no concentration of fishing means nor of fish landings and the fishing enterprise was a lone fisherman, owner of his pirogue and sometimes supported by a paid helper. The fishermen, of very diverse ethnic origins work spread out along the length of the reach, and throughout it the physical, biological (migrations) and human factors show a great spatio-temporal variability. Statistically, this is an extreme method of fishing as it is entirely individual, the only relatively favourable factor being the sufficiently raised level of fishing effort in the study area. This type of fishing has rarely been studied and the need to acquire quantitative information necessitated the adjustment of adapted methods, based on direct observations and on the collaboration of fishermen.

Loubens and Franc (1972) and Loubens (1973) give a detailed description of the methods used to determine fishing efforts, catch per unit effort and total catches for each fishing method. The fishing effort was determined by counting the pirogues while fishing at different times of the day for the drift nets. As the average area of the nets was known, it was thus possible to extrapolate to 24 hours to obtain the daily effort characterizing the study period. The effort was also obtained by counting fishing gear and the pirogues for the fixed nets and the lines. The results obtained between July 1971 and December 1973 are indicated in Table 4.

Three major characteristics are immediately apparent on examination of this

Table 4 Daily fishing efforts in a reach of the Shari delta between July 1971 and December 1973 (after Loubens 1973, and Quensière 1976).

Month		Drift nets (100 m ⁻² h ⁻¹)		Stationary nets (100 m ⁻² day ⁻¹)	Lines (1000 hook day ⁻¹)
		Small mesh	Large mesh		
1971	J	1180		30	340
	A	720	80		340
	S	470	470		
	O	220	800		
	N	1290	350		
	D	1640	30		
1972	J	1320			
	F	2750		90	
	M	390		500	
	A	210		370	50
	M	610		370	170
	J	1310		500	170
	J	1250		60	170
	S	2040			
	O	1760	440		
	N	670	300		
	D	1110			
1973	J	1370			
	F	1230			
	M	200			
	A	90			
	A	290			
	S	100			
	O		100		
	N		100		
	D		300		

table: the general predominance of drift nets of small mesh; a marked seasonal variation in fishing effort for each fishing method considered and a highly marked between year change during the observation period.

For the annual cycle 1971–72, the catch per unit effort showed obvious variations. Concerning the small mesh GN (Fig. 5), starting from high values

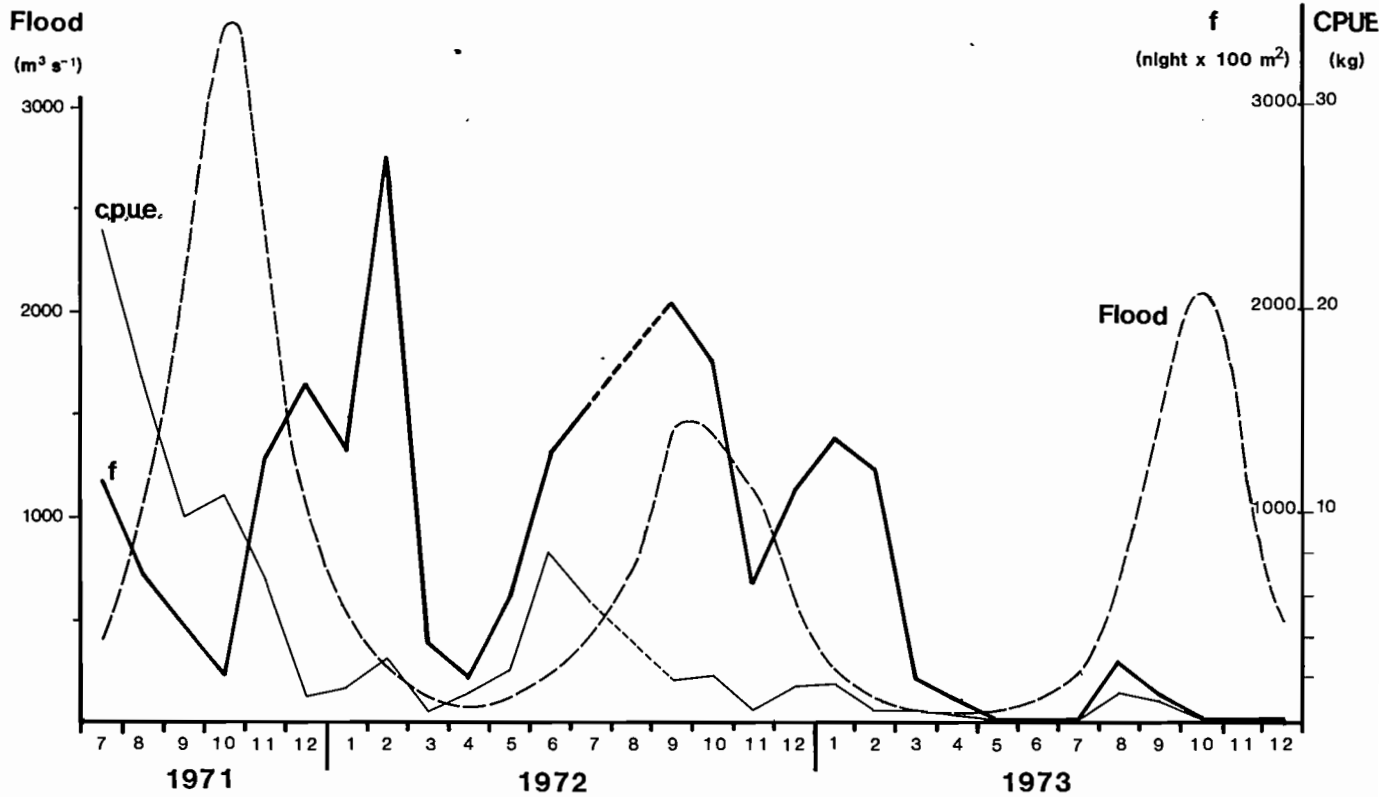


Fig. 5 Daily total fishing effort and corresponding c.p.u.e. between July 1971 and December 1973 for small mesh drift nets in a Shari delta reach (after Loubens 1973 and Quensièrre 1976); dashed line=flow of the Shari river at N'Djamena.

during July and August 1971, the average c.p.u.e. progressively dropped until December. It then stayed low until May, then increased during the flood of 1972 with a maximum in June. The c.p.u.e. showed an appreciative lowering during July 1972 in relation to homologous values of 1971 (Fig. 5). This lowering was followed by a collapse in 1973 as the average c.p.u.e. from February to September was about $0.5 \text{ kg } 100 \text{ m}^{-2} \text{ hour}^{-1}$, that is, 10 to 15 times less than the yields obtained during 1971 at the same time. The large mesh drift nets were the only gear in use at the beginning of October 1973.

The interpretation of concomitant variations of c.p.u.e. and fishing effort for small mesh GN involves the fishermen, the fishes and environmental change both for the river and the lake. Figure 5 puts together the data on the mean c.p.u.e., the daily efforts and the Shari flood for the entire period studied. The small mesh drift GN activity was governed by fluvial hydrology for the period corresponding to a normal flood (July 1971 to June 1972): the effort dropped to very low values during the flood (normal during 1971), culminated over the course of the subsidence with a new minimum when the lowering was the most marked. All this was independent of the catch per unit effort although this varied considerably over the course of this period. It reflected the difficulty of operating during the excess current in October, and with the water and current shortage during the subsidence. This interpretation was confirmed during the following annual cycle: due to the exceptional low value of the 1972 flood volume, the fishing efforts remained very high during September and October 1972; in November, the time of maximum flood, they were still higher than in the preceding year, although the c.p.u.e. stayed very low. The first third of 1973 was similar to 1972 but from May and up to July the fishing completely stopped, the low waters being very marked and the c.p.u.e. remained at a very low level. It was this low c.p.u.e. which explains, that although the placing of drifting nets would not have suffered the pronounced lowering, they disappeared completely by 1973 while they were still very active from March to June 1972 (Table 4).

During 1973, the positioning of the fishing effort was progressively modified with a gathering of all the fishermen in the downstream part of the reach where they expected to have the best catches. This expectation was not achieved and the fishermen finally learned that in the isolated north basin of Lake Chad it was possible to work easily and with raised yields, so they left the delta and went there to try their luck (Quensière 1976). This explains why in August the fishing was not done by professionals but mostly by the farmers for whom the fishing was complementary and who therefore did not look for optimal exploitation.

Total catches were the sum of the concomitant variations of yields and efforts and they became almost negligible during the last six months of 1973. Table 5 summarizes the results between July 1971 and December 1973 for the four fishing methods. The fixed nets and the multiple hook lines were not used

Table 5 Monthly and annual total catches (tons) for the reach of the Shari delta studied; sdr=small mesh drift nets; sfi=small mesh fixed nets; lsd=large mesh drift nets; mhl=non-baited multiple hook lines (*corresponds to total monthly catches of less than five tons).

Month	1971					1972					1973		
	sdr	sfi	ldr	mhl	Tot	sdr	sfi	ldr	mhl	Tot	sdr	sfi	Tot
January					70					70	70		70
February					170	20				190	10		10
March					50	60				110	*		*
April					10	50		10		70	*		*
May					30	310		60		400			*
June					170	250		50		470			*
July					270	30		20		320			*
August	450		10	60	520						10		10
September	200		80		280	110				110	*		*
October	110		100		210	130		70		200		10	10
November	230		40		270	10		10		20		30	30
December	150		10		160	60				60		20	20
Total	1140		240	60	1440	1080	720	80	140	2020	90	60	150

during 1973. Over the course of the first annual cycle, from August 1971 to July 1972, total catches amounted to 3000 tons and were about eight tons hectare⁻¹ for the reach studied. Considering that the reach did not represent the entire north branch of the delta and by granting to the west branch this same importance as the north branch, about 8000 tons would have been caught in the delta (Loubens 1973). The apparently very high density does not correspond to a sedentary biomass but mostly to a permanent replacement of migrant populations rejoining the lake or the river system following the hydrological cycle. Thus the catches of the delta must be integrated inside the large ensemble where the migrations occur, as was attempted in the previous section.

During the second annual cycle, from August 1972 to July 1973, total catches collapsed to 600 tons, five times less than during the course of the preceding cycle. This catastrophic change then continued, as shown by the comparison of September to December data: 920 tons were taken in 1971, 390 in 1972 and only 60 in 1973.

Actually the fishermen did not leave the deltaic fishing grounds during the period of very low floods of 1972 and 1973. Indeed although this created some unfavourable conditions during the 1973 low waters, conditions during the maxima of 1972 and 1973 were better than during an average year. The lake was the refuge of fluvial stocks between two anadromous reproductive migrations and it was this lowering which encouraged them to move in step and invade the lake. This change was unavoidable because the displacement towards the lake had already begun several years earlier with the rapid increase of fishing effort and the concomitant lowering of yields.

13.5 Fishing and flooded areas

In spite of their temporary nature, the flooded zones were colonized very rapidly by several species that represented a significant biomass. The wealth of this environment involved the development of traditional fisheries, very hardy activities that also showed an obvious seasonal character.

The two large flooded zones dealt with here both depended on the Logone: the flooded zone of Ba Illi (cf. Fig. 22, Chapter 2) between the left bank of the Shari and the right bank of the Logone and the flooded plain of North Cameroon.* These two zones differed in their morphology and in their connection to the permanent hydrological system.

The flooding of the plain between Logone and Shari originated upstream

* The Yobé, a poorly known intermittent river will not be considered here. Although its water supplies to the lake are low, it is important because its basin reaches 85 000 km² and extends westwards in Nigeria as far as the Jos plateau.

from several outlets on the right bank of the Logone and from the major outlet of the 'Grande Courant' that originated downstream of Lai. The flood waters were drained by the N'Gourkoula which joins the Logone a little upstream from Logone-Gana and other various communications probably existed between the plain and the Logone in several places downstream of the last best known outlets. The morphology of the plain led to a relatively varied but temporary aquatic environment containing depressions, channels, flat vegetation zones and regions of raised cover. Several openings on the permanent river environment and the easy internal communications explain why this zone was mostly open and affected the fish populations found there.

The large flooded plain of North Cameroon was very flat and interrupted only by hillocks on which the Kotoko villages are placed and where the only trees were found. The plain was exclusively occupied by grasses (*Echinochloa*) in water depth of 0.70 to 1.00 m. The major origin of the flood was the Logomatia which was the only important tributary on the left bank. The drainage of the flooded plain occurred partly through the Logomatia which served as an outlet, but also through several temporary drains which rejoined the El Beid flowing into the southernmost region of Lake Chad (Fig. 1, Chapter 10).

During the flood, the dispersion of fish made them difficult to catch and the flooded environments were often poorly accessible, thus concentrating all the fishing activities on the tributaries during the subsidence. Three fishing zones should be noted in particular: the large dam upstream of Logone-Gana, the fisheries of Logone-Gana, the fishing weirs of the El Beid. The first two were good examples of the diversification and complementarity of the traditional fishing techniques used in the exploitation of these aquatic environments; on the contrary, in the El Beid fisheries, a single technique was used for the bulk of the catch.

13.5.1 *The traditional fishery of Logone-Gana*

The main outflow of the flooded zones of the right bank of the Logone, upstream of Logone-Gana called Koulambou or N'Gourkoula drained the regions of the North and South Ba-Illi plains (Fig. 22, Chapter 2). When the Kotoko fishing head of Logone-Gana had decided that fishing could begin, generally at the end of December, depending on the degree of subsidence, the river was completely blocked by a series of small spaced screens that made the passage of fishes trying to reach the Logone at the beginning of the subsidence difficult. Several fishing techniques were then used: when the fishes reached the dam they could turn back upstream, but then they were likely to be caught by the large Kotoko basket traps whose opening is turned downstream and which occupied the whole river bed (Fig. 6A). Some species tried to jump the barrier (particularly *Hydrocynus*) and often fell into the pirogues downstream. The

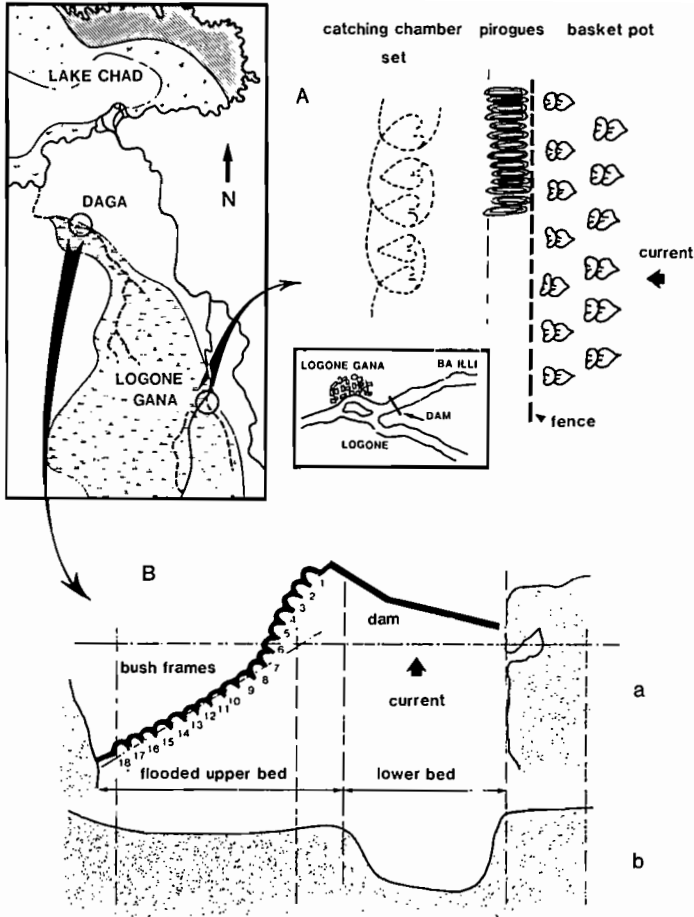


Fig. 6 Two examples of the traditional fisheries on the outlets of the flooded areas; (A) the great fishing of Logone Gana (cf. text); (B) a fishing dam in the El Beid river; (a) plan; (b) cross section; 1 to 18 = numbers of the fishing chambers.

fishes avoiding the basket traps and the pirogues met the large Kim and Kabalaï capture chambers set up downstream of the first dam right across the river. Last but not least, numerous gillnets of average mesh size were set during the first week.

The main feature of these subsidence fishings was that they dealt with adult fishes only. *Alestes* constituted the bulk of the first day's catches and the dominant *Alestes dentex* was 10 to 20 times more abundant than *A. baremoze* which was generally very abundant in all the other environments (cf. Chapter

10). *Alestes* was then replaced by still water species which were carried away at the end of the fall.

The basket traps were set only for about a week and then removed; the capture chambers, however, remained on for one or two months and the residual waters of the reach were still exploited by fixed gill nets, non-baited multiple hook lines etc. ... Total catches could be appreciable about 250 tons were caught in 1969 during the first three days which generally gave the highest catches. The variability of yields from one year to the next must have been particularly high because of the underlying natural variability, linked to the yearly hydrology, and the human estimates which sometimes led the fishing head to authorize very late the placing of the dams, when the first migrations had already begun.

13.5.2 *The Logomatia fisheries*

The seasonal fishing activities in the Logomatia region were followed for two consecutive years, 1977–79 by Vidy (1982). Comparisons with the data from before the drought were therefore not possible and the results of these two years cannot be considered in the general context.

Subsidence fishing developed from the beginning of October in the downstream end of the Logomatia, a temporary river which well represented an arm of the Logone, an outflow zone through the flood plain of North Cameroon and a zone of returning water from the flood plain to the Logone. Five types of fishing gears, corresponding to eight different ways of fishing were found there: gill nets; triangular nets or 'sakamas' similar to those of the El Beid; little catch weirs on man-made channels; unbaited multiple hook lines and dams.

The total calculated production of the reach was similar in 1977–78 and in 1978–79: about 300 tons, mostly comprising the young of a few months as for the El Beid fish. It is interesting to note that this homogeneity of total results hid the considerable differences between the catch per unit effort from one year to the next as the very weak flood of 1977 involved an increased vulnerability of fishes and very high yields. An analogous study of the 'Kafue flats' (Welcomme 1979) implied that 'a weak flood affected the stock not only by limiting the recruitment but also by augmenting the efficiency of fishing towards the young fish' (Vidy 1982).

The satellite observations of 1975 and 1978 lead to an estimation of 60 000 hectares for the area drained by the Logomatia during similar floods. This represented about 15% of the maximum flooded area for the entire Yaéré (400 000 ha). Given the very low population density in this region, we can estimate that the fish production on the Logomatia was well represented by what was caught. We thus arrive at some yields between 5 and 7 kg ha⁻¹ for five months flooding. It is true that these very low figures refer to the

exploitation of stocks that did not always regain their past importance (e.g. *Alestes baremoze*, cf. Section 6.2) after the drought. It is however possible that the low yields were partly due to the difficulties of exploiting a flood plain where communications were a problem.

All the same, the 300 tons caught during the four months of traditional fishing activity in the Logomatia were quantitatively significant because it was practically the only commercial resource in this region. One needs to question whether this is sensible as the general economy of fishing might suffer from catches of young fish of two to five months. It would be theoretically more rational to take individuals that have completed their potential growth, but the young fish from the Logomatia and Logone could be food for ichthyophages (*Hydrocynus*, *Lates*...) which have a tendency to gather in the rivers bordering the subsidence outflows. We will return to this problem with the El Beid fisheries.

13.5.3 *The El Beid fisheries*

The El Beid only flowed for five to eight months per year, when the waters of the North Cameroon plain arrived: through the El Beid, they flowed out towards Lake Chad where they reached the southernmost region of the south basin. The river bed was well marked, from 50 to 60 m wide and from April to July only consisted of a string of muddy ponds. The supply of the El Beid was dependent on local precipitation which corresponded to the first flows of August and September and of the Logone flood which included the maximum flood of El Beid in December. The river then overflowed and the subsidence lasted until the end of March.

The floods of the El Beid were evidently highly dependent on the Logone floods, the inundation of the North Cameroon plain being all the more important as the flood of the Logone was strong and prolonged above the level from which it flowed out towards the lower plain. Thus the irregularity of the floods was particularly high, the extremes in the last 25 years corresponding to a mean annual volume estimated from $87.5 \text{ m}^3 \text{ s}^{-1}$ (1953–54) to $0 \text{ m}^3 \text{ s}^{-1}$ (1972–73 and 1973–74); the between year mean could be estimated at about $40 \text{ m}^3 \text{ s}^{-1}$ corresponding to an annual volume of 1.3. thousand million m^3 , or only about 4% of the Shari supplies to the lake.

The importance of the El Beid for the fish stocks of the Lake Chad region was due to its connecting role between the floodplain, where the young of several species gathered and obtained shelter and food, and Lake Chad. It was by far the easiest way to leave the flooded plain at fall as the water passed mainly to the north: 85% of the flooded zone could be considered to be drained via the El Beid and only 15% via the Logomatia (Bénech et al. 1982).

The El Beid fisheries were based on the presence of fish dams associated with

the use of triangular nets, the 'Boulous'. Aerial observations showed that these permanent dams were distributed throughout the length of the river from Tildé to the lake (Fig. 1, Chapter 10). In January 1969 there were about 270 (Durand 1970b). During 1968–69 fishing was active on 165 dams while in total 200 could be used normally. The average density for the whole was almost 2.0 km^{-1} and for active dams alone 1.2 km^{-1} , i.e. one dam every 800 m. The distribution was actually unequal as two thirds were found in the lower part of the course of the El Beid. The maximum density of the dams was found about 100 km away from the flooded zones where only 150 m separated them from each other. The development of these structures corresponded to old and steady fishing activities.

The dams were made of interlaced thorny branches secured very tightly onto trunks sunk into the river bed. They were renovated every year and they diverted the fishes to the minor bed where the dams were extended by some semi-circular joining frames, with their opening turned upstream (Fig. 6B). Following the morphology of the bed, the number of fishing places was highly variable: from 4 to 28, the average being 15.2 per dam. Nets were always placed in very shallow water, a meter at maximum and at the time of the subsidence, the frames in the major bed were progressively emptied and the fish reached the lower bed.

The catches almost exclusively included individuals under one year, on average 3 to 5 months (Durand 1970a). Table 6 shows the relative importance by number and weight of 18 major species caught over the whole 1968–69 fishing season, as well as their average length. The comparison with the maximum sizes observed for the Chad basin (LMO) showed that they were mostly juveniles, much smaller than the sexually mature fish.

Total catches during the fishing season 1968–69 were estimated at 7.7 tons for the studied dam. The extrapolation of these figures to 150 active dams in 1968–69 gave a total figure of 1200 tons. By its location and number of fishing frames (18) the chosen dam could be considered as representative of the average dam of the El Beid. On the other hand, it appeared that the year of observation was lower than a normal year because there was a certain correspondence between the total yield and the importance of the flooding, thus of the flood. The 1968–69 flood was low with an annual volume lower than half of the average of the last 25 years; the low yields obtained at the time of a mediocre flood gave rise to a diminishing fishing activity and an emphasized decrease in total catches in comparison to a year of normal flood. It can thus be concluded that the total catches of an average year should clearly exceed the 1200 tons given above.

Considering the importance of catches made in the El Beid of 3 to 5 months old juveniles, one can wonder if this practice is not harmful to the total adult catches of the same species in the lake or in the rivers. We were able to examine this for *Alestes baremoze*, the only sufficiently well-known species. The young

Table 6 Relative importance by weight and number of the main species caught by triangular nets over the fishing season 1968–69. \bar{L} is the average length in the catches and LMO the maximum length observed in the Chad basin.

	W_T (%)	N_T (%)	\bar{L} (mm)	LMO (mm)
<i>Sarotherodon niloticus</i>	17.4	6.6	97	395
<i>Hyperopisus bebe</i>	12.8	8.3	162	508
<i>Marcusenius cyprinoides</i>	11.1	9.5	125	330
<i>Alestes nurse</i>	9.5	9.0	97	218
<i>Sarotherodon galilaeus</i>	9.0	5.5	93	410
<i>Sarotherodon aureus</i>	6.7	5.0	98	260
<i>Brienomyrus niger</i>	4.4	12.7	69	130
<i>Alestes dentex</i>	3.3	2.8	127	410
<i>Distichodus rostratus</i>	3.2	1.1	37	625
<i>Polypterus bichir</i>	3.1	0.2	340	660
<i>Clarias</i> spp.	2.8	4.4	90	(890)
<i>Schilbe uranoscopus</i>	2.7	11.1	74	340
<i>Alestes baremoze</i>	2.1	3.8	91	330
<i>Labeo senegalensis</i>	1.6	1.3	108	550
<i>Citharinus citharus</i>	1.3	0.4	133	580
<i>Siluranodon auritus</i>	1.2	7.5	60	123
<i>Mormyrus rume</i>	1.1	0.4	194	870
<i>Distichodus brevipinnis</i>	1.0	0.1	188	588
Total	94.3	89.7		

weigh between 7.5 and 10 g at four months, the average age reached when they are caught in the El Beid. The weight of 100 of these juveniles has been compared to the yield they would represent in the riverine fisheries for various combinations of the instantaneous coefficients of mortality. F varies from 0.05 to 1.5 and M is 0.3 or 0.5. Figure 7 summarizes the results obtained for each sex separately as there is a difference for growth in weight.

In most of these cases, the gain would be appreciable since the ratio of the ponderal yields of these 100 recruits would range between 2 and 6, supposing that — as it has been verified otherwise — the sex ration is close to 50%.

We tried to estimate the consequences on the total catches by supposing that the dynamic parameters of *A. baremoze* stocks represented those of an average stock among those of Lake Chad. The total catches were estimated at 1200 tons for the 1968–69 fishing season, thus corresponding to a rather poor year. A probable range for the entire catch of the juveniles of the region might be from 1000 to 3000 tons. Table 7 shows the results obtained for each of these two figures in the various hypotheses of mortality. It is seen that the increase in total

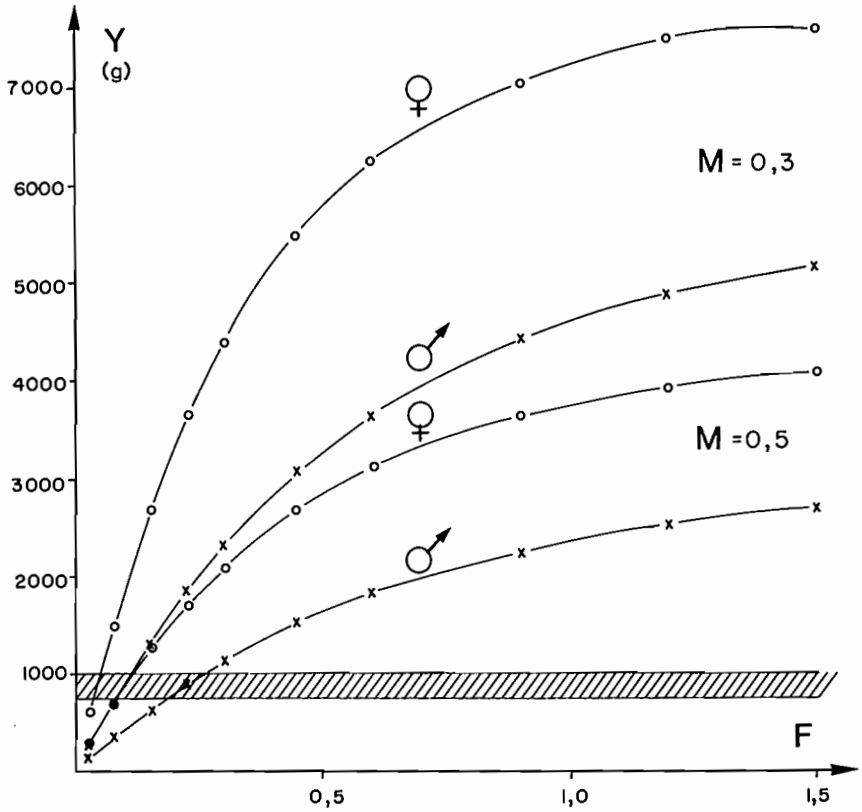


Fig. 7 Comparison of the yield (for 100 four-months old recruits) in the riverine fishery (males: $t_c = 3$ years; females; $t_c = 2.75$ years) with the weight of these 100 young *Alestes* caught during the fall fishing (////).

Table 7 Potential catches (tons) in the fluvio-lacustrine fisheries if there was no fishing of juveniles in the El Beid (cf. text). M and F are the instantaneous coefficients of mortality.

El Beid catches	1000		3000	
	M	F	M	F
F {	0.3	0.5	0.3	0.5
	0.4	2200	13 800	6600
	0.7	3000	18 000	9000
	1.0	3500	20 100	10 500
	1.5	4000	21 000	12 000

catches should be between 5000 and 15 000 tons. Of course, it must not be inferred that all the juvenile catches have to be stopped because one ignores the extent to which the rivers and the lake would have reached this large number of supplementary recruits without increased competition and increased natural mortalities.

The temporary aquatic environments thus develop traditional fishing activities that are characterized by their very seasonal nature and their occurrence mostly on the outlets. The latter are chosen because fishes in search for permanent rivers or laker at the subsidence concentrate and get through them, as well for adults (Logone-Gana) as for juveniles (Logomatia and El Beid).

The flooded zones had many beneficial effects in the general economy of fishing. Above all there was an increase in the general productivity because of the considerable extension of the water area, where new sources of food developed very rapidly with the flooding (phytoperiphyton, zooperiphyton, insects ...). They also offered shelter for the young, as is particularly clear for plains such as North Cameroon's. The density of vegetation cover was such that the fishes of large size could not penetrate it easily and the predators were relatively rare. The type of connection with the permanent environment also played a role because it was probable that the natural predation rate on the young was much higher in the rivers than in the lake where the relative dispersion of prey and the presence of some shelter must have diminished the risks that they encountered. Thus this was another positive aspect of the flooded plain of North Cameroon.

Nevertheless it cannot be denied that the predation exerted by man was important in the El Beid. It was not obvious, despite the considerable fishing system in use, that removal was very high. If the total catches in the flooded area during 1968–69 are reduced to 350 000 hectares, a yield of 4 kg ha^{-1} is obtained, similar to the results of Vidy (personal communication) for the Logomatia. A recent global estimate for the entire flooded plain of North Cameroon, taking into account every kind of gear, led to a 14 kg ha^{-1} figure (Quensière, personal communication). The latter represented the actual total production which remained far lower than the figures given by Welcomme (1979) who gives a range of 40 to $60 \text{ kg ha}^{-1} \text{ year}^{-1}$ for the mean sustained production of flooded tropical zones.

13.6 The exploitation of a fluvio-lacustrine stock: *Alestes baremoze*

This species was chosen for the study of population dynamics and exploitation of stocks for several reasons, in particular its importance in the Chad basin as well as in all the large basins of the Sudano-Saharan region. The potential yield of stocks for the whole region must be between 30 and 50 000 tons in a normal climatic context and the construction of large reservoirs in the region should be

favourable to the development of zooplanktophagous lacustrine stocks. The results obtained can be extrapolated to other stocks similar to this species and showing analogous characteristics. On the other hand this species benefits from a particular commercialization route that allows the calculation of fishing quantity to be obtained in some conditions with some precision. Finally, most of its biology is known, providing the essential data for demographic studies. After a brief review of major biological features, the evolution of stocks and catches since 1969 will be discussed, followed by some aspects of exploitation.

13.6.1 *Main biological characteristics*

The biology of this species and its behaviour in the Chad basin are strongly influenced by the existence of the lake and the migratory cycle originates from Lake Chad. This is so both for the adults which leave the lake for upstream reproduction only and for the immature fish which stay inside the lake until the time at first reproduction, that is to say at the end of the third year when Lake Chad has its normal extension. On the other hand, if the permanent lacustrine character weakens with the fall of the lake, they return to the biology observed in the western river basins of the Sahel where *Alestes baremoze* reproduce mostly at two years. There cannot be more than one spawning a year due to the short reproductive season and the necessary maturation times. Above 130 grams — corresponding to an age of about 30 months — there is a linear relationship between the fecundity (in thousands of eggs) and the females weight. The fecundity is high and corresponds to 230 000 eggs kg^{-1} . Associated with the percentage of mature females at each age, this relationship permits the study of the stock fecundity as a function of the exploitation rate (Section 6.3.3).

The abundance of *Alestes* is partly explained by the fitting of the biological cycle to the hydrological cycle as they spawn mostly by the border of the flooded zones at the time of the Logone overflowing. The latter carries the young fry lower down inside the flooded plain where they find rich and varied food and are protected from predation by the density of aquatic and semi-aquatic macrophytes. The catadromous migrations of many fish via the El Beid allow them to rejoin the lake without being exposed to an intense predation pressure when descending the river (Fig. 1). The lacustrine environment is well suited to the zooplanktophagous *Alestes* which finds shelter in the archipelago, the vegetation and the shallows of the east and the north.

The influence of a permanent lacustrine environment is also apparent in the case of growth. The factor controlling growth in length is certainly temperature, the variations are similar in river and lake environments but the possibility of permanent zooplankton food in the lake allows *Alestes* to acquire a very high condition during the period of growth check in the cold season while the rivers

in subsidence do not have any substitute food. This results in better total growth than in the Ivory Coast and Senegal. These results were confirmed by observations made in the eastern region of the southern Sahelian zone (lakes Albert and Rudolph) where growth was clearly more rapid than in Chad and accomplished mostly during residence in the lacustrine environment (Hopson J. 1975). The zooplankton diet there allowed the best food yields and, as the annual temperature variations were very small, there was no growth check.

The study of growth in length confirmed that there is a clear difference between sexes, and for the same age *Alestes* the weight is 25 to 35% greater in large adult females than in males. From four months growth fits the von Bertalanffy model well (Fig. 8). In the very young fish growth is clearly more rapid because it occurs from September to November in the flooded zones where the presence of an abundant zooperiphyton is particularly favourable. Starting from the age of four months, the two following equations are thus retained:

$$\begin{aligned} \text{♂ } L_t &= 251.80 \left[\frac{1 - e^{-0.058 (t+2.91)}}{1 - e^{-0.043 (t+3.82)}} \right] \\ \text{♀ } L_t &= 292.00 \left[\frac{1 - e^{-0.058 (t+2.91)}}{1 - e^{-0.043 (t+3.82)}} \right] \end{aligned}$$

with monthly values of k , as time is given in months.

The marked condition cycle, with an annual difference of about 30% for adults, is characteristic of several Sudano-Sahelian migratory species for which the phase of river displacement is generally a phase of scarcity. These changes in weight for length directly affect the production. From the equations given

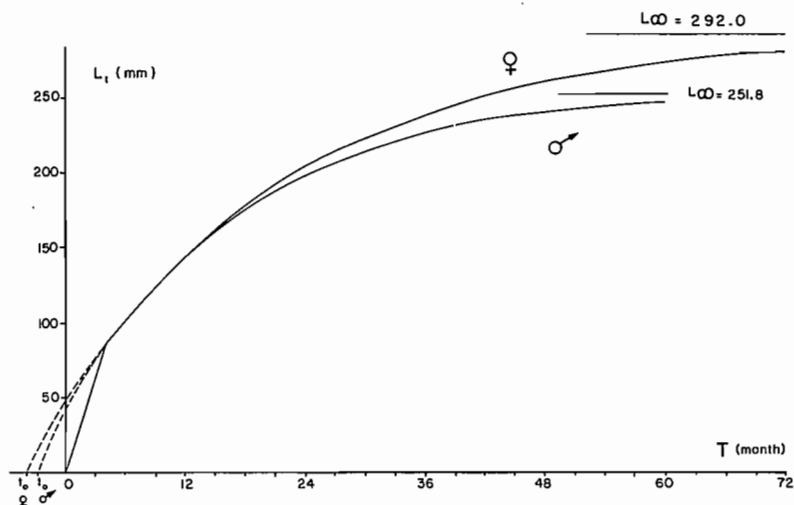


Fig. 8 Length growth curve for *Alestes baremoze* males and females in the Lake Chad basin after Von Bertalanffy's equation. Between 0 and 4 months, the best fit is the straight line $L_t = 20.785 t$, (L in mm; t in months).

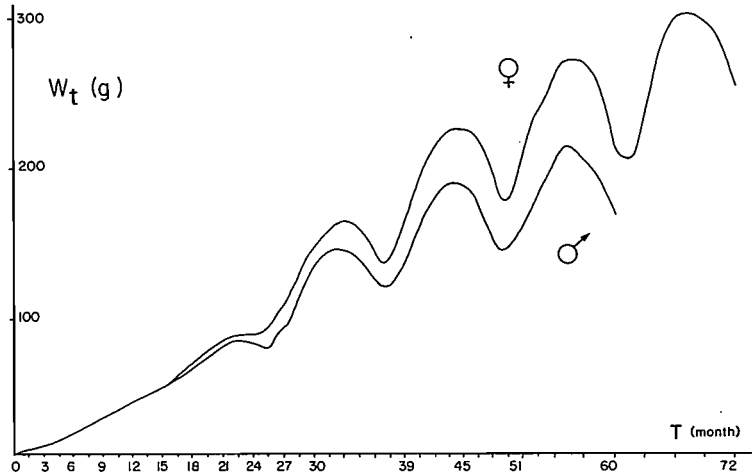


Fig. 9 Weight growth curves taking condition factor variations into account for *Alestes baremoze* males and females in the Lake Chad basin.

above describing the growth in length the average growth by weight curves can be obtained (Fig. 9), by considering the existence of different allometric coefficients for the sexes, the immatures and the adults and by integrating the seasonal variations of condition. Estimates of average weight as a function of age have been used in the production models.

13.6.2 Changes in the *A. baremoze* stock

The configuration of the lake basin and the enormous demand for fish in the Nigerian market resulted in the relatively simple scheme of traffic for dried fish given in Section 2.2. It should be noted merely that from the fishing statistics collected from 1969 to 1977 (Stauch 1977) and from some corrections and extrapolations of results, it has been possible to reconstruct the total quantity of *Alestes baremoze* (fresh weight) corresponding to the quantity checked on the commercialization routes. These estimated annual catches are shown in Table 8 and on Fig. 10.

From 1969 to 1971 and to a lesser extent 1972, most of the catches were made in the river system and the delta region (graph A on Fig. 10). From 1972, the proportion of lake catches increased rapidly: 13.7% in 1972 to 60.3% in 1974. In the river system, however, the decrease was continuous from 1970 to 1976: from more than 8000 tons to an apparent disappearance. On the whole during the period 1975–77, an average of 50 to 100 times less *Alestes baremoze* were fished than during a normal year.

Table 8 Estimated annual catches (tons) of *Alestes baremoze* between 1969 and 1976 based on controls at Maiduguri, after corrections; A = lower river system and delta (1969-72) and south basin (1973-76); B = north basin.

	A	B	Total
1969	6120	240	6360
1970	8070	210	8280
1971	4435	535	4970
1972	4380	695	5075
1973	2345	1425	3770
1974	1310	1990	3300
1975	*	145	145
1976-77	*	*	*

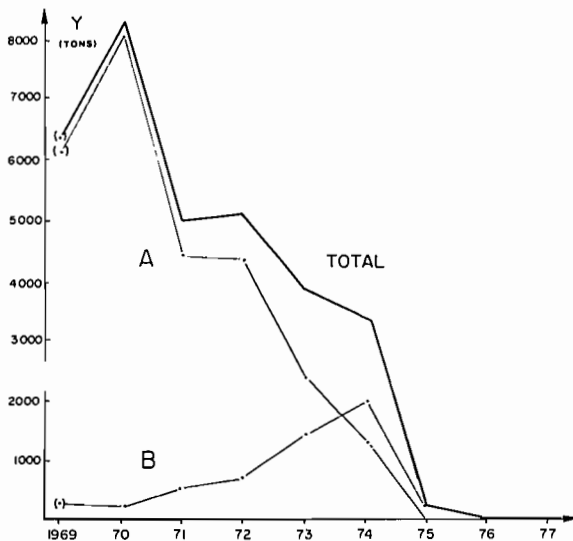


Fig. 10 Estimated yearly catches (Y) for *Alestes baremoze* between 1969 and 1977 from Maiduguri. Check-points data, after correction; (A) river, delta and south basin; (B) north basin.

To outline the analysis of the general change in stocks, it is necessary to know the change in the catch per unit effort (c.p.u.e.), failing that of the effort itself which remains the most difficult to understand and assess in the individual artisanal fisheries. A satisfactory description can be obtained from the experi-

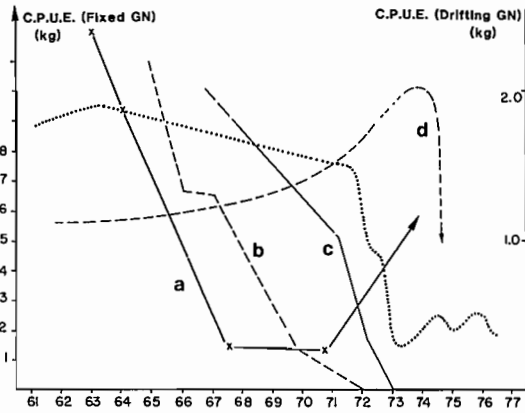


Fig. 11 Schematic evolution of the c.p.u.e.; ---- = experimental fishing; — local fishing; (a) large mesh GN, north basin; (b) GN 30, drift nets, riverine fishing; (c) GN 28.5, drift nets, Shari delta; (d) GN 25–30, fixed nets, north basin. The dashed line shows the Lake Chad water level evolution.

mental data especially in as much as the observed phenomena have been particularly marked (Fig. 11). As it is impossible to attach the same importance to experimental and to local c.p.u.e. we have simply indicated the tendencies as they appear to be, based on the partial data obtained between 1965 and 1975. In the fluvial system the catch per unit effort from drift nets was clearly much higher during 1966–67 in the river upstream of N'Djamena as well as in the delta. These catches corresponded to a little exploited stock. There was then an appreciable reduction in yields, in a ratio of about 10 to 1 until 1972. The exact speed of this lowering is not known but the c.p.u.e. had already been lowered considerably by 1971 and it is thus possible that this change had been fairly continuous since 1966–67. The experimental data of the southern archipelago showed a similar but earlier phenomenon, as the catches were already low for the adults in 1969–70. While the c.p.u.e. in 1965 (CTFT) reached 15 kg, they were only 1 to 2 kg $100 \text{ m}^{-2} \text{ night}^{-1}$ during 1969 (Fig. 12). On the contrary, the density of *Alestes* in the north basin was higher in 1971 and later increased in 1973 and 1974 due to the division of the lake and the rapid reduction of the remaining water volume.

During normal times in the Chad system, the north basin is the most marked lacustrine environment and thus a refuge for a large part of the various fish stocks. The use of large mesh nets developed much earlier there than fishing with average size gill nets. This explains the slower reduction in the catch per unit effort for *Alestes baremoze* (Fig. 11). Between 1966 and 1971, although there was no direct influence of the early fall of the lake on the catches of *Alestes*, their behaviour was affected as during this period adults of the southeastern archipelago disappeared. It is probable that they went to the north basin where they found some very deep waters and where the zooplankton

remained considerable. Even if this phenomenon could have played a certain role, the change in the fishing effort in the river system was preponderant between 1966 and 1971.* Four to five years later, we recognize the same scheme as for the large mesh gill net fisheries in the north basin (cf. Section 3.3).

From the beginning of 1971, the change in the lake environment was felt much more clearly. The catches per unit effort as well as the average sizes decreased rapidly in the delta fisheries during 1972, before the catastrophic effects of this very low flood could be recognized. The degradation of environmental conditions in the south of the lake resulted in a gathering of *Alestes* in the north basin and an apparent absence of the 1972 migration, well before the interruption of the communications between the two basins. In 1973 there was practically no more fishing in the delta and the fishermen gathered in the north basin which was isolated: the concentration of fishes led to an increase of catches during 1973 and 1974, then to a disappearance of stocks in 1975. From 1973 to 1975, fishing did not play any role as the fishes were anyway in a critical situation that had to end with a natural collapse. The change in total catches is in agreement with all these hypotheses (Fig. 12).

In conclusion, the fishing effort, corresponding to traditional techniques until 1960–65, though significant, has not been considerable. Through the introduction of nylon and industrial gill nets the total effort was considerably increased and became too high between 1970 and 1972. The shift of the Sahel drought led to the disappearance of stocks in 1975. The reconstitution of *Alestes* stocks, again allowing considerable catches, depends on the total fishing effort level and on the way it would be distributed.

13.6.3 *Dynamics and exploitation*

Three complementary aspects of the dynamics of *A. baremoze* populations will be examined: the mortalities, the yields per recruit and the fecundity of the stock.

13.6.3.1 *Instantaneous mortality rates.* To approach the problem of production and yields per recruit separate estimates of instantaneous rates M and F are needed. No direct calculation can be made for *Alestes baremoze* in Lake Chad. However, there is a correlation between the type of growth observed and species longevity: the former is generally slower as the latter increases. In a study of the relationship between growth rate and natural mortality Beverton and Holt (1959) showed that there was a more or less linear relationship between M

* This change in total effort intervened at first through its total increase, but also through the progressive concentration of the fishing in the delta area.

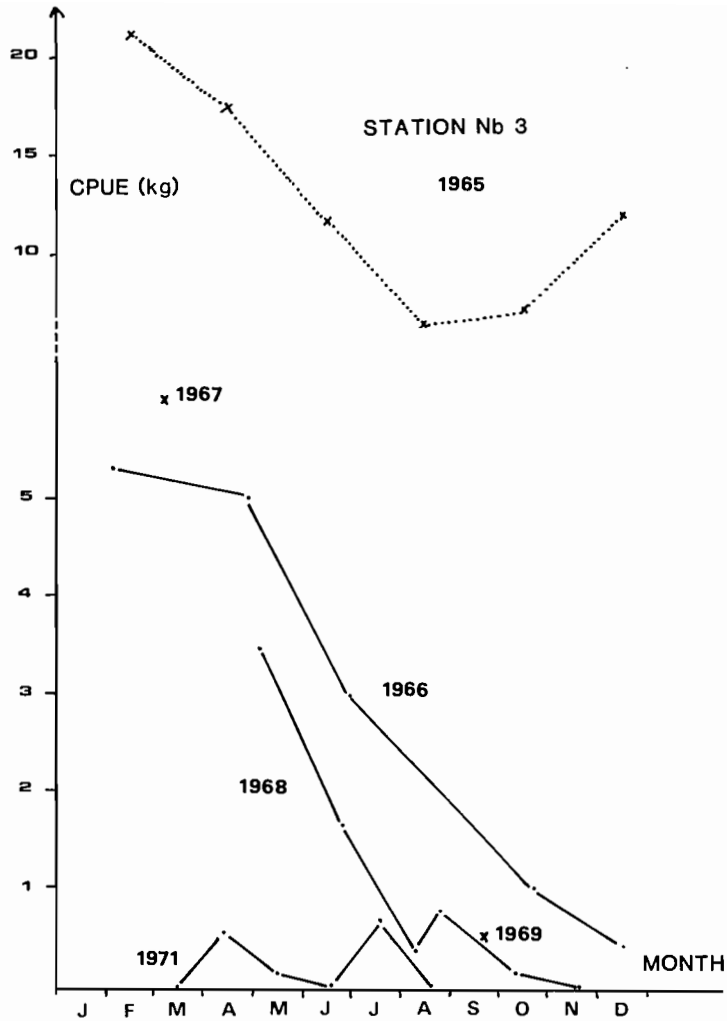


Fig. 12 C.p.u.e. for *Alestes baremoze* in the Southeastern Archipelago (GN 30; kg 100 m⁻² night⁻¹); c.p.u.e. always equals 0 from January 1972. The dashed line shows the evolution of the c.p.u.e. at station 3 (CTFT; *Alestes baremoze* and *A. dentex* gathered).

(instantaneous rate of natural mortality) and k (Bertalanffy coefficient) for some well known marine fish families.

Studies on estimates of M for tropical fishes of continental Africa are rare if not non-existent. In a study of *Pseudotolithus elongatus*, a species with a longer life span than *Alestes*, Le Guen (1971) found values of M ranging between 0.162

(M 0/1) and 0.439 (M 4/5). Similarly, Fontana (1979) recorded values of M between 0.2 and 0.6 for Congolese demersal fishes.

Alestes baremoze has a short life-span (five years for males, six years for females). Moreover, the variability of environmental conditions in the Sahelo-Sudanian zone (periodic drying of flooded zones, severe deoxygenation and frequently increased temperatures in the shallow water) must involve a very high natural mortality. Here M is taken as 0.3 to 0.5, corresponding to the first phase of the study with a well developed lake environment. With the drying of the lake, the so-called natural mortality would have increased.

From estimates of Z and M , the major traits of the changes in mortality due to fishing F can be inferred. From 1966 to 1970, F must have been low (about 0.4) and the exploitation moderate (Fig. 13). The exploitation intensified slowly, leading to F value of 0.6 to 0.8 during 1971–72. From the end of 1972 until December 1974, when the stocks disappeared, Z again increased maybe up to 1.70.

These two phases of increased mortality due to fishing are not at all similar:

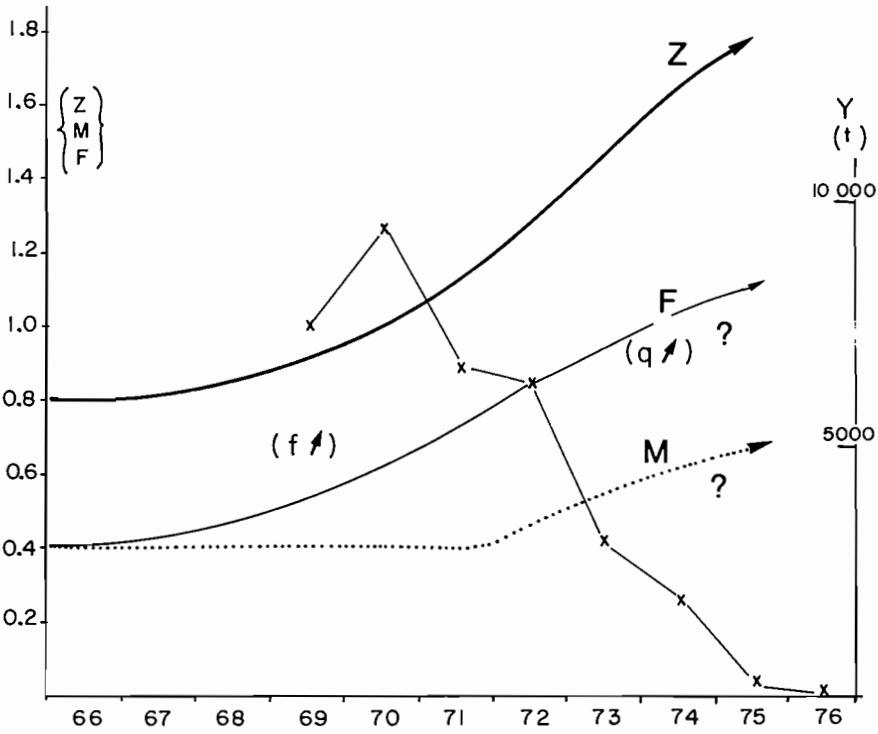


Fig. 13 Probable schematic evolution for instantaneous mortality coefficient of *Alestes baremoze*. The thin line corresponds to the yearly total catches.

in the first phase the increase in fishing effort, f , as well as its concentration in the delta zone probably led to the increase in F . In the last phase just preceding the disappearance of the stock, there was not necessarily an increase in total fishing effort. It was limited by the increasingly reduced distribution area of *A. baremoze* and also by increased vulnerability of fishes concentrated in the environments where the fishing was much easier, thus q , which represented the mortality per unit of fishing effort in the expression $F = q \times f$, increased. There was also a parallel increase in M over the course of the drought.

13.6.3.2 *Yields per recruit.* Beverton and Holt's model was chosen to describe the variations in yield per recruit as a function of the mortality coefficients M and F on one hand, and of the age at first catch, t_c , on the other hand. Four cases have been considered, for males and females separately, for two likely values of M , 0.3 and 0.5, in the scale of hypothetical values going from 0.25 to 4.75 years for t_c and from 0.1 to 0.5 for F . Figure 14 shows the types of results obtained for males with $M=0.5$; the drawn curve corresponds to maximum yields per recruit for a given F and the black part corresponds to the situation prevailing from 1966 to 1971.

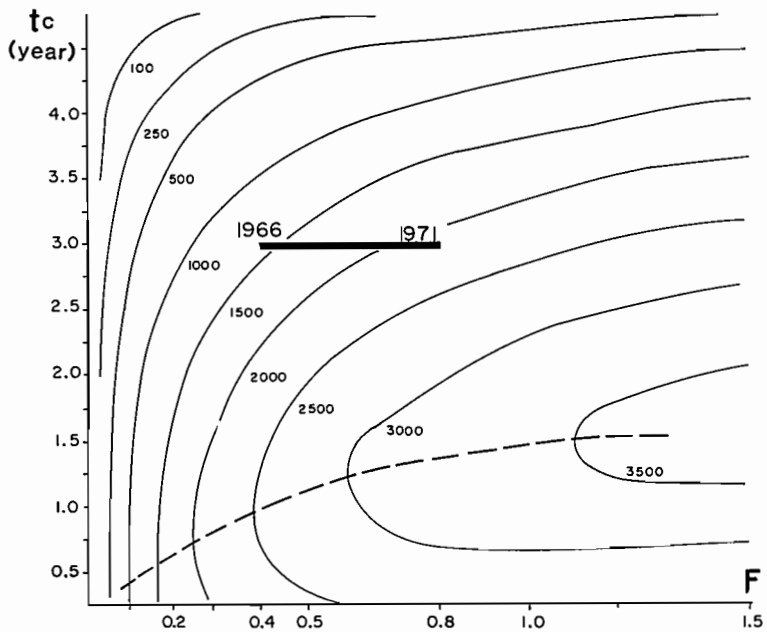


Fig. 14 Contours of equilibrium yield per recruit (Beverton and Holt) for the males of *Alestes baremoze* in the case of $M=0.5$. The dashed line corresponds to a Y maximum for a given F . The black strengthened segment corresponds to the situation observed between 1966 and 1971.

Between 1966 and 1971, the fishing was mostly fluvial and only caught adults during spawning migrations from the lake. These adults were mostly in their third year and they reproduced at the age of three years. They began to invade the river system during the first quarter and thus the average age at recruitment could be estimated to be about 2.5 years for the two sexes, as the fishes enter the fishing zone as soon as they leave the lake. This average age at recruitment corresponds respectively to 215 mm for males and 224 mm for females.

The river fishing was then entirely based on the use of gill nets. The average length of *A. baremoze* caught by GN 28.5 was about 240 mm and the recruitment sizes were thus clearly lower. The sizes corresponding to the average age at first catch must be higher than those reached at 30 months, which is why the estimated average ages at first catch were respectively chosen as 2.75 years for males and 3.0 for females. Therefore, to have an estimate of the total yield for the species, it is necessary to add the yields corresponding to the t_c chosen above (Table 9), supposing that fishing mortality and recruitment are identical for both sexes. The contribution of females is always higher and represents more than two thirds of total yields as long as F values stay low and still 60% for $F = 1.5$.

Over the course of the period considered here the total fishing effort probably increased progressively and F doubled, passing from about 0.4 to 0.8. The corresponding change in yields per recruit is shown in Fig. 14 for the males.

It is certain that the stock was clearly underexploited in 1966 at the beginning of our observations and the increase of the mortality due to fishing was completely positive while leading to a considerable increase of yields: for M 0.3, Y increased 48% in males, 32% in females when F went down from 0.4 to 0.8;

Table 9 Estimation of total yield, Y (in grams for 200 recruits of 4 months, 100 males and 100 females) as a function of M and t_c .

F	M=0.3			M=0.5		
	$Y_{\delta}(t_c=3)$	$Y_{\varphi}(t_c=2.75)$	$Y(\delta+\varphi)$	$Y_{\delta}(t_c=3)$	$Y_{\varphi}(t_c=2.75)$	$Y_{\delta}+\varphi$
0.03	294	638	932	142	293	435
0.08	705	1493	2198	341	690	961
0.15	1318	2686	4004	640	1257	1897
0.23	1851	3642	5493	904	1724	2628
0.30	2315	4409	6724	1135	2111	3246
0.45	3071	5523	8594	1520	2701	4221
0.60	3646	6251	9897	1821	3117	4938
0.90	4422	7052	11 474	2244	3635	5879
1.20	4882	7419	12 301	2514	3926	6440
1.50	5162	7599	12 761	2691	4103	6794

for M 0.5 there was an increase of 52% in males and 42% in females (Table 9). Beyond this a new increase in fishing effort would have much less effect. A new doubling, from 0.8 to 1.5 gives no more than a gain of 15 to 20% for the males and about 30% for the females. Although considerable in absolute value, this increase in catches would have implied, all else equal, a doubling of fishing effort and thus a very clear decrease of catch per unit effort.

It is thus more likely to be a decrease in the age at the first catch that could lead to a new improvement of yields. Figure 15 shows the so-called eumetric fishing curves as they are obtained when writing out the values of t_c corresponding to a maximum yield for a given value of F . It is seen that the various hypothetical ages at first catch are placed mostly above the eumetric curve. For males, the optimum age at first catch would be placed at 1.5 (F about 0.9); for females, the best value of t_c would be near 2.35 (M 0.3) and 1.75 (M 0.5). It must be noted however that the corresponding gain of yield to this level of fishing effort is not very high: from 5 to 20% according to sexes and M values.

Until now we supposed that F remained constant and therefore that the fishing effort was regularly distributed throughout the year. In reality, however,

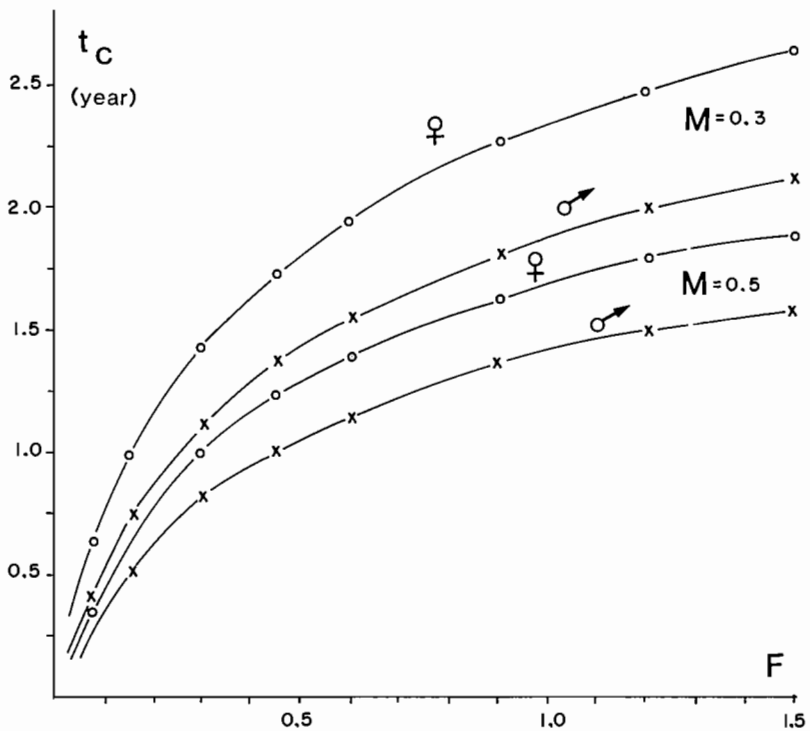


Fig. 15 Eumetric fishing curves for *Alestes baremoze*.

the fishing activity was rhythmically related to the hydrological cycle of the rivers. This cycle was accentuated in the Sahelo-Sudanian zone, where during the two extremes; low and high waters, there was a very clear reduction in fishing activity. The fish dispersed during high water with the increase in current speed, and, during low water, some techniques (drifting GN) could not be used and the fish took refuge in the lake (cf. Section 4).

To our knowledge, there have been very few attempts at direct evaluation of fishing effort for continental artisanal fisheries and none within tropical Africa prior to the study of Loubens (1973) in a reach of the Shari delta. This study has been summarized in Section 4.

In order to see if the annual modulation of fishing effort, thus of F , introduced an appreciable difference, we recalculated the yields with the help of the Ricker model. For males, when $M=0.3$, it was supposed that the quarterly values of F would have corresponded to variations of f found by Loubens (Section 4). The comparisons made for constant F and F changing quarterly showed that there was a slight increase in yields due to the fact that the most active fishing of the first quarter caught fish in optimum condition.

To know if the systematic catch of individuals in a better condition had a considerable influence on the total catches, we used the Ricker model by simulating a concentrated fishing effort during the quarter when the *Alestes* have the best condition, supposing that the fishing was closed during the nine other months. If the quantitative aspects only are considered, the gain is noticeable by comparison to the model at uniform F : from 8 to 15% for the F/t_c couples chosen for 1966–1970.

13.6.3.3 *Stock fecundity.* The study of stock fecundity is based on the notion of theoretical fecundity per recruit introduced by Le Guen (1971). From the relationship between weight and fecundity ($\varphi = 0.345 W - 25$ where φ , the fecundity, is given in million of eggs and W in grams) and taking into account the proportion of ripe females of a given age we obtain the relationship between female fecundity and age; we admit here that the average number of spawnings for the entire female stock is equal to one, this should slightly overestimate the absolute fecundity since a part of the lacustrine females, especially in the context of a greater Lake Chad, did not reproduce each year.

The theoretical fecundity is the sum of individual fecundities at a given time so that $\varphi = \sum N_i \varphi_i$. It thus depends on the structure of the stock and of fishing. Expressed as a function of virgin stock theoretical fecundity, it allows, for a given combination of F and t_c , the estimation of the relative level of stock reproductive potential (Garcia 1977). The various fecundities for various combinations of t_c , F and M have been calculated here (Table 10). The results are given for an initial total number of 10 one year females during the period 1966–70.

The two values circled in Table 10, 2798 when $M=0.3$ and 1504 for $M=0.5$

Table 10 Fecundity of *Alestes baremoze* stock as a function of F and t_c (years) for M=0.3 and 0.5: fecundity of females from 1966 to 1970 (in millions of eggs for 10 females of one year).

F		t_c	1.25	1.75	2.25	2.75	3.25	4.25	5.25
M=0.3	0.04	2458	2545	2596	2646	2689	2759	2798	2798
	0.2	1508	1751	1932	2120	2298	2587	2760	2760
	0.4	848	1144	1390	1665	1940	2412	2718	2718
	0.8	305	555	824	1152	1497	2161	2646	2646
	1.6	60	197	403	638	1105	1886	2540	2540
	2.0	31	135	300	400	700	1600	2300	2300
M=0.5	0.04	1338	1386	1407	1433	1455	1487	1504	1504
	0.2	848	985	1085	1187	1279	1415	1489	1489
	0.4	498	672	803	970	1116	1344	1473	1473
	0.8	194	353	514	710	908	1246	1446	1446
	1.6	70	139	280	488	714	1120	1405	1405
	2.0	19	99	229	434	665	1085	1391	1391

practically represent the fecundity of virgin stock as they refer to theoretical values of the age at first catch, 5.25 years, which is close to the maximum age reached, and to some extremely low values of fishing mortalities: F annual=0.04. Rather than build the curves of general isofecundity similar to those obtained for the yields per recruit, the relative fecundity for $t_c = 2.75$ and $t_c = 1.75$ have been shown here (Fig. 16). When the age at first catch is 2.75 years — the estimated mean value in the fluvial fisheries — the relative fecundity of the stock is still 35% for M=0.3 (and 42% for M=0.5) when F=1.0. Thus it may be concluded that the traditional exploitation which does not catch females before 30 or 36 months protects the reproductive potential of the stock even if the exploitation is quite heavy (F=1.0). If a new type of exploitation were to be introduced, with females caught before sexual maturity ($t_c = 1.75$), the relative fecundity of the stock would remain appreciable: 20% for Z=1.5 (M=0.5; F=1.0) (Fig. 16).

In conclusion, three results can be considered in the forecasting of optimal exploitation of *Alestes baremoze* stocks: (a) the suppression of fishing dams on the El Beid could involve an average annual gain of some hundreds of tons in the fluvio-lacustrine fisheries; (b) the concentration of fishing effort during the months when the *Alestes* have the best condition would lead to another gain; (c) the stock fecundity is not, *a priori*, a limiting factor.

Obviously, (a) and (b) cannot be practiced due to strong socio-economic constraints.

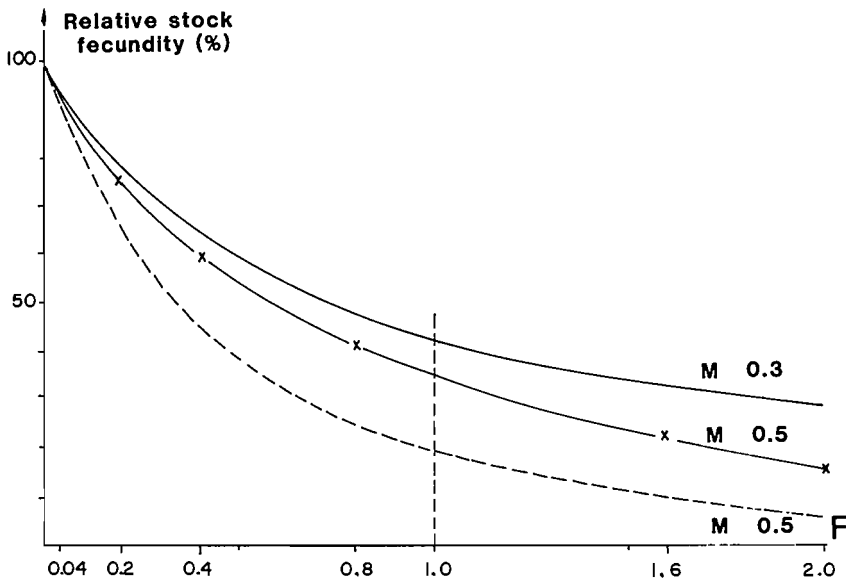


Fig. 16 Relative fecundities for the stock of *Alestes baremoze* (%); — = $t_c = 2.75$ years; ---- = 1.75 years.

13.7 Rational exploitation and prospects of fisheries

In comparing the total catches obtained for the *Alestes baremoze* stock and for all the large sized fish, between 1969 and 1977 some spectacular differences can be seen (Fig. 17). Between 1970 and 1974, the *Alestes* catches were reduced by three fifths, although during the same period the production of large mesh fisheries tripled from 65 000 to 220 000 tons. Some analogous tendencies appear between 1974 and 1975 with a very rapid reduction of catches in the second year. However, some fundamental differences in the reaction of stocks were noted later when the *A. baremoze* practically disappeared during 1976 and 1977 and the total catches of average or large sized fishes stabilized around 100 000 tons (Fig. 17).

The explanations on the preceding pages considered first the nature of the stocks compared, monospecific and multispecies; in the latter species replaced each other in a succession due to the changing of the lake environment. Some intervening human factors also partially affected the changes in catches as seen in the underexploited multispecies stocks between 1969 and 1971 when the catches of *A. baremoze* in the rivers were not far from the optimum. However, it is clearly evident that the primary factor remained the change in the environment which was effective in two ways:

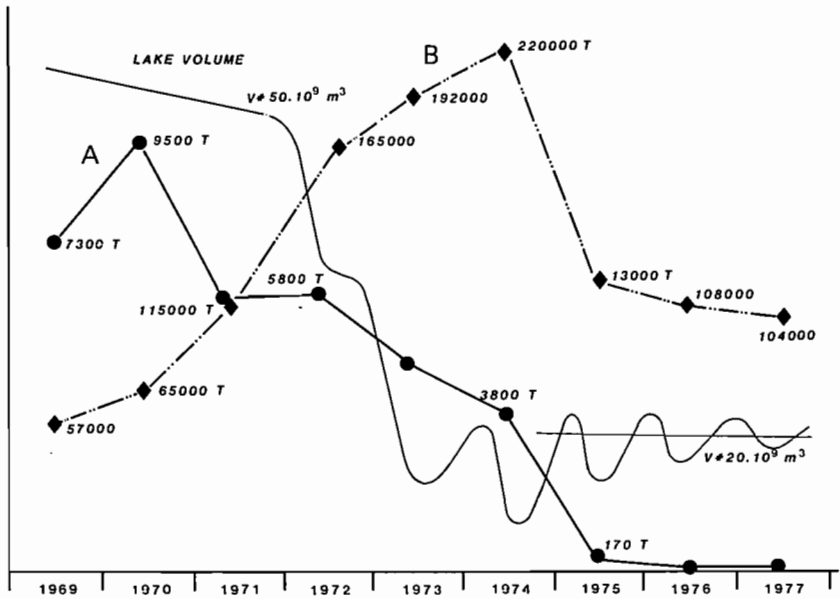


Fig. 17 Compared changes in total catches of salanga (*Alestes*, curve A) and banda (large size fish, curve B).

- on the *annual recruitment*, by the importance of the river flood and of some temporary flooded environments which were directly dependant on it;
- on production, through the development of permanent aquatic environments which conditioned the general productivity of the ecosystem.

Any rational exploitation, or, in a more realistic way, any attempts bringing a contribution to it, will depend on the various foreseen patterns of environmental evolution. The following will be examined in this view.

13.7.1 Possible trends of *A. baremoze* exploitation

For the dynamics study and for the estimates of yield per recruit (Section 6.3) we have limited ourselves to the period characterized by a well-developed Lake Chad and a unique fluvial fishery. From 1971–72, an intermediate period began with a concentration of fishing effort in the deltaic region and the change in catch per unit effort which fell in 1972. For some months very small mesh nets appeared (about GN 25) indicating a lowering of the age at first catch. This was a very transitory stage because there was an almost immediate transfer of fishing effort towards the south basin of the lake during 1973, the north basin in 1974 and a rapid depletion of stocks that would have been killed by the drought

in any case. Contrary to several species whose stocks were either maintained or developed after 1973, *A. baremoze* was very vulnerable to the deteriorating environmental conditions.

Although the period 1972–77 barely resembled the classic equilibrium exploitation, it is instructive to examine all the hydrological factors that contribute to the good condition of fish stocks in general and of *Alestes baremoze* in particular in the Lake Chad region and to the resilience of stocks subject to severe climatic risks.

Two hydrological parameters were paired:

- the Logone flood on which the flooding of North Cameroon and the flood of the El Beid depended (cf. Chapter 2);
- the total volume of the lake which itself was a function of yearly supply balances by the Shari. The latter affects the total level of stocks through all the susceptible lacustrine factors that play a role such as shelter for the young, available space, food etc. ...

It should be emphasized that these two aspects were practically independent because, apart from exceptional periods, the supplies of Logone to the lake change scarcely from one year to the next and played a relatively minor role in the lake level.

The beneficial effects of the Logone flood can be shown in two ways: (Bénech and Quensièrè, personal communication).

- *growth of juveniles* (Fig. 18). There was a positive correlation between the overflowing of the Logone and the average weight of some species from El Beid, the one migratory, the other sedentary. First growth is thus stronger since the juveniles stayed longer in the flooded plain. The fishing yield showed the same tendencies (Fig. 18). The 1974–75 fishing season is placed separately because it corresponded to the first flooding after two consecutive years of drought and the flood accumulated over these two years (livestock, vegetation cover ...) may have led to an exceptional productivity;
- *recruitment of migratory species*. There was a satisfactory relationship between the overflow volume of the Logone and total catch per unit effort for a number of migratory species (Fig. 18). For 1974–75, the catch per unit effort did not follow the relationship for the same reasons as above. The data did not permit further species analysis because for the years of observation the effect of the variability of the Logone overflow may have been concealed by the consequences of the drought on the reproductive potential. However, that a connection existed between the importance (extent) of the Logone flooding and recruitment of migratory species is highly probable. Moreover this does not exclude the Shari from being able to play a role, probably less important, with the notable extension of its major bed during high waters.

The reduction of *Alestes* stocks between 1972 and 1977 was expressed by an apparent disappearance of adults in the fishing statistics but also by a lack of recruitment during 1972, 1973 and probably 1974. We saw that during 1972

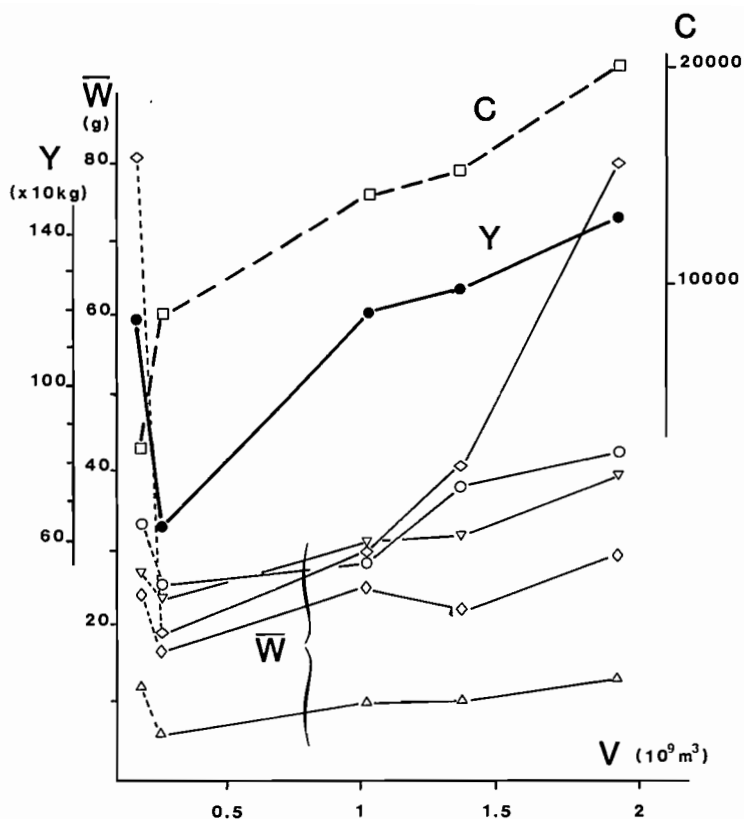


Fig. 18 Relationships between the flood volume of the Logone river (V), and the specific mean individual weights (\bar{w}), the global yield (Y), the c.p.u.e. in number for some migratory species (C) in the El Beid river.

and 1973 the weak floods of the Logone scarcely included any overflowing into usually flooded plains and that the El Beid did not flow at all. The young spawned during September 1972 and 1973, which were moreover fewer than in a normal year, thus could not rejoin the permanent hydrographic regime. During 1974 the lake was at its minimum and in spite of an almost normal river flood the recruitment did not appear to be considerable. On the other hand, during November 1977, *Alestes baremoze* again began to be caught in the delta fisheries. The nets used, GN 15 to 20, were catching 180 to 200 mm *Alestes*, two-year old fish during September 1975 when the presence of older *Alestes* appeared much more sporadic.

We may come to the conclusion that the recruitment of *Alestes* was practically stopped for three years, from 1972 to 1974, and it was only in 1975

that the spawns enabled a rebuilding of stock. This partial reconstitution in these conditions can only be explained by their very high fecundity: it was enough that a small group of spawners survived to be able to reproduce in 1975; it confirms that the fecundity should not be a limiting factor in any of the possible patterns.

Besides these disturbances, linked to a regression or an extension of Lake Chad, two stable situations appear to be plausible:

- existence of a large lake of 18 000 to 24 000 km² corresponding to some normally occurring rains and floods;
- Lake Chad reduced to a single south basin as a permanent environment, the annual floods being much less on the average than in the first case and not sufficient to fill in the north basin.

The first situation corresponds to that from 1966 to 1971 and the second prevailed since 1973. In the last case, the south basin was not homologous to typical lacustrine environments because as a whole it was much more influenced by the Shari flood (Chapter 2).

This rather fluvio-lacustrine character had two major consequences:

- sexual maturity occurred earlier and the first reproduction took place at an average of two years. The fishing in the river system would then operate from an age at the first catch up to 1.75 years, which has been seen to correspond to the best exploitation;
- on the other hand, the sustained yield per unit lake area for such a fishery would be lower than that of the large lake because the higher annual instability would make it less productive.

For the exploitations of stocks corresponding to a well-developed Lake Chad, and by referring to an average situation, particularly for recruitment, two situations should be considered to find the best combinations of t_c and f — thus F — for an optimal exploitation.

1. The habits of fishermen are not radically modified and they are reluctant to set *Alestes* nets in the waters of a lake regaining ground. The situation of the years 1966–1970 again occurs with the movement of migrating adults which direct the fishing so it only develops in the rivers and the delta. The age at the first catch is then a little lower than three years and cannot be reduced. The use of 25 mm mesh nets would improve the yields somewhat, in particular for the males.* Moreover, the optimum fishing effort would correspond to instantaneous coefficients of mortality due to fishing of about 0.8 to 1.0. In these conditions it must be possible to obtain an average yield a little higher than that obtained during the four years for which we have some observations: an

* Recall that in all the cases, the best exploitation would be led with 25 to 28 mm mesh when the actual legal minimum size is 35 mm resulting in an underexploited stock where the catches would only deal with the largest sized females.

average of 7500 tons from 1969 to 1972. An increase of 20% leading to annual catches of about 9000 tons would appear to be reasonable.

2. Lake fishing is kept up in spite of the raising of lake waters, giving a combination of two fisheries. The fluvial fisheries would continue to be exploited seasonally at the time of migration of the large adults. In the lake, a moderate fishing could take place, with 22 to 25 GN, on 18 to 30 juveniles. We saw that the age at first catch should be lowered in order to obtain an optimal exploitation. It is not obvious that fishing on adults would be of great benefit because they are more dispersed than the juveniles who have a tendency to gather in certain regions of the archipelago particularly in the northeast of the lake. The combination of limited fishing efforts in the lake and the river would lead to an increase in yield due to the lowered age at first catch. The gain, depending on the sex and level of F, would average from 15 to 20% by comparison to the previous one and thus the balanced total catches reach 10 to 11 000 tons.

13.7.2 *General prospects of lake exploitation*

It is not possible to analyze the involvement of multispecies stocks in the varying exploitation and environmental circumstances, as has been done above for a single species. Even if the specific data on biology and demography had been obtained, it would be still very difficult to build up something serious since interspecific relations intervene. However, it is possible to consider the total productivity of the lake through total fishing yields.

13.7.2.1 *The yields.* For flat waters like those of Lake Chad, a direct relationship can immediately be noticed between the area occupied by the waters — and the incident solar radiation — and the fish production through the various trophic chains. Thus the total catches of the fisheries depend on the total extent of the lake water and it is interesting to estimate the average annual yields per hectare from 1969 to 1977.

The total estimates must be affected by some factors such as the local production of the flooded zones and the rivers, the state of the lake (in particular the importance of the vegetation and of different types of plants that are more or less favourable to aquatic life). Nevertheless, by comparing total production and areas of basins and lake over the course of the period 1969–1977 (Fig. 19) some yields per hectare are obtained that could be calculated more precisely in further studies.

The figures used for estimations are gathered in Table 11 and yields obtained for the entire lake and the north and south basins considered separately, are shown in Fig. 20. To distinguish the production of the two basins it is necessary to arbitrarily assign, starting from 1975, a major part of the tonnages counted on the Baga-Kawa road to the south basin.

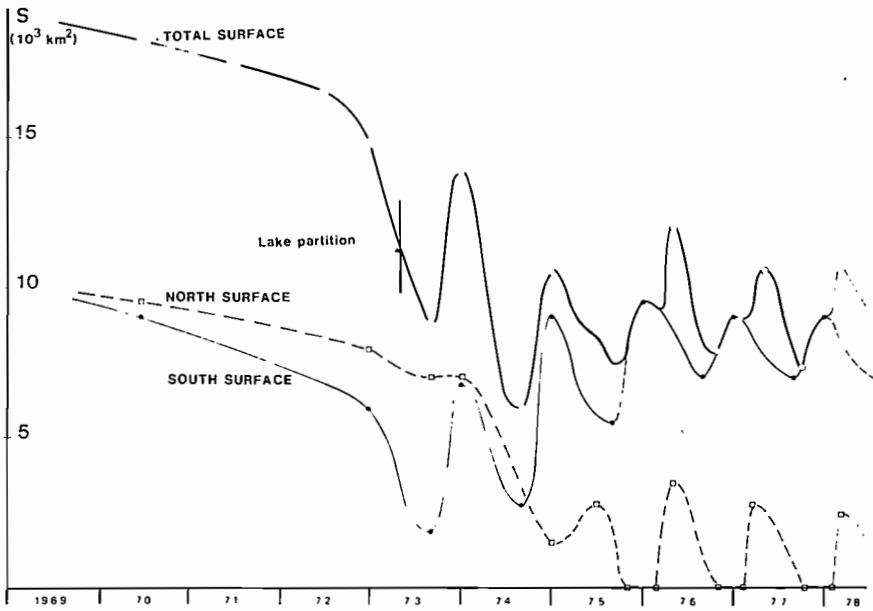


Fig. 19 Water areas approximate variations for Lake Chad between 1969 and 1978.

Table 11 Approximate calculation of water areas (S_s =south basin; S_n =north basin; S_t =total area in km^2) and corresponding average annual yields (kg ha^{-1}) between 1969 and 1977.

Year	Water areas (km^2)			Yields (kg ha^{-1})		
	S_s	S_n	S_t	Y_s	Y_n	Y_t
1969	9500	9500	19 000	26.4 ^a	42.5	34.4
1970	9100	9200	18 300	30.8 ^a	51.2	41.0
1971	8500	9000	17 500	40.8	96.6	69.5
1972	8000	8600	16 600	59.9	144.4	103.7
1973	(4000)	7500	11 500	98.3	206.9	166.2
1974	(5000)	(4300)	9300	105.4	406.5	244.6
1975	6800	(1700)	8500	127.8 ^b	248.8 ^b	152.0
1976	7600	(1200)	8800	112.1 ^b	191.7 ^b	123.0
1977	8000	(1000)	9000	106.0 ^b	186.0 ^b	115.5

^a In 1969 and 1970 the values of lacustrine yields were overestimated because the riverine fisheries were still notable. The mean values in parentheses correspond to the years 1973 and 1974 for the south basin and since 1974 for the north basin where seasonal fluctuations have been particularly important.

^b It was supposed that a growing part of fish checked on the Baga-Kawa route had been fished in the south basin.

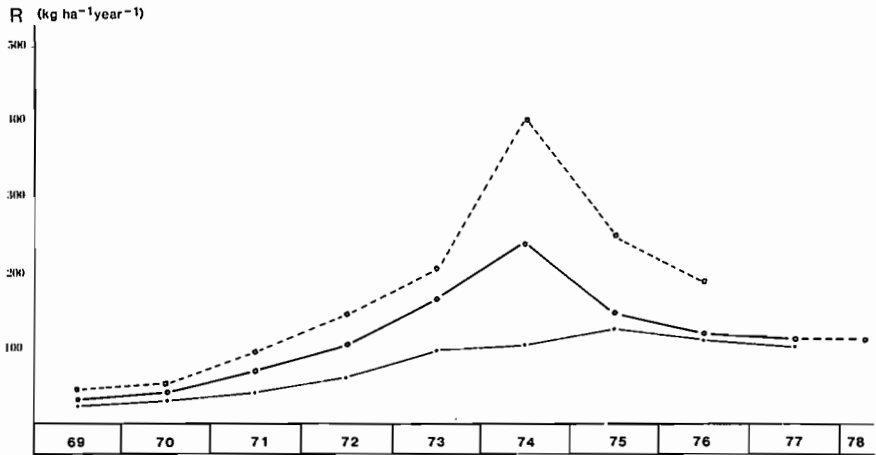


Fig. 20 Yield estimates (R , $\text{kg ha}^{-1} \text{ year}^{-1}$) between 1969 and 1978 for the north basin (---), the south basin (thin line) and the whole Lake Chad (thick line).

It should be emphasized here that the foreseeable increase in yield was particularly significant for the entire lake area; it increased from 34 kg ha^{-1} in 1969 to 104 in 1972 and 245 in 1974. After a severe decrease in 1975 (142 kg ha^{-1}) it appeared to stabilize at about 100 to 120 kg ha^{-1} .

The yields were always higher in the north after 1969, corresponding to a relative underexploitation of the southern lake. The yields per hectare regularly increased during four years: 51 kg in 1970, 97 in 1971, 144 in 1972 and 207 in 1973. The depletion of the north basin in 1974 corresponded to a yield of 407 kg ha^{-1} and from 1975 to 1977 the yields stayed very high, about 250 to $180 \text{ kg ha}^{-1} \text{ year}^{-1}$.

The change in yields in the south basin was quite different. By considering that a part of the fluvial fishery accounted for catches in the statistics of the N'Djamena route from 1967 to 1972 and that the Baga-Kawa route also corresponded to the south basin starting from 1975, the yields per hectare can be estimated to increase from 10/15 during 1969–70 to 100 in 1973 (Table 11). After 1973 the yields appeared to stabilize at about 105 in 1977 and did not show the fluctuations recorded in the north basin. A similar value was found for the entire lake in 1972 when it was reflooded and did not appear to give way to an excessive exploitation.

Thus, 100 to 120 kg ha^{-1} seems to be an average yield which is possible to maintain under the adopted exploitation conditions. It does not mean that, in the frame of rational stock exploitation, it would be impossible to increase the yields in Lake Chad fisheries.

13.7.2.2 *Prospects of lake fisheries.* The level of total catches that can be achieved each year in Lake Chad depends first on its extension and then on the pattern of exploitation. No forecasts can be made on an eventual rise of the lake that would reflow the north basin, but it is evident that the latter would have increased the total catches to about 180 000 tons. Unfortunately, one cannot be optimistic in the short term due to the high evaporation and the actual deficit of the north basin: two to three exceedingly strong floods in succession are needed to bring about an average lake, still far from the extension of 'Greater Lake Chad' in the years 1960–65. This unfortunately improbable scenario means that the lake may not recover its past extension in the next few years especially as the recent floods have often been very low. Thus the total volume flowing during the course of the hydrological cycle year 1979–80 has been similar to the two low floods of 1972–73 and 1973–74.

It is thus likely that the extension of lake waters in the next few years will stay the same as over the recent period. Since 1975 the average area of the lake was seen to be close to 9000 km² with a permanent lake reduced only to the south basin, about 8000 km². A stable system appears there: on the one hand, a reduced south basin is unlikely since it would mean a new worsening of the Shari supplies; on the other hand, the excess waters in average years form bogs in the shallows of the north basin and evaporate before the following flood appears.*

According to the yields obtained, the annual total catches should thus stabilize at a level of about 90 to 100 000 tons, provided that the exploitation stays balanced, both for the gill nets and for the total fishing effort level. As already seen, the case of multispecies stocks is too complex as they are constituted of biologically varied species that may necessitate distinct exploitation patterns for each species. Nevertheless, some reasonable 'mean' modifications could be adopted. Scattered observations in the Shari delta during November 1977 showed that the catches were very diversified with nearly twenty species caught, especially *Tilapia* spp., *Hemisynodontis membranaceus*, *Heterotis niloticus*, *Hydrocynus* spp., *Citharinus* spp. The common occurrence of probably immature individuals in the catches indicates that the mesh size was already too small, and that it would have been necessary to prevent the large mesh from getting below 60 to 70 mm.

Before the environmental changes influenced the fisheries, the effect of the fishing effort was already considerable and an excessive rate of exploitation was reached by 1971 for *Alestes baremoze*. A precise analysis for the total fisheries of the Lake Chad region will not be possible until specialized studies to estimate

* These are particular temporary aquatic environments which have not been considered among the usually flooded zones of the lake Chad region. It is nevertheless certain that the productivity of these bog zones is very high (*Clarias* spp., for example).

the major fisheries parameters (specific catch per unit effort, size distribution with gear, age of fish caught, fishing effort ...) have been carried out. If the estimates of total catches from the road-checks start again and are reinforced, then it would be possible to understand the change in stocks and appropriate measures could be taken to insure the rational management of resources which are still important in spite of a very unfavourable climatic context.

At the present time, it is difficult to go any further in stock management. Later, a predictive model could probably be built for particularly well-known stocks. For migratory species with a fluvio-lacustrine cycle, it should be possible to find recruitment indices built from hydrological indices combining various characteristics (floods, flooded zones ...) one or two years before, but the total multispecies yield (here a high value of about 100 kg ha^{-1} which will be discussed further in Chapter 17) appears to be linked only to the extension of permanent waters, essentially the Lake Chad area. The forecast can solely be made from one year to the following due to the effect of each annual flood in relation to the variability of supplies that cannot be modelled as they depend on the climate of the entire African continent.

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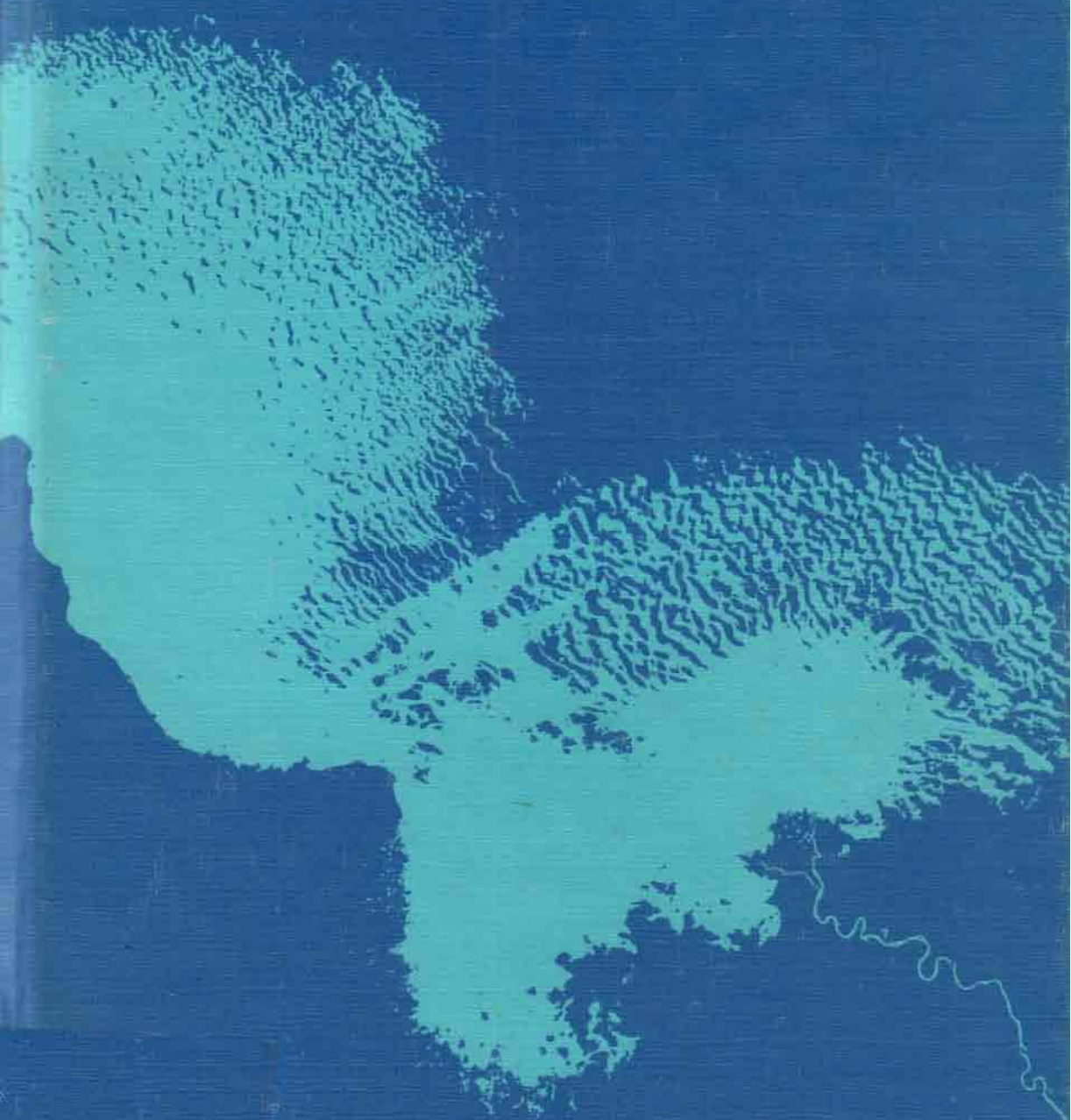
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