

10. Fish communities of Lake Chad and associated rivers and floodplains

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The concept of fish community as used in this chapter must not be confused with the concept of ichthyocenosis from which it is fundamentally different. We call 'fish species community' the possibly biased image given by the sampling of a group of fishes able to be caught in a particular environment at a given time. This definition only names a description — in the meaning of Legendre and Legendre, 1979 — of an ecological entity, but not this entity itself. This remark will be justified by the large complexity of the whole fluvio-lacustrine Chad system in the following discussion.

As described above for other groups, the study of the composition and distribution of fish communities requires the consideration of large spatial, seasonal and between year variability. However the study of fish communities includes certain aspects that increase the difficulties of description and interpretation. The mobility of fishes introduces some additional difficulties, both those of proper sampling and those due to the often considerable migratory activities. The first point sometimes results in biases including some systematic deformations of images of multispecies structures given by the samples. This bias depends on the proper selection of the fishing gear and/or fishing techniques (cf. Section 1), on their use and also on specific behaviours which are themselves varied. According to the richness of data gathered and the aims, we will attempt to minimize this sampling bias by comparing for the same period some groups of data obtained according to different methods. On the contrary some changes will be characterized by comparing some series of surveys of the most repetitive sampling methods.

The migratory movements do not allow the construction of a valid interpretation only from the data on lake communities, and the integration of data on the connecting environments communities, the rivers and flood zones is necessary. Thus in addition to Lake Chad, the study area includes the delta region, the lower reaches of the Shari and the Logone above 10°50'N latitude, the flood plain of north Cameroon and the two temporary rivers that connect the plain to the general system: the El Beïd and the Logomatia (Fig. 1). This is

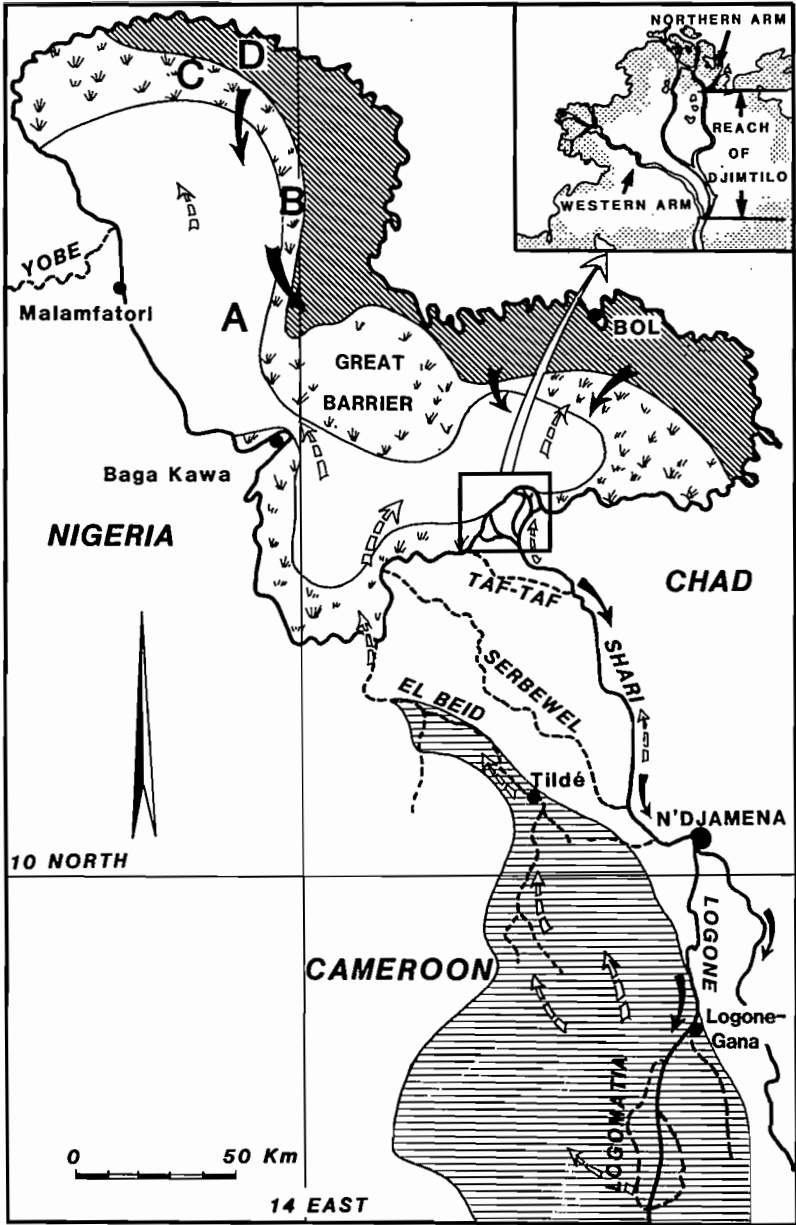


Fig. 1 Map of the study area. Arrows show the migration pattern of adults (black arrows), and juveniles (white arrows) of a typical migratory fish (*Alestes baremoze*). A, B, C, D = sampling sites in the north basin.

▨ = Archipelago; □ = Open Water; 🌳 = Reed Islands; ▨ = Flooded areas.

the hydrographic system almost corresponding to what is called 'the conventional basin', by the Lake Chad Basin Commission (LCBC).

The hydrology of these environments explains a large part of the spatio-temporal variability found and the description here constantly refers to Chapter 2 of this book. This is so for the average scheme of water supplies and circulation then corresponding to a well-developed lake and to some high or average floods as well as for the years of drought (since 1972) which only saw frequent mediocre floods and a spectacularly reducing lake.

Only an initial general outline is presented here because not all the results obtained from 1966 to 1978 have yet been analyzed. The in-depth study now in progress could not be included in the reduced space of this chapter where after a presentation of methods and data the main results will be discussed under two headings corresponding to the two periods of the lake: the 'Normal Chad' (as defined by Tilho, 1928) from 1965 to 1972 and the change during the Sahel drought from 1972 to 1977.

10.1 Collection and treatment of data

The multi-species approach would be incomplete if it had been based only on the local fisheries. The latter did not include all the permanent and temporary aquatic environments, they could not be operated in all seasons and, except for subsistence fisheries, they were oriented towards the capture of fishes of medium or large size. It was thus necessary to carry out some experimental sampling using several traditional techniques as well as new fishing gear for the Chad basin.

Several sampling methods, from the Kotoko basket trap to the electric trawl were experimented with and used during thirteen years of observation. The required data was mainly obtained from four methods: two foreign — ichthyotoxins and river seines — and two traditional — triangular net of the El Beid and gill nets.

10.1.1 *Fishing with ichthyotoxins*

This method, with possible sources of bias and the results obtained with it, has been described by Loubens (1969, 1970). The poison used contained 5% rotenone and was harmless to man. Its use was justified by the 2 main objectives of the study: to sample environments where other methods could not be used, and to obtain accurate estimations of community structure, fish densities and biomasses in restricted environments.

The poisoning could only be carried out over small areas (one hectare at maximum) in well-sheltered regions. Thus observations were limited to bio-

topes that are enclosed (subsidence ponds) or specialized (back waters, lake creeks). The open water biotopes had to be sampled by other means.

In spite of these restrictions, precise and acceptable data on biomasses and their composition in the restricted environments could be obtained only by poison fishing. The results obtained by other sampling methods could often be made more explicit by these data. Collected between 1966 and 1968, they essentially concerned a small creek of the southeastern archipelago of the south basin, close to Bol and a secondary arm of the Shari, upstream of Mailao (Fig. 2) during the withdrawal of waters and the first part of the flood.

10.1.2 *Beach seine*

The beach seine is a pulled net capable of catching all the fish encountered above a given size for a given species. Outside the very limited fishing of the Yobé in Nigeria, there were no such local fishing gear. The one we used was made in France and measured 200 × 7 meters with a 40 mm mesh* for the two wings and a 20 mm mesh for the 100 m long central part and for the bag. This net can give excellent results but is not easy to use. It demands a fishing team of 15 to 20 trained men and can only be used in some areas because it is set from a cleared beach and on a clean and firm bottom. In the river, these conditions limited its use to the low water period when the sand beds were exposed and setting was not complicated by currents. In the lake, the use of the seine was limited to the island borders adjacent to the non-muddy bottoms.

It is possible that the total catch underestimated fish biomass to a varying extent because error could result from the escape of fish during setting and pulling-in (above, below and through the net). These escapes were doubtless not the same for all species and all sizes encountered, resulting in some element of bias. Moreover, the gear selection of the beach seine also interfered and essentially corresponds to the passage through the central mesh of 20 mm, as in codend of trawl net. The mean selection length although not too high (for example it was 150 mm for *Alestes baremoze*) led to a notable underestimation in the abundance of the smaller sized species. From poison fishing data, it is known that 95% of the ichthyomass was composed of fish larger than 100 mm, thus biomass data were less affected than density estimates. It can be deduced (Lauzanne 1977) that the underestimation of the biomass due to gear selection of the seine was about 10%.

The seine was used from 1966 to 1974 essentially in the southeastern archipelago (Bol area, Fig. 2) but also more temporarily in the Shari delta and around Mailao on the Shari during the subsidence.

* For all fishing nets we always give the length of the mesh bar.

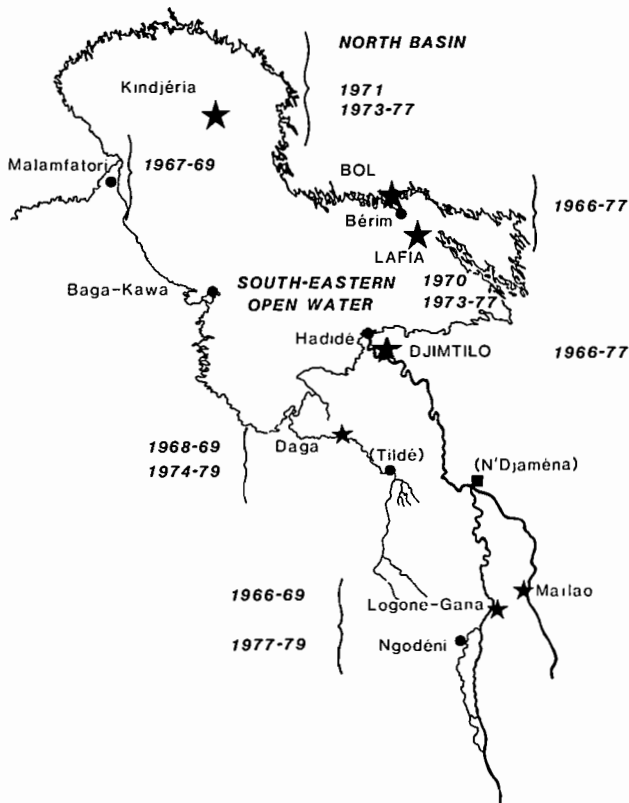


Fig. 2 Sampling sites and periods.

★ = main stations;
● = occasional surveys.

10.1.3 *The triangular nets of the El Beid*

The traditional fisheries of the El Beid were based on the use of triangular nets of the push net type inside of semi-circular frames built against the permanent dams found along the river from Tildé up to the lake (Fig. 1). Until 1970 these nets, whose opening generally measured 4 to 5 m, included some lateral bands of a medium mesh of 14 mm and a central piece from 6 to 10 mm. After 1974, the fitting on of the net became slightly different with the entire net except a frontal band being made of a small mesh (Fig. 3). It has been shown (Durand 1970) that species smaller than 50 mm were rare in the environment and that the selectivity was negligible for fish between 50 and 200 mm. This size range included the majority of standard fish lengths in the El Beid where the fisheries were based entirely on catching 3–6-month old fish leaving the flood plains for

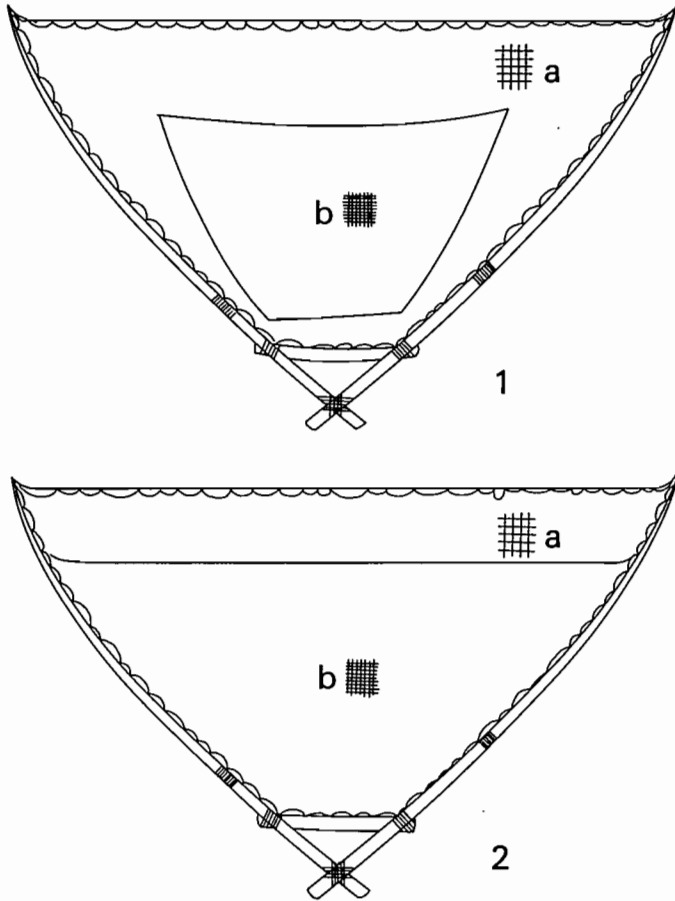


Fig. 3 Characteristics of the 'boulou' (triangular net of the El Beïd).
 1=from 1968 to 1969; 2=from 1974 to 1979; a=large mesh; b=small mesh.

Lake Chad during the flood withdrawal. Some systematic observations were made in 1968–69 and from 1974 to 1978 at the Daga station.

10.1.4 Gill nets

As a sampling method, the gill nets had a serious disadvantage as they did not permit biomass to be calculated and only gave some relative abundance indices of relatively limited size ranges. The size of the fish caught was directly related to the mesh used and this very marked selectivity was the object of several

studies. In particular, the efficiency was not independent of the mesh size (Hamley and Régier 1973) and the selectivity curves were frequently far from the normal curves (Bénech 1975; Durand 1978).

Practically however, gill nets had a very considerable advantage because they could be set in all the lake environments and also used as drift nets in rivers outside the period of high water. It also appeared to be a technique familiar to all the fishermen of the region.

Before 1971, two fisheries corresponding to two types of meshes coexisted: large mesh gill nets (GN 80 to 130)* — used in the rivers at the subsidence and in the north basin throughout the year — and average mesh gill nets (GN 25 to 30). The latter mostly caught *Alestes* (*A. baremoze* and *A. dentex*) along with some medium sized species. The large mesh nets caught adults of large species (*Lates*, *Labeo*, *Citharinus*, etc.). With the change of the aquatic environment and its exploitation (cf. Chapter 13) the size of mesh decreased in each of the fisheries respectively to 50 and 20 mm.

The absence of small mesh local nets as well as the gap between the medium and large mesh only permitted a limited study of fish populations from specific biotopes to be made. As elsewhere, the local nets were made with fine thread which made them very efficient, though fragile; therefore we chose an experimental homogenous battery including 18 nets. The most frequently used mesh were the following: 10, 12, 14, 15, 16, 18, 20, 22, 25, 30, 35, 40, 50, 60, 80, 110, 115 and 130 mm. This series was able to catch the complete range of fish sizes present in the environments sampled (with the exception of the smallest). Of course, the use of a battery of nets did not solve the difficulties due to gear selectivity, and the reservations made in the introduction remain. The results must be used with caution because the summation of the catch per unit effort did not provide a complete and accurate picture of the entire community because of gear selection and because vulnerability to the net varied with species, depending on morphology and behaviour. Nevertheless, the use of total or specific catch per unit effort for a given mesh, for spatio-temporal comparisons, remains justified and permitted the analysis of relative abundance.

10.1.5 *Sampling stations*

Figure 2 shows the various stations or the regions sampled as well as the periods of observation between 1966 and 1979. The distribution of observations was very unequal temporally as the initial objectives were oriented towards a biological study of the chosen species, at relatively modest means for the extent of the programme; on the other hand because of the change in the aquatic

* In the following text, the abbreviation 'GNx' denotes gill nets of x mm mesh bar.

environment with the drought, the collection of multi-species data in the lake and in the flooded areas became essential.

Between 1966 and 1970, the main concern was to acquire biological data. Five main stations were visited more or less regularly: Bol in the Southeastern Archipelago, Djimtilo in the Shari delta, 17 km from Lake Chad, Mailao and Logone-Gana, situated respectively on the Shari and the Logone about 60 km upstream of the confluence of N'Djamena and Daga on the El Beid in 1968–69 (Fig. 2).

The years 1971–72 constituted a second period in the collection of data. After collecting the biological data the river stations were abandoned, but a permanent team was installed for fishing at Djimtilo and in the Southeastern Archipelago at Lafia to provide continuous sampling for a fairly long period from 1971 to 1973. In 1972, the acceleration of the contraction of the lake led to an interruption of the activities of the permanent team. However, the southeastern Archipelago (Bol-Berim) and the Shari delta (Hadidé) as well as the Southeastern Open Water continued to be regularly visited. The third phase (1973–79) was characterized by the examination of the north basin during the drought, in particular at Kindjéria from 1973 to 1975, and by the revival of fishing in the El Beid at Daga from 1974 to 1979 (Fig. 2). Between 1976 and 1977 a permanent team fished at Hadidé, to compare the migratory passages in the period of the 'Lesser Chad' to those observed before the drought at the end of 'Normal Chad' (1971–72).

In addition to these base data, some surveys were made along the Cameroon border of the south basin during 1968–69, in the Southeastern Open Water during 1970 as well as at the confluence of the N'Djamena, in the flooded zones and their annexes (in particular the Logomatia from 1977 to 1979) and in the entire north basin in February 1971. The western border of the north basin was studied by H. Hopson from 1967 to 1969, from the Nigerian research station of Malamfatori, and complemented the observations made by A. J. Hopson (1964, 1968) (Fig. 2).

10.1.6 *Treatment of data*

The choice of statistical methods was related to the aims pursued, the available information and the general progress in the analytical methods in use by the ecologists. According to the goals pursued, one or another type of treatment could be preferred. It is possible to distinguish biological studies which essentially rely on parametric statistical methods and some adjustments to established models such as growth curves etc.

The study of communities increasingly calls upon descriptive statistics such as hierarchical classification and factorial analysis used from tables of distances, whether euclidian like the χ^2 or non-euclidean such as Kendall's index.

The available information was highly variable. In fact, although some samples (by number and weight) were collected very early for each of the species fished, their periodicity and reliability was linked to the aims of the observers. Thus the data collected between 1966 and 1970 were often lacking in the study of communities and the treatments were limited to the catch per unit effort by weight, more appropriate to the study of production. For the following period, however, only the c.p.u.e. in number was used thus the treatments could not be standardized for the whole period of study and did not lead to the same degree of investigation.

The change of development of statistical methods, due mainly to the popularity and increase of descriptive statistical methods, also had a role in the heterogeneity of treatments. The first studies were done essentially by hand from simple calculation methods whereas the more recent studies were based on computers and all the calculations and comparison facilities they provide.

10.2 The communities during 'Normal Chad': 1966–1971

10.2.1 *The lake*

The data for the comparison of multi-species samples were mostly obtained with the help of experimental batteries of gill nets. Thirty distinct stations were visited occasionally between 1966 and 1971 and are shown on the map in Fig. 4. Some complementary observations were made in the Southeastern Archipelago using beach seines (1966–70) and rotenone poisoning (1965–67). The distribution of the principal species will be described by separately reviewing the two basins, then by examining the total data on the richness of the populations.

10.2.1.1 *Distribution of principal species.* The degree of dissimilarity between two zones depended upon species common to both and species peculiar to each of them. The general description made here does not consider rare or accidental species. Only the species that were regularly counted in our catches were considered as they constituted most of the biomass.

For convenience, we have divided the lake into two parts, south and north on each side of the 'Great Barrier' (Fig. 1) and we have considered the major natural zones (archipelagoes, open water). Since more data were obtained from the south basin, we have carried out an initial sorting of species for this zone and then attempted to see how this was represented in the north basin.

10.2.1.1.1 *South basin.* To locate the main factors responsible for community structure in the south basin we shall first consider the results of a correspondence analysis on the results of a series of catches made in the south basin in 1964 and 1965 by the 'Centre Technique Forestier Tropical' (Durand 1973a).

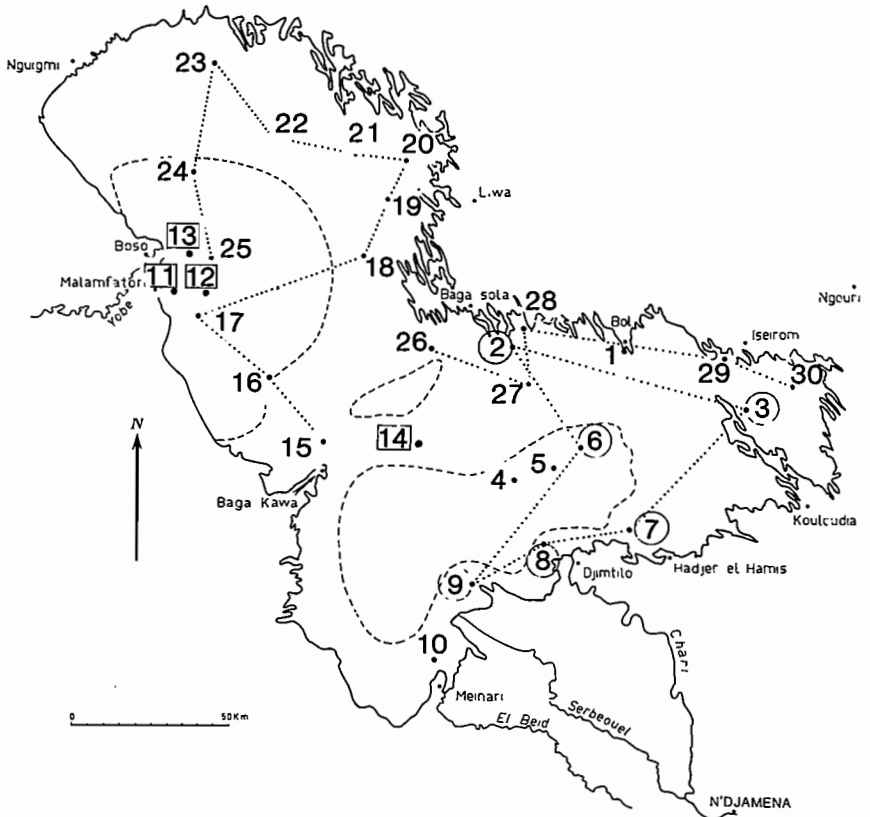


Fig. 4 Locations of the 30 fishing stations. The stations sampled by the Fishing Department of Nigeria and by the CTFT in Chad are respectively indicated with a square and a circle. The dotted line links up the homologous stations: 2, 3, 6 to 9 (CTFT, 1965) 15 to 30 (ORSTOM, January 1971), 26 to 30 (ORSTOM, May 1971).

From November 1964 to December 1965 some periodic catches were made at stations 2, 3, 6, 7, 8 and 9 (Fig. 4). The sorting was not carried out to species but to categories as follows: the Mormyridae, *Hydrocynus*, *Alestes*, *Distichodus*, the Schilbeidae, *Synodontis*, *Labeo* and *Polypterus*.

The percentage of inertia selected for the first three axes: 48.7, 20.3, and 15.8% were important and the position of points in the plane of the axes 1 and 2 was sufficiently explicit (Fig. 5). The ordination of surveys according to axis 1 was in close correlation with the relative abundance of *Alestes*; axis 2 separated the surveys according to the relative importance of *Hydrocynus* on the one hand and of the Schilbeidae on the other. Thus there was a triangular classification: *Alestes*/*Hydrocynus*/Schilbeidae.

The classification of samples led to a grouping of stations in pairs: stations 2

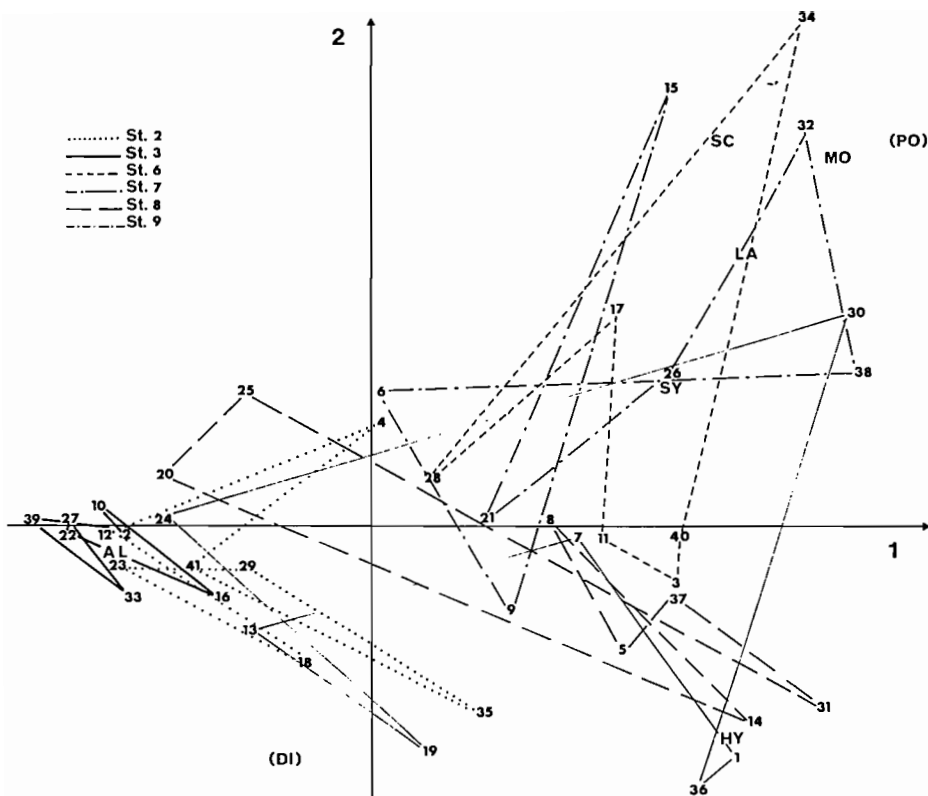


Fig. 5 Correspondence analysis on species and sampled sites (GN 30 in 1965; stations 2, 3 and 6 to 9). Projection in the plane of axes 1 and 2.

AL = *Alestes*; (DI) = *Distichodus* (rare); HY = *Hydrocynus*; LA = *Labeo*; MO = *Mormyridae*; (PO) = *Polypterus* (rare); SC = *Schilbeidae*; SY = *Synodontis*.

and 3 where the preponderance of *Alestes* was well marked (43 to 99% of total catch); stations 6 and 9 where *Alestes* was never dominant and where communities fluctuated through the year. Stations 7 and 8 were composite with the *Schilbeidae* and not very important and *Hydrocynus* dominant or, sometimes, *Alestes*.

Two points emerged from this analysis: the pairs of stations defined above corresponded to regions of the lake: archipelago (2 and 3), reed islands and open water (6 and 9), deltaic limits (7 and 8). One or two characteristic species were associated with each of these pairs, respectively, *Alestes* (probably *A. baremoze*) for the archipelago, *Schilbeidae* for the reed islands and open water, *Alestes* and *Hydrocynus* (certainly *H. forskalii*) near the delta.

It must be emphasized that seasonal variations were particularly notable and

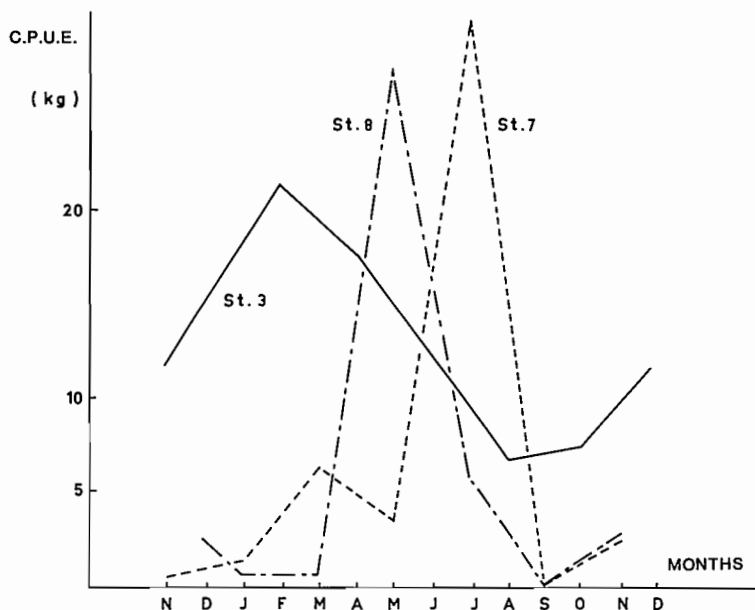


Fig. 6 Seasonal variations in c.p.u.e (GN 30; $\text{kg } 100 \text{ m}^{-2} \text{ night}^{-1}$) of *Alestes baremoze* in Shari delta (station 7 and 8) and in the Southeastern Archipelago (station 3).

that every definition of zonations must consider yearly fluctuations. The *Alestes* example was instructive in this respect (Fig. 6). The migration of these fish takes them towards the fluvial system at the time of reproduction and this explains the predominance of *Alestes* in May and July at stations 7 and 8 which were characterized by the permanent presence of *Hydrocynus*.

A. Communities and environments

To specify the relationships between communities and the major types of lacustrine environment presented in the preceding analysis, it is preferable to return to the experimental data that we collected between 1966 and 1971 in the south basin of the lake.

The communities of this zone were described by three series of data from: the Cameroon coast in the south of the basin during 1968 (station 10); Southeastern Open Water in 1970 (station 4 and 5); Southeastern Archipelago at Bol from 1966 to 1969 (station 1). So as not to attach illusory significance to the very heterogeneous data (obtained during various annual cycles and at different seasons), the data on c.p.u.e. were regrouped to provide a table of the species present in each of these zones with total abundance. We have therefore gathered in Table 1 the values found (from 7 to 14 GN following the zones) in

Table 1 Catch per unit effort (decagrams $100 \text{ m}^{-2} \text{ night}^{-1}$) for the main species caught in the south basin between 1966 and 1970. S=GN 10 to 16; M=GN 20 to 40; L=GN 50 to 100. South shore= station 10 in 1968 (cf. Fig. 4); open water= stations 4 and 5 in 1970; archipelago= station 1 from 1966 to 1969. The thick frames outline the group of species characteristic of a zone. Hatching represents the species that are missing or not characteristic.

	South shore			Open water			Archipelago			
	S	M	L	S	M	L	S	M	L	
Ubiquitous species	<i>Hydrocynus forskalii</i>	11	99	4	16	117	23	4	56	50
	<i>Eutropius niloticus</i>	21	38		29	69	3	95	46	*
	<i>Lates niloticus</i>	3	21	81	*	1	116	*	14	57
	<i>Hydrocynus brevis</i>	*	10	23	*	5	35		2	16
	<i>Synodontis schall</i>	2	9	*	3	10	16		13	15
	<i>Labeo senegalensis</i>	1	5	14	11	2	16	1	2	13
	<i>Distichodus rostratus</i>	3	22	51	13	4	26	3	8	35
	<i>Pollimyrus isidori</i>	9	*		3			5		
	<i>Schilbe uranoscopus</i>	10	56	4	2	78	32	1	17	1
	Characteristic species	<i>Labeo coubie</i>	/	*	/	*	*	28	/	/
<i>Citharinus distichodoïdes</i>		/	/	*		*	24	/	/	/
<i>Synodontis clarias</i>		/	*	/	4	8	5	/	/	/
<i>Bagrus bayad</i>		/	*	/		1	17			**
<i>Citharinus citharus</i>		*	*	*	*	*	15			**
<i>Hyperopisus bebe</i>		/	12	3		4	12	*	2	28
<i>Hemisynodontis membranaceus</i>		/	*	/	2	4	43			**
<i>Brachysynodontis batensoda</i>		*	*	/	2	5	4	3	45	2
<i>Marcusenius cyprinoides</i>		*	19	/	*	*	/		5	*
<i>Petrocephalus bane</i>		1	7	/	*	*	/	*	16	
<i>Alestes dentex</i>		2	24	1	1	4	/	1	12	1
<i>Alestes baremoze</i>		2	68		11	30	*	25	153	1
<i>Heterotis niloticus</i>			*	69	/	/	*			**
<i>Synodontis frontosus</i>		1	14	6	/	*	/	1	22	33
<i>Polypterus bichir</i>		3	63	46	/	/	*		5	42
<i>Chrysichthys auratus</i>		*	8	*	/	*	/	*	6	
<i>Ichthyborus besse</i>		9	*	/	/	/	/	/	/	/
<i>Siluranodon auritus</i>		6		/	/	/	/	/	/	/
<i>Polypterus senegalus</i>		1	17	/	/	/	/	/	/	/
<i>Tetraodon fahaka</i>			2	46	/	/	*	/	/	/
Mean c.p.u.e.	95	540	423	102	353	458	137	437	312	
N	4281	6088	400	9381	5904	946	8101	11 931	515	
f	47	104	70	64	92	80	43	111	34	

* corresponds to catch per unit effort $\leq 5 \text{ g m}^{-2} \text{ night}^{-1}$.

** large sized species common in the archipelago and not represented due to the absence of large mesh (only GN 50).

three groups*: small mesh GN (10 to 16), medium mesh GN (20 to 40), large mesh GN (50 to 100). These three categories corresponded fairly well to some characteristic size groups: the small mesh caught the adults of small sized species and some young of mostly medium or large sized species, the medium meshes, the adults of medium size (standard length 25 to 40 cm), and the large mesh, the adults of large sized species. Each of the columns of Table 1 was obtained by calculating the arithmetic mean of c.p.u.e. from nets in each category. The total number of fish caught (N) and the corresponding fishing effort (f) at the base of the columns provide a comparison of abundance. Some species that were not caught by the gill nets are not mentioned in Table 1 but taken into consideration from observations obtained by other fishing gear.

The distinction of three sub-regions within the south basin established by factorial analysis was confirmed by the distribution of species established from their abundance and/or their scarcity (their complete absence) in each of the major zones in this region of the lake (Table 1): the archipelago, the open water and the southern portion of the south basin.

B. Ubiquitous and characteristic species

(a) Ubiquitous species

Three species were very abundant everywhere: *Hydrocynus forskalii*, *Eutropius niloticus* and *Lates niloticus*. Four other common ones were associated with these: *Hydrocynus brevis*, *Synodontis schall*, *Labeo senegalensis* and *Distichodus rostratus*.

The ecophases of these species were not equally represented in all the environments: the young *Lates* were found especially along the southern coast (st. 7, 8 and 9); the young *H. forskalii* were less frequent in the archipelago, whereas the young *H. brevis* were not common anywhere. The young of *D. rostratus* and *Labeo senegalensis* were more particularly caught in the open water in October, (st. 5) probably an index of migratory activity.

The case of *Eutropius niloticus* is probably more complex since some individuals of all ages were caught at all stations. There appeared to be a particular abundance of small sized individuals in the region of the reed islands with a c.p.u.e. higher than 4 kg in May 1966 north of station 6. This distribution probably uncovers two distinct groups differing in size at the first reproduction and egg-laying season.

Three of the most common ubiquitous species (the two *Hydrocynus* and *Lates*) were strictly ichthyophagous and the stomach contents of these predators from all regions often contained *Micralestes acutidens* (Lauzanne 1977). This very small sized species (45 mm standard length) was thus also ubiquitous.

* Detail of species c.p.u.e. are found in Carmouze et al. (1972). These c.p.u.e. themselves were calculated from previously published raw data (Durand et al. 1972).



Photo 14 An electrified front trawl, experimented in Lake Chad.



Photo 15 Boats used by fishermen: dugout canoes and papyrus canoes.

(b) Characteristic species

South of the lake. Three species were caught in this region exclusively: *Ichthyborus besse*, *Siluranodon auritus* and *Polypterus senegalus*. *Tetraodon fahaka* was also common in this region along with young *Schilbe uranoscopus* and *Hyperopisus bebe*. However the adults of this last species were very rare in this region, with three species being found only occasionally: *Bagrus bayad*, *Citharinus citharus* and *Hemisyndontis membranaceus*.

The open water. During the period of 'Normal Chad' there did not appear to be any species that were exclusively associated with the open water; however three species appeared to frequent this zone: *Labeo coubie*, *Citharinus distichodoides* and *Synodontis clarias*. The importance of the large sized *Hemisyndontis membranaceus* is shown. Although a small sized species, *Alestes dageti* had been found occasionally in other regions; it should be noted here that this zooplanktophagous Characidae was especially abundant in the open water as well as the stomach contents of predators (Lauzanne 1977). In contrast, the species absent from the open water were more numerous: all the *Sarotherodon* species (*S. niloticus*, *S. aureus*, *S. galilaeus*) and *T. zillii* which were common in all the regions of the archipelago and vegetation banks (caught by beach seines and poisoning); and another Cichlid of small size, *Haplochromis bloyeti*, dominant in all the vegetation banks of the south basin and in the stomachs of *Lates* (Lauzanne 1977).

Eight species were common south of the lake and in the archipelago, and accidental or rare in the open water (Table 1): *Marcusenius cyprinoides*, *Petrocephalus bane*, *Alestes dentex* and *Heterotis niloticus* (only adults of these four species were present); *Synodontis frontosus* and *Polypterus bichir* (young present especially in the south); *Chrysichthys auratus* and *Alestes macrolepidotus*.

Alestes baremoze must also be associated with this group because this zooplanktophagous species was very abundant especially in the zones of reed-islands and the archipelago. Its presence in the open water (Table 1) corresponded to seasonal migrations.

Other species absent from the open water were small sized species only found in the sheltered zones and the vegetation banks. This was particularly true of *Barbus* (especially *B. pleuropholis*, *B. callipterus* and *B. leonensis*) very common in the archipelago (Loubens 1969) and in the stomachs of predators (mainly *Hydrocynus forskalii*) (Lauzanne 1977).

Archipelago. No species were exclusive to this region. However the zooplanktophage *Brachysynodontis batensoda* appeared to develop particularly in the Southeastern Archipelago.

Few species were abundant in the southern part of the lake and the open water, and absent or rare in the archipelago. In spite of its significant importance in the archipelago, *Schilbe uranoscopus* can be associated with this group because of its particular abundance in the open water and southern part of the lake; the young were found especially near the Cameroonian shore.

10.2.1.1.2 *North basin*. Two series of data can be used here: some surveys of experimental fishing carried out initially in all environments of the north basin in January 1971 (stations 15 to 25, Fig. 4); the analysis of the unloading done by fishermen at Malamfatori and Baga-Kawa from 1968 to 1971 for the 90 to 100 GN set in the open water and in the border of reed islands (Durand 1973b).

Three species that were ubiquitous and abundant in the south of the lake, *Lates niloticus*, *Hydrocynus forskalii* and *Eutropius niloticus* were again found in the north but with some differences in distribution. *H. forskalii* and *E. niloticus* were caught in notable quantities at stations 15, 16 and 24 in the region of reed islands. *Lates* was the only large sized fish caught in all the lacustrine environments. Three of the four other ubiquitous species were found in the north: *Distichodus rostratus* and *Labeo senegalensis*, at least in the open water, and *Synodontis schall* everywhere. The presence of *D. rostratus* is explained by the seasonal migratory pathways (Hopson 1968). *Alestes dageti* was also common in all fishing environments at all the stations in January 1971, and was an important component of stomach contents of *Lates* in the open water (Hopson 1968; stations 11 and 12).

The large mesh nets of the north basin fisheries (90 and 100 GN) caught the large individuals of a dozen species in the open water and in the region of reed islands. The precise origin of the fish cannot be determined from the data obtained. The unloading, at Malamfatori and Baga-Kawa respectively (stations 13 and 14 of Fig. 4), had a very similar composition (Table 2). Four species clearly dominated all the catches: *Lates niloticus*, *Heterotis niloticus*, *Citharinus citharus* and *C. distichodoides* always represented more than 90% of the total catch. *Distichodus rostratus*, *Bagrus bayad*, and *Labeo* (especially *L. coubie*) were next, while *Hemisynodontis membranaceus* was much less common than in the open water of the south basin.

From the January 1971 surveys and these relatively few data, two groups of species could be distinguished: species characteristic of the southern region found in the north with an analogous distribution and those which did not have a distribution homologous with those of the south. Thus *Alestes baremoze* had exactly the same distribution as in the south basin at the same time of the year. It was absent from the open water and the adults were found in the zones of reed islands, while the young and adults were present in the Northeastern archipelago (st. 18 to 23). The densities were exceptionally high: c.p.u.e. between 5.7 and 9.5 kg (25 to 35 GN) at stations 20 to 22. The *Tilapia* and *Sarotherodon* also appeared to be very abundant in all zones of reed islands and the archipelago along with *Heterotis niloticus*. The less common *Synodontis frontosus* appeared to be caught everywhere in these sheltered zones.

Several species appeared to have a different distribution in the north. *Hemisynodontis membranaceus* has already been shown to be less abundant. Similarly, *Brachysynodontis batensoda* was found in the south of the northern region, without being very abundant, and practically absent elsewhere. *Schilbe*

Table 2 Mean annual species composition (%) for the unloading at Baga-Kawa and Malamfatori (GN 90 to 100). f indicates the total fishing effort (100 m⁻² night⁻¹)

Species	Malamfatori		Baga-Kawa	
	1968	1969	1968	1970
<i>Lates niloticus</i>	38.1	48.2	36.5	36.5
<i>Heterotis niloticus</i>	18.8	14.1	24.6	14.4
<i>Citharinus</i> spp	29.1	22.1	23.8	30.8
<i>Distichodus rostratus</i>	3.7	6.3	5.3	6.6
<i>Labeo</i> spp.	5.1	3.3	2.9	3.1
<i>Bagrus bayad</i>	0.6	0.7	1.8	3.2
<i>Hemisynodontis membranaceus</i>	0.7	0.1	*	0.7
Others	3.9	5.2	5.1	4.7
Total c.p.u.e. (kg 100 m ⁻² night ⁻¹)	1.460	1.150	2.400	0.740
f	20 120	38 520	16 580	7800

uranoscopus was abundant in the two reed island stations (15 and 16), rare in the open water (st. 17 and 25) and totally absent from stations 18 to 24. This was also true of several Mormyrid species: *Pollimyrus isidori* abundant at stations 15 and 16, absent from station 18 to 25, *Petrocephalus bane*, *Marcusenius cyprinoides*, *Hyperopisus bebe*.

10.2.1.1.3 *The medium sized species (GN 30) in the whole lake.* In order to cross-check and complete this report we have attempted a more total and systematic analysis with the help of multifactorial analysis (Durand 1973a). This analysis was carried out on a systematic list of 32 species found in 42 surveys carried out between 1966 and 1971 at station 1, 4, 5 and 15 to 30 with GN 30 (Fig. 4).

Because of the great heterogeneity of the surveys and a higher species richness, the direct interpretation of results was less easy than in the preceding case. The first two axes alone corresponded to 23.9 and 20.5% of the total inertia extracted and a third (13.0%) must also be considered.

In the plane of the first two axes and of axes 1 and 3 the Southeastern Archipelago and the Northeastern Archipelago were close; the characteristic species was *Alestes baremoze*, *A. dentex* being secondary. In contrast, three other series of samples, reed islands and Northern Open Waters, southern coast of the lake (st. 10), Southeastern Open Waters (st. 4 and 5) were close and in the plane of axes 1 and 2, the projection in the plane of axes 1 and 3 separated the

southern coast from two others. *Schilbe uranoscopus* and to a lesser degree, *Eutropius niloticus* were characteristic species of the Northern and Southern Open Water and *Polypterus bichir* was characteristic of the southern coast.

The interpretation involved several distinct sources of variation.

1. The zones of the lake differed, particularly the archipelagos and the open water zones. The individuality of the southern coast was shown (st. 10) by the presence of *Polypterus bichir* but also by some members of the fluvial fauna which were only found here, and were of major importance (*Mormyrus hasselquisti*, *Auchenoglanis biscutatus*, *Synodontis nigrita* ...).

2. Seasonal variations were also evident in the Southeastern Archipelago (st. 1): from 1966 to 1969 the surveys of the first six months form a homogenous group where *A. baremoze* dominated. In contrast, those of the second half of the year were mixed and gave the impression of reflecting some unstable situation, when a variety of species (*Synodontis frontosus*, *Brachysynodontis batensoda* ...) could be dominant.

3. The annual variations could be considerable here too and we will return to this aspect in the general conclusions. We simply emphasize here that there was some instability even in the absence of major events such as the drought of 1972 and following years. The exploitation of stocks by man could play an important role, as in the scarcity of *Labeo coubie* in the north basin of the lake between 1963 and 1968. But an intrinsic variability could be linked to some successions and long-term replacements such as of *Schilbe mystus* by *S. uranoscopus* (Mok 1975).

10.2.1.2 *Richness of the communities.* The number of species caught in comparable samples was of interest in the study of fish communities. In order to make valid comparisons it was necessary that the fishing gear and its use were identical. Thus the usable data in Lake Chad were obtained by experimental gill nets, particularly from the north of the lake in January 1971 (st. 15 to 25) and from the Southeastern Archipelago in May (st. 26 to 30).

The total number of species caught in one night by the batteries used (10 to 60 GN) varied between 9 and 22 for the north basin of the lake and between 17 and 33 for the Southeastern Archipelago (Fig. 7). The considerable variations were verified for each mesh as well as for the whole group. In the Southeastern Archipelago, stations 26, 27 and 28 were comparably rich with about 30 species whereas more to the east, only 23 species were found at station 29 and only 17 at station 30 or almost less than half the number at station 26. This last was a station of reed islands whereas the five others were poverty of the eastern zone. On the other hand, conductivity values (Fig. 7) increased, passing east, from 120 to 180 $\mu\text{S cm}^{-1}$ at stations 26 to 28 to 240 (st. 29) then 450 μS (st. 30). It thus appeared that the species paucity increased from west to east on a par with the increase of conductivity.

In the north of the lake the three southern stations were clearly richer than all

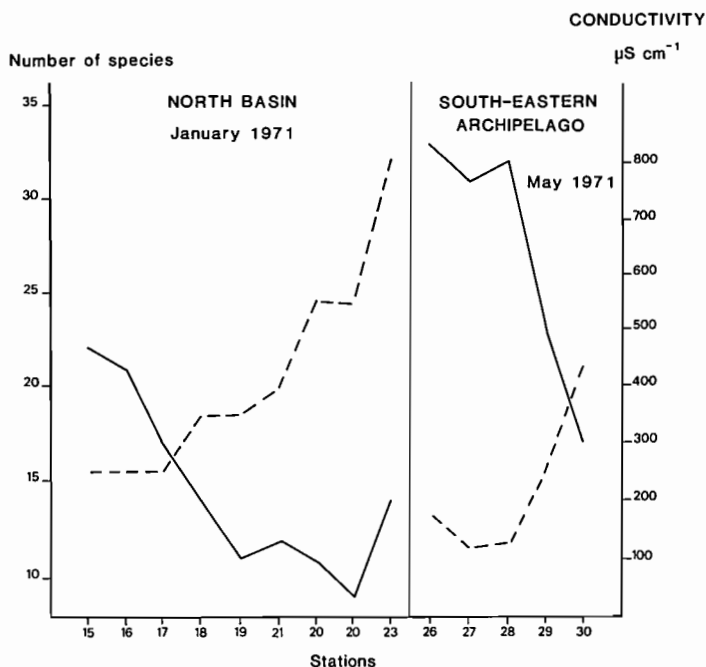


Fig. 7 Number of species caught in the same set of gill nets (GN 10 to 130; continuous line) and for the same fishing effort in different stations ordered according to increasing conductivity (dashed line).

the others, with an average of more than 20 species being caught (not all the small mesh GN were fished at station 17) whereas the other stations were poor or very poor (14 to 9 species). The richest stations were those where the conductivity showed the smallest increase and the stations of the Northeastern Archipelago were the poorest. Several species of Mormyridae were not found in the north of the lake (above 3 to 400 $\mu\text{S cm}^{-1}$) to the same extent as in the Southeastern Archipelago, independent of the zone type.

The richness of the north could not be directly compared with the Southeastern Archipelago of the lake as the fishing effort was only half that in the latter region. The difference was thus probably underestimated and the Southeastern Archipelago was probably richer than the entire north basin. For the same zone the difference remains considerable between the north and the south, with 17 to 31 species found in the archipelago compared with 9 to 12 in the northeast: 34 species in the Southeastern Reed Islands and 21–22 in those of the north.

In other stations of the south basin where systematic sorting was complete, the classification as a function of conductivity (low in all cases; less than 100 $\mu\text{S cm}^{-1}$ at stations 4, 5, 10 and about 150 at station 1) could not be made. As a

whole, the Southeastern Archipelago was richer than the Southeastern Open Water, but the southern coast (st. 10) with a total of 62 species was by far the richest in the entire lake.

10.2.2 *The rivers and their temporary annexes*

Some data are available for three distinct zones: the region of the Shari delta, the riverine environments and the temporarily flooded environments.

10.2.2.1 *The deltaic zone.* The delta region consisted of two main branches of the Shari rejoining near Djimtilo, the village chosen for the initial experimental fishing (Fig. 2). It was not possible to poison fish in this zone because there was no zone of calm waters. However, it was possible to use the beach seine at low water but this could be done only after 1971, and thus the only data obtained were from gill nets. The nets were also subdivided into three main categories: small, medium and large mesh.

(a) Small sized mesh

Gill nets (10 to 16 GN) were used from March 1971 to December 1972 and the corresponding mean c.p.u.e. regrouped by period from 3 to 4 months are gathered in Table 3. The catch by weight was always low. Initially this corresponded to less efficient fishing (relatively thick thread for the small mesh nets set close to the banks) but was also probably related to the scarcity of fish vulnerable to the 10–16 mm mesh. Whatever it was, these fisheries provided useful qualitative results, at least until July/August 1972 as the major perturbation of the very low flood of 1972 commenced in August/September.

Of the 43 species caught at least once over these 16 months, 18 are recorded in Table 3. It only considers the normal catches per mesh size and not the fish whose size is shown without comparison with the mesh of the net. For example, *Schilbe* and *Synodontis* which were caught by their thorny spines, were eliminated after being caught.

Five species appeared to be common in all the surveys: *Schilbe uranoscopus*, *Eutropius niloticus*, two *Polypterus* species (*P. senegalus* and *P. bichir*) and *Hydrocynus forskalii*. Two other species, *Petrocephalus bane* and *Brachysynodontis batensoda* showed significant variations in abundance.

The transitory character of the delta zone was conclusively shown by the presence of *Alestes dageti*, the only endemic species of the lake and *Alestes nurse* and *Ichthyborus*, riverine species caught only in the southernmost region of the south basin of the lake (cf. Section 2.1.1.1).

(b) Medium sized mesh

Two series of data exist for these nets: those obtained when the experimental fishing was with GN 30 drift nets in 1966 and 1967 and those gathered for the

Table 3 Mean catch per unit effort (g 100 m⁻² night⁻¹) for the small mesh fixed gill nets (GN 10 to 16) at Djimtilo (Shari delta) between April 1971 and November 1972.

Species	1971		1972			T	%
	4-7	10-12	1-3	6-8	9-11		
<i>Marcusenius cyprinoides</i> ^a	*	4	*	*	3	1	0.6
<i>Petrocephalus bane</i>	2	3	10	28	2	9	5.2
<i>Pollimyrus isidori</i>	1	1	3	12	*	3	1.7
<i>Hydrocynus forskalii</i>	11	4	7	12	9	9	5.2
<i>Alestes baremoze</i>	12	4	4	3	*	5	2.9
<i>Alestes macrolepidotus</i>	*		1	10	3	3	1.7
<i>Alestes nurse</i>	4	5	10	5	2	5	2.9
<i>Alestes dageti</i>	20	*	1	3		5	2.9
<i>Ichthyborus besse</i>	1	2	5	5	1	3	1.7
<i>Distichodus rostratus</i>	2	8	2	8	1	4	2.3
<i>Chrysichthys auratus</i>	3	1	7	16	2	6	3.5
<i>Schilbe uranoscopus</i>	27	27	25	34	7	24	14.0
<i>Eutropius niloticus</i>	20	40	15	16	18	22	12.7
<i>Brachysynodontis batensoda</i>	1	4		6	74	17	9.8
<i>Synodontis schall</i>	1	1	6	9	5	4	2.3
<i>Lates niloticus</i>	2	16	9	4		6	3.5
<i>Polypterus senegalus</i>	1	4	23	41	12	16	9.2
<i>Polypterus bichir</i>		16	4	20	46	17	9.8
Others	2	21	23	9	13	14	8.1
total c.p.u.e.	110	161	155	241	198	173	100.0
f (nights 100 m ⁻²)	222	72	128	139	152		713

^a The systematic order adopted by Blache (1964) is followed for the species list of Tables 3, 4 and 5.

local fisheries (drift and fixed GN 25 to 32) between July 1971 and August 1972 (Loubens 1973). The corresponding total results are shown in Table 4 for the species representing at least 1% of the c.p.u.e. by weight in one of the data series considered.

During 1966-67, the pelagic community of the delta rivers was dominated by two species which represented together nearly 90% of the catches: *Alestes baremoze* and *Hydrocynus forskalii*. *Alestes dentex* appeared secondarily as well as the two common Schilbeidae, *Eutropius niloticus* and *Schilbe uranoscopus*. The 1971-72 data confirmed the predominance of *Alestes baremoze*; however *H. forskalii* was less abundant whereas *A. dentex* and *S. uranoscopus* appeared more abundant.

Table 4 Relative composition by weight (%) of catches in 1967–1968 (experimental GN 30) and in 1971–1972 for the delta fisheries (after Loubens 1973).

Species	1966–1967	1971–1972			
	(Exp.)	(Local fisheries)			
	GN 30 Drifting	GN 25–32		GN 50–120 Drifting	Lines
		Drifting	Fixed		
<i>Hyperopisus bebe</i>	*	1.6	0.2	0.7	18.1
<i>Mormyrus rume</i>			0.1	2.4	21.5
<i>Hydrocynus forskalii</i>	28.6	2.6	1.3		
<i>Hydrocynus brevis</i>	0.4	0.3		4.2	
<i>Alestes dentex</i>	5.8	14.2	5.3		
<i>Alestes baremoze</i>	59.5	63.3	50.7		
<i>Citharinus citharus</i>				14.2	
<i>Citharinus latus</i>				5.7	
<i>Distichodus rostratus</i>				23.6	
<i>Labeo senegalensis</i>		0.2	0.8	7.3	
<i>Bagrus bayad</i>				0.7	8.5
<i>Schilbe uranoscopus</i>	2.0	14.0	25.9		3.2
<i>Eutropius niloticus</i>	2.7	0.8	0.9		
<i>Brachysynodontis batensoda</i>	0.1	0.9	11.1		3.2
<i>Hemisynodontis membranaceus</i>		0.2	0.1	36.7	1.7
<i>Synodontis schall</i>		0.3	1.6		31.5
<i>Polypterus bichir</i>	0.1	0.3	1.8	2.2	7.0
Others	0.8	1.3	0.2	2.3	5.3
Mean c.p.u.e. ^a	3.63	3.96	4.86	4.08	8.04
Total f (surveys) ^a	40	786	194	219	84

^a c.p.u.e. in kg hour⁻¹ or night 100 m⁻² of GN; in kg 1000 hooks⁻¹ day⁻¹ for the lines. Effort in hours (drifting GN), nights (fixed GN) or days of fishing (lines).

The view of the community obtained from local nets used as fixed nets (only partial because they were only set February to June 1972) was similar to that described above (Table 4): always more than 50% of *Alestes baremoze* and then a notable abundance of *Schilbe uranoscopus*. The same accompanying species appeared the only difference being the 11% of *Brachysynodontis batensoda* in the fixed GN.

The mean c.p.u.e. values showed some very important seasonal variations with the maximum for the medium mesh fixed nets occurring at the end of the withdrawal and at the beginning of the flood (June to August). The comparison

of values at 5-year intervals shows a very probable lowering of fishing yield. The parallel trials of experimental GN 30 and local nets of equivalent mesh showed that the latter, made with much finer thread, caught on average, 2 to 3 times more than the experimental nets. It is thus likely that the local nets caught between 7 and 11 kg 100 m⁻² night⁻¹ in 1966–67 as compared with the mean c.p.u.e. of about 4 kg in 1971–72.

(c) Large sized mesh

The only data evaluating the importance of large sized fish are those of Loubens (1973) and of the non-baited multiple hook lines (Table 4). The large mesh drift GN (50–120) caught three species in particular, in the following order; *Hemisynodontis membranaceus*, *Distichodus rostratus*, *Citharinus citharus*, followed by *Labeo senegalensis*, *Citharinus latus* and *Hydrocynus brevis*. The comparison with the lines was instructive because it illustrated the problems of sampling: the three species caught most often with hooks were rare (*Hyperopisus bebe*, *Mormyrus rume*) or absent (*Synodontis schall*) in the 50 to 120 mm gill nets (Table 4). The behaviour of non-baited hooks, the random catches and the differences in composition also partly reflected the heterogeneity of the community as the species caught by the lines were characteristically benthic that is linked to the research on nutrition.

In this example there were thus two complementary fisheries. The catches in the delta fisheries would probably have provided a clear picture of the communities in the reaches containing exploited stages (Loubens 1973).

10.2.2.2 *The rivers.* The Mailao station on the Shari, and the Logone-Gana on the Logone were both situated far upstream of the confluence (Fig. 2) and were only visited at the beginning of the surveys (especially 1966–67). As in the delta, the fixed and drift gill nets supplied the basis of the experimental samples in the absence of active local fisheries. There was also some fishing by beach seines during low water (April to August) and some poisoning in a secondary arm of the Shari.

The main results of the experimental fishing practised in the Shari at Mailao are shown in Table 5. Only the most common species (at least 1% of the c.p.u.e. by weight of one series) were retained. The catches from nets of similar mesh were combined when the sampling effort was insufficient.

In the drift GN 30 a very marked predominance of *Alestes baremoze* was found forming nearly 60% of the total weight caught, a value comparable with that obtained in the delta in 1966–67 and 1971–72. The next two most common species were *Hydrocynus forskalii* (15.7%) and *Eutropius niloticus* (14.6%). Only three other species exceed 1% of the c.p.u.e.: *Schilbe uranoscopus*, *Alestes dentex* and *Petrocephalus bane*. The presence of *Synodontis nigrita*, *Polypterus endlicheri* and *Alestes nurse* was confirmed by the fixed nets and appeared to be

characteristic of the river surveys, as these species were generally not found in the delta.

If all the fixed nets of medium mesh are considered, the total view was fundamentally the same as the preceding one; however there was the lesser importance of *A. baremoze* (26.4%) and greater diversity: 16 species compared with 6 in the drift GN 30 which approached or exceeded 1% of the total c.p.u.e. Among the latter, *Hyperopisus bebe*, *Marcusenius cyprinoides* and *Brachysynodontis batensoda* appeared (confirming that *B. batensoda* normally zooplanktophagous can adopt a very different trophic behaviour in its feeding when close to the bottom, Lauzanne 1977). The importance of *Polypterus bichir* (10% of c.p.u.e. from fixed GN 20 to 40) and the presence of *Synodontis sorex*, confirmed by fishing at GN 50, should also be noted.

The largest mesh nets and the seine also provided some complementary information. The three species of *Citharinus* dominated the catches in the GN 60 to 100 (60%) and in the beach seine (41%). The presence of *C. latus* which is classed among the characteristic river species has already been noted in the delta. We then found the two *Labeo* and the two *Distichodus* species: *L. coubie* and *D. brevipinnis* which were as common as *L. senegalensis* and *D. rostratus* which were normally dominant. *Lates niloticus* was also common as well as *Synodontis* cf. *schall* (22% of c.p.u.e. in the GN 50). For the first time *Campylomormyrus tamandua* was caught and in notable quantities: 4.7% of c.p.u.e. of GN 50. Finally the abundance of *Heterotis niloticus* and of *Sarotherodon galilaeus* in the seine fishing also illustrated the inefficiency of the gill nets for some species.

The low yields from the small sized mesh in the delta fishing corresponded initially to a limited efficiency of the fishing method and to a lesser importance by weight of small sized fish. The diversity was low and three species dominated the catches: *Eutropius niloticus* and *Hydrocynus forskalii*, confirming the general importance of these two species and also a new species *Alestes nurse*. Among the other species, the presence of *Synodontis nigrata* in the river was confirmed whereas *Petrocephalus bovei* was comparatively new to the lake and the delta.

Not all the results collected on the Logone contradict the description for the Shari and only two points are worth mentioning: the seasonal increase in diversity of catches in the small mesh GN is probably an index of the return of some river species from the flooded zones in subsidence, a phenomenon which was confirmed by the samples from the El Beid (cf. *infra*). Moreover, large adults of *Alestes dentex* which were already very common in the Shari (16% of mean c.p.u.e. from 35/40 GN) were important seasonally. The rush of these fish in the Logone corresponded to the beginning of the draining of the flooded zones of the right bank and also indicated the composition of the traditional main fishing of Logone-Gana (cf. Chapter 13). *A. dentex* generally contributed more than 3/4 of the total catches during the first week of fishing or 5 to 10

Table 5 Relative composition by weight (%) of experimental catches in the Shari at Mailao in 1966–1967 (Fi = fixed; Dr = drifting).

Species	Fi GN 10–15	Fi GN 20–25/30	Dr GN 30	Fi GN 35/40	Fi GN 50	Fi GN 60–80–100	Beach seine
<i>Heterotis niloticus</i>							8.6
<i>Hyperopisus bebe</i>		0.2		7.9	2.6		3.2
<i>Campylomormyrus tamandua</i>		0.1			4.7		0.1
<i>Marcusenius cyprinoïdes</i>		3.1	*	0.3			0.1
<i>Petrocephalus bovei</i>	2.4						
<i>Petrocephalus bane</i>	2.4	5.0	1.7	0.5			0.2
<i>Hydrocynus forskalii</i>	19.5	13.4	15.7	5.7	4.9		1.6
<i>Hydrocynus brevis</i>		0.2		0.1	1.0		2.4
<i>Alestes dentex</i>		4.5	3.3	16.0	0.6		5.8
<i>Alestes baremoze</i>	7.8	26.4	58.7	9.5			17.1
<i>Alestes nurse</i>	18.2	0.1	*				*
<i>Citharinus citharus</i>		0.2		0.4	0.7	13.1	4.6
<i>Citharinus latus</i>				3.3		3.1	7.9
<i>Citharinus distichodoïdes</i>						43.6	28.8
<i>Distichodus rostratus</i>	*	0.1			3.3	9.6	0.2
<i>Distichodus brevipinnis</i>				0.3	1.2	6.6	0.3
<i>Labeo senegalensis</i>		1.2	*		8.7	4.7	0.4
<i>Labeo coubie</i>		0.6			3.6	7.1	
<i>Chrysichthys auratus</i>	7.3	2.1	0.2	0.3			*
<i>Auchenoglanis spp.</i>				0.7	2.8	0.8	*
<i>Schilbe uranoscopus</i>	3.6	5.3	3.5	9.2	1.5		1.6
<i>Eutropius niloticus</i>	34.0	13.8	14.6	8.1	1.0		1.7
<i>Brachysynodontis batensoda</i>	3.6	0.8	0.2	15.7	13.3	0.8	0.3
<i>Hemisynodontis membranaceus</i>			*	1.6		2.9	1.2

<i>Synodontis nigrita</i>	2.4	0.9	*	0.8			
<i>Synodontis sorex</i>		0.6	*	1.1	3.9		
<i>Synodontis cf. schall</i>		0.8	0.2	2.0	22.0	1.0	0.3
<i>Lates niloticus</i>	*	2.9	0.7		12.1	5.8	5.4
<i>Sarotherodon galilaeus</i>							5.3
<i>Polypterus senegalus</i>	*	1.9		0.1			0.1
<i>Polypterus bichir</i>		11.8	*	10.4	5.3		0.2
<i>Polypterus endlicheri</i>		3.8	0.6	2.8			0.5
c.p.u.e. ^a	0.14	1.9	7.4	1.5	2.1	2.0	100.7
f ^a	27	30	31	16	23	17	50

^a Cf. Table 4 for the GN. For the c.p.u.e. in kg ha⁻¹ and effort in number of hauls.

times more than *A. baremoze*. This was inversely proportional to the numbers generally found in the lake and the rivers.

The rotenone poisoning of an intermittent arm of the Shari at Mailao confirmed the importance by weight of *Lates niloticus*, *Heterotis niloticus*, *Sarotherodon galilaeus*, *Alestes baremoze*, *A. dentex* and *A. nurse* and all the *Polypterus* species as well as *Mormyrus rume*, *Synodontis eupterus*, *Bagrus bayad*, *Tilapia zillii* and *Sarotherodon niloticus*. Among the small sized fish present in high numbers, there were some adults of small species where *Barbus* dominated: *Barbus pleuropholis*, *B. punctitaeniatus*, *B. anema*, *B. lawrae*, *B. macrops*. *Micralestes acutidens* was also generally abundant (whereas *Petersius intermedius* was found in large numbers in a pond dependent on the Logone). Several young were also caught in the intermittent arm at the subsidence: *Synodontis nigrata* and *S. eupterus*, the three *Sarotherodon* and *Tilapia* already cited, the three *Alestes* and *H. forskalii*.

Finally, particular mention must be made of the fish inhabiting oyster beds (*Aetheria elliptica*) in the lower bed of the Shari. The species composition was novel, consisting of the young of medium or large sized species which found a particularly favourable environment there (shelter, food). These young belonged to some species caught in other places near Mailao: in the river (*Synodontis* cf. *schall*, *Labeo coubie*, *Chrysichthys auratus*), or in the intermittent arm (*Synodontis eupterus*); to some rare species from other samples (*Mormyrops deliciosus*, *Malapterurus electricus*, *Synodontis courteti*, *Bagrus docmac*) and finally to some species never found elsewhere in our samples *Petrocephalus simus*, *Nannocharax fasciatus* and *Synodontis filamentosus* (Loubens 1969).

10.2.2.3 *Temporary aquatic environments.* The association of floods of an almost tropical type with a well-marked annual flood, and the very flat plains and the very low river slopes led to some overflowing and flooding of adjacent plains (cf. Chapter 2). This phenomenon which was common in the Sahelo-Sudanian zones, was particularly pronounced in the Chad basin and in its northern part, which is of interest here. In this zone, the lesser Logone was characterized at the Logomatia by some lateral outflows which flooded the north Cameroon plain of about 5000 km² in an average year. The drainage of the flood zone was carried out partially by the Logomatia and principally by the El Beid which flowed into the southernmost part of the south basin of Lake Chad (Fig. 1).

We only have some fragmentary information on the Logomatia prior to 1971. However, some data exist on the flood plain (poisoning of ponds during the dry season) and the El Beid was followed continuously during the 1968–69 flood.

10.2.2.3.1 *The North Cameroon floodplain.* The sampling efforts during the flood period were hindered by considerable growths of grasses (*Echinochloa*)

which prevented boat use. There was also a lack of fishing techniques appropriate for such an environment, where the water was generally shallow and transparent with low fish density. Without considering the indirect information supplied by the study of outflows (cf. section on El Beid) we must, therefore, be content with some limited observations on the residual ponds which remains in the depressions of the north Cameroon plain after the El Beid water flowed out completely or before it was flooded by the first rains.

The extremely heterogenous nature of these water bodies (area, depth, vegetation, distance from outflows) combined to create all types of biotopes from the small rapidly drying temporary pond to the large deep pond serving as a refuge until the following rainy season. Yet some species were constantly found: *Brienomyrus niger*, *Barbus gourmansis*, *Neolebias unifasciatus*, *Synodontis nigrita*, *Clarias* spp., *Aplocheilichthys* spp., *Epiplatys senegalensis*, *Polypterus senegalus* and *P. bichir*, *Sarotherodon* spp. and *Tilapia zillii*. The sedentary species may very grossly define the ubiquitous community of these ponds (Durand 1971).

Some other species were caught occasionally without being abundant: *Alestes baremoze* and *A. dentex*, *Distichodus rostratus* and *D. brevipinnis*, *Labeo senegalensis* and *L. coubie*, *Brachysynodontis batensoda*, *Synodontis cf. schall*. *Schilbe mystus* and *Siluranodon auritus* were caught in abundance only in a northern pond not far from the El Beid. We will see that these two species migrated slowly in the El Beid and behaved as trapped individuals which could not migrate before the end of the overflowing period.

Finally, the scarcity or absence of species whose young were very common in the El Beid fishery must be noted in these ponds, particularly *Alestes nurse*, *Hyperopisus bebe* and *Marcusenius cyprinoides*. This is surely an indication of migration in these species.

10.2.2.3.2 *The fishes of the El Beid.* The traditional fishing of the El Beid was carried out from permanent dams constructed perpendicular to the lower bed and extending into the upper bed. These dams were found all along the length of the river, from Tildé until the lake (cf. Section 1.3) with a very high mean density of 270 dams counted from aerial observations in January 1969 (Durand 1970). The fishermen stood facing upstream, immersed to hips, in adjacent bush frames extending the dam into the flood upper bed. They used a previously described triangular net, with a 4 to 5 meter opening (cf. Section 1.3). Various experiments showed that no experimental technique gave results that were efficient and less selective than the traditional nets which were therefore retained for the study. The sampling plan adapted and used at Daga (Fig. 2) has already been described elsewhere (Durand 1970).

If the catches from triangular nets are added to data from poison fishing carried out near the sampling station, the total number of species collected increased to 74, of which the 47 most common ones were kept for a quantitative analysis. Most of the species belonged to a distinct size range of small fish and

the study of corresponding ages showed that they were first year juveniles which contributed about 95% in number and weight to the fishery.

Over the course of the flood withdrawal, generally in the month of January, the fishing yields followed a significant change with a very rapid lowering followed after 15 days by a very distinct rise. This phenomenon was accompanied by an appreciative change in the species composition. A comparison of the December surveys with those of the second fortnight of January confirmed that, considering only the 22 most common species (the two rarest species only represented 1.7% of the total number), the Kendall's rank correlation coefficient only reached 0.039, a value much lower than the 0.05 significance threshold: 0.30 for 22 species. The two groups considered thus had no clear affinity. Based on the physico-chemical data this phenomenon appeared to be related to variations in conductivity which themselves reflected the relative importance of the two water bodies: the first flood due to the precipitation in July and August, and then the overflowing of the Logone (Durand 1970).

Although this explanation appears valid, it should however be pointed out that there was great variation in the behaviour of different species. Some species such as *Sarotherodon niloticus* were found at all times while others such as *Brienomyrus niger* were found at the beginning and end of the overflow. This variation in the behaviour was confirmed by the analysis of correlations between surveys and the analysis of interspecies correlations which shades the scheme presented above concerning the time change in the community (Durand 1971).

The analysis of the rank correlation matrix between the surveys showed that inside the first group, no correlation was found between distant samples. It appeared as if the first group was not stable because while retaining some of the main common features the community constantly evolves and could be arbitrarily divided into two sub-groups. The second group, on the other hand appeared more homogenous with some correlations having tendency to increase with time so that community structure appeared to stabilize at least temporarily.

This structure of the surveys corresponds to some species structures that are also fairly marked. The correlation analysis shows three homogenous basic groups of four species. The 22 other species considered in this analysis were classed by function of their average relation to each of the three groups. Figure 8 shows the three basic elements and the most characteristic species in relation to them.

These three groups were characterized essentially by the chronology of appearance of the species making them up. The first group included *Marcusenius cyprinoides*, *Hyperopisus bebe*, *Alestes dentex* and *Labeo senegalensis* whose abundance was maximum with a very distinct mode from mid-November to the end of December. Some accompanying species appeared in November before those of group I: *Alestes baremoze*, *Polypterus bichir* and secondarily *Hydro-*

cynus brevis and *Lates niloticus*. Other accompanying species of group I appeared much later, *Heterotis niloticus*, a rare species; *Distichodus rostratus* also being present in January and *Sarotherodon aureus*. Finally three species whose relations were less clear but whose maximum abundance was in the first two months were *Pollimyrus isidori*, *Distichodus brevipinnis* and *Mormyrus rume*.

Whereas group I was clearly separated from the following two, groups II and III were partially related by some intermediate species. The four species defining group II were characteristically very abundant at the end of January: *Sarotherodon galilaeus* and *Brienomyrus niger* which were relatively closer to I than *Barbus* spp. and *Clarias* spp. which were closer to group III. Two accompanying species were also found here: *Sarotherodon niloticus* and *Labeo coubie*.

Group III was the most homogenous with *Ichthyborus besse*, *Siluranodon auritus*, *Schilbe uranoscopus* and *Synodontis* cf. *schall* which were caught at the beginning of the overflow, then disappeared to reappear only in February when their maximum abundance occurred. There was one accompanying species: *Synodontis nigrita* (Fig. 8).

No clear relationship with the three groups defined above can be put forward for species that did not appear to have a very precise period of abundance. This was particularly true for *Citharinus citharus*, an isolated species; *Brachysynodontis batensoda* and *Hemisynodontis membranaceus* which with the less com-

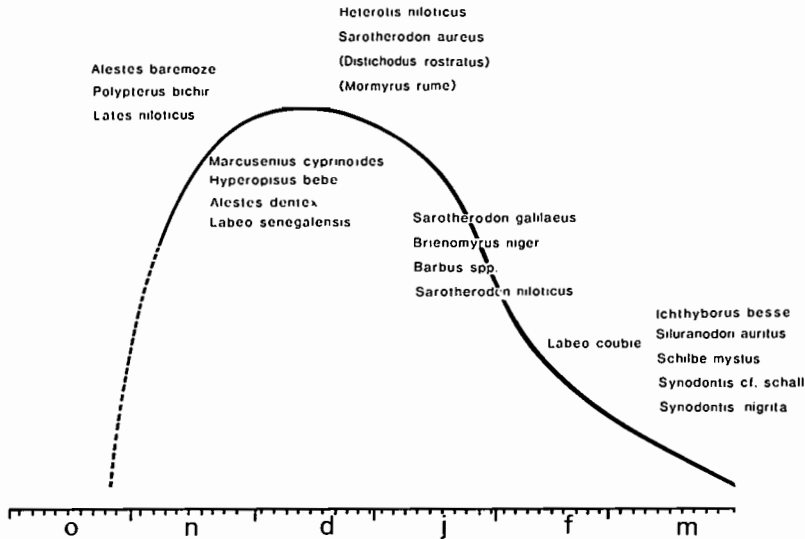


Fig. 8 Groups of migratory species observed at the Daga station (El Beïd) for the different phases of the flood.

mon *Synodontis clarias* made up a small intermediate group; *Alestes nurse*, an isolated and very abundant species which was the peculiar in being common at all times yet had a maximum abundance in the month of February. It would have been interesting to isolate the two species of *Petrocephalus*, *P. bovei* and *P. bane* but these were not separated in the sorting.

In conclusion, the study of species absence may also indirectly help with the attempted description of the communities. For example, we did not find *Xenomystus nigri* of which Blache (1964) said that in some years it could constitute most of the subsidence fisheries in December and January. This is one example of between years variability which will be discussed in the conclusions. A single individual of *Alestes dageti* was caught in four years at Daga, confirming the lacustrine endemism of this species. Finally we did not find any *Eutropius niloticus* or *Hydrocynus forskalii*, two of the most common species in all the permanent aquatic environments, observations which agree with Daget's (1954) for the Niger.

10.2.3 Zonation and cycles during 'Normal Chad'

The general description of the community undertaken here attempted to consider all the aquatic environments of the Lake Chad regions whether they were temporary or permanent, flowing or stagnant. Two major and complementary aspects were examined; the zonation inside a lacustrine system, sensu stricto, during a normal lake phase, and the part played by fluvio-lacustrine or lacustrine migrations. Combining the results led to a classification of species that considered their distribution and their more or less migratory character, both characteristics related to fairly specific ecological characters.

10.2.3.1 *Lacustrine zonation.* The distribution of species in the lake was governed by two main factors: distance from the river system and type of zone, whether open water or archipelago.

In the south basin, the ichthyofauna was most varied along the southern coast, the richness being due to contact with both a permanent (Shari) and a temporary (El Beid) river system. Three species appeared characteristic: *Ichthyborus besse*, *Siluranodon auritus* and *Polypterus senegalus*. Moreover, the young of *Hyperopisus bebe* and *Schilbe uranoscopus* were not found elsewhere in the lake. There did not appear to be any species strictly confined to the open water but on the other hand, some were absent, such as several species of Cichlidae and *Heterotis niloticus* and to a lesser extent. *Alestes baremoze* and *A. dentex*. By contrast, these species were dominant in the Southeastern Archipelago where a clear impoverishment is seen towards the east with the disappearance, for example, of Mormyridae.

In the north basin, with the exception of the southernmost part of the open

water which appeared to show a community similar to that of the Southeastern Open Water, some significant differences were found. The differences were related to progressively decreasing species diversity, towards the north east, and to a scarcity of species which were common in the south basin. Thus to the north of an approximate line Malamfatori-Baga Sola (Fig. 9) neither *Schilbe uranoscopus*, nor several species of Mormyridae (*Pollimyrus isidori*, *Petrocephalus bane*, *Marcusenius cyprinoides*) occurred. The scarcity of *Brachysynodontis batensoda* and *Hydrocynus brevis* was also to be noted.

10.2.3.2 *Fish migrations.* All the results obtained in the various environments, showed the existence of seasonal variations which corresponded to migrations of usually abundant species. These movements of entire populations were divided into two main types:

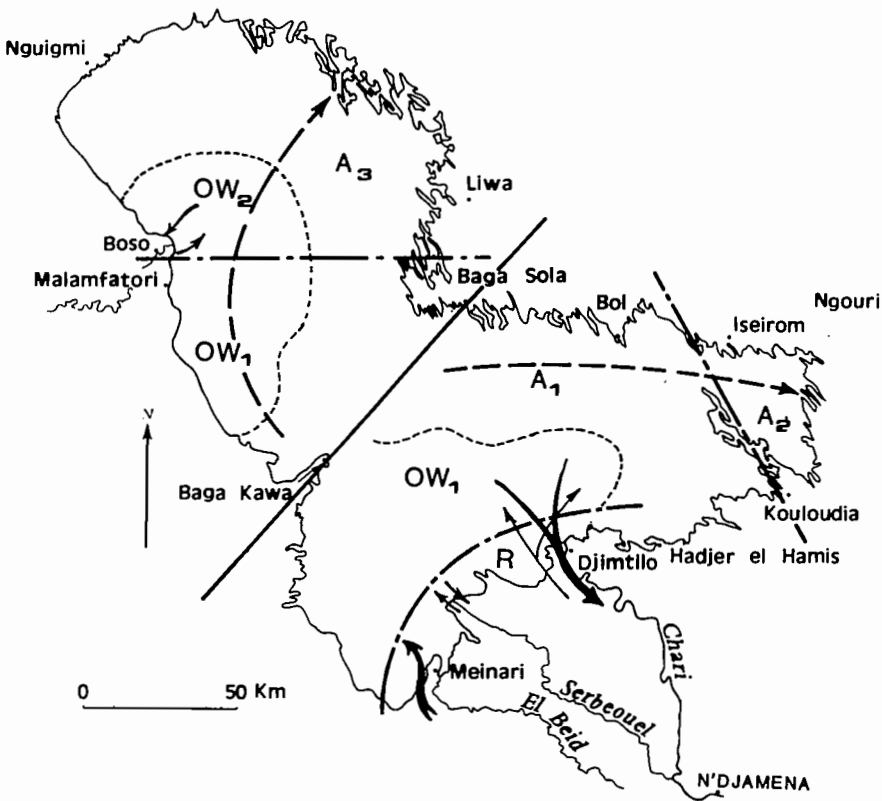


Fig. 9 Diagram of the zonation of the fish. The black arrows correspond to the different migrations observed, and dashed ones correspond to the decreasing number of species in the fish communities.

OW = Open Water; R = Rivers; A = Archipelago.

1. The longitudinal, or 'true', migrations over the course of which the fishes often covered considerable distances between the lake and the rivers or inside the river system. Most of these migrations appeared to be linked to reproduction of which the most common were anadromous migrations at the subsidence or at the beginning of the flood and a reverse migration during the flood;

2. Lateral migrations which corresponded to movements of low amplitude between the rivers and the flooded zones. The latter were invaded at the time of the flood and the fish returned in the lower bed when the flood waters receded at the time of the subsidence. The migratory cycle of *Alestes baremoze* (cf. Fig. 1, Chapter 13) is a good example of the migratory behaviour of several species of the Lake Chad region during the period of 'Normal Chad' (Durand 1978). Two populations of adults lived in the lake and more particularly in the sheltered zones of the reed islands and the archipelago. With a slight shift in time, they both made out widespread reproductive migrations which took reproducing fish to the Logomatia during July and/or August. After spawning, the adults dispersed in the upper layers and the margins of flooded zones, to set out towards the lake at the subsidence. The young fry in the Logomatia were carried away towards the flooded zone of north Cameroon. After spending two to three months in the flood zone, most of them returned to the lake via the El Beid, the direct connections with the river system being interrupted precociously. The young *Alestes baremoze* then remained almost two and a half years in the lake, having undertaken their first reproductive migrations in the rivers.

Due to variations in the migratory cycle, three species groups can be distinguished with varying migratory behaviour.

— *The true migrants*. Only the adults made large-scale longitudinal movements at the time of reproduction. They were *Alestes baremoze*, *Brachysynodontis batensoda*, *Distichodus rostratus*, *Marcusenius cyprinoides* and *Petrocephalus bane*. Three other species should also be noted here: *Hemisynodontis membranaceus*, *Labeo senegalensis* and *Hydrocynus brevis*, for which the data are not quite complete. *Alestes dentex* was an extreme case because its migrations were greater than those of *A. baremoze*. Although *A. dentex* were very common in Lake Chad, it is possible that they reproduced in the higher reaches of the rivers, since we never saw a single mature individual.

— *The 'mixed' migrants* also make large-scale longitudinal movements but some young did reascend at the same time as the adults, in particular *Schilbe uranoscopus*, *Synodontis schall*, *Hyperopisus bebe*, *Mormyrus rume* and *Eutropius niloticus*. This last species was however distinguished from the preceding ones and those of the first group because no individuals of any age were ever found in the flooded zones.

— *The 'lateral' migrants* were fish living in the rivers and moving towards the extended river bed and flooded zones with the flood and only making short movements into the lower layer. The movements were related to feeding rather than to reproduction and can be divided into two categories. The first were

riverine species such as *Alestes nurse* and *Citharinus latus* that were rarely found in the lake. The second were the species present in the lake as well as in the rivers but forming a more or less separate sedentary group. This group included all the Cichlidae, particularly *Tilapia* spp. and *Sarotherodon* spp as well as *Lates niloticus* and *Polypterus bichir*.

A very common predator, *Hydrocynus forskalii* appeared to represent a particular case because it spawned in the lower bed at the time of subsidence. It then appeared to have separate populations: fluvial and fluvio-lacustrine (Srin 1976). As with *Eutropius niloticus* no representatives of these species were found in the flooded zones or in the El Beid.

10.2.3.3 *Summary classification of the species.* This division of species of the Lake Chad region is partly valid over the Sudano-Sahelian zone. It can be related to the environments inhabited and provides a fairly extensive distribution, which depends upon species behaviour, and various adaptations (trophic plasticity, genetic behaviour, resistance to hypoxia, for example). A detailed classification of the large number of species found (over 100) is in progress but will not be discussed here. It is sufficient to show the variety of types of species distribution.

Few species appeared to be totally ubiquitous in the region considered. Those that were included *Lates niloticus*, *Synodontis schall*, *Labeo senegalensis*, *Distichodus rostratus* and probably *Hemisynodontis membranaceus*, some of whose individuals could be caught in all the lacustrine environments, in the permanent fluvial environments, and in the flooded zones. Although the last three species were migrants, *Lates* was different because of more limited displacements highly motivated by the search for prey. *S. schall* was a mixed migrant (cf. Section 2.3.2)

Several species had a wide distribution which excluded some environments. This characteristic distribution was shown by three very common species: *Hydrocynus forskalii*, *Eutropius niloticus* and *Micralestes acutidens* which frequent all the permanent environments although not a single individual was caught in the flooded zones. or the El Beid. Another type corresponded to species that could be found everywhere except in the northern half of the north basin. They included *Schilbe uranoscopus*, *Brachysynodontis batensoda* and several species of Mormyridae (*Pollimyrus isidori*, *Hyperopisus bebe*, for example). A third important category was represented by species whose distribution excludes the lake open water. This was also a diversified group of quantitative importance since it included, besides several aquatic grass beds species (*Barbus* ...), most of the Cichlidae, and particularly the genera *Tilapia* and *Sarotherodon* as well as Characidae such as *Alestes Baremoze* and *A. dentex*. Some true migratory species and some typically sedentary species were placed together here.

There were some species whose distribution was more limited than that of the

preceding species, but were not attached to any particular environment. They included the endemic species of the lake, *Alestes dageti*, and the fluvial species which were never caught in the typical lacustrine environments, namely *Petrocephalus bovei*, *Ichthyborus besse*, *Citharinus latus*, *Siluranodon auritus* and *Polypterus senegalus*. Some species could be placed near this group, having a marked predilection for marshy environments and flooded zones: *Clarias*, *Ctenopoma*, *Brienomyrus niger*, *Synodontis nigrita* and *Barbus gourmansis*. We will see later that most of these species developed some tolerance to the anoxic conditions, which partly explained the change in the lake populations during the drought.

Finally some species had a more specific distribution: *Barilius* was caught on the river sand banks; the characteristic population of *Aetheria* beds in the river: *Petrocephalus simus*, *Nannocharax fasciatus* and *Synodontis filamentosus* were never been found elsewhere; *Protopterus annectens*, a dipnoid fish, common in all the flooded zones, encysted during the drying up period; *Nothobranchius*, frequent in isolated ponds, laid eggs that hatched after a long time.

10.3 Influence of the drought on the fish communities (1973–1978)

The lake at this time was in the 'Lesser Chad' stage by the definition of Tilho (1928); it started with a severe change in water level caused by the period of drought present throughout the Sahel since 1972. An extreme and lasting modification of the lacustrine hydrology caused serious disturbances in the fish communities as seen in the north basin, the Southeastern Archipelago and Southeastern Open Water. Indirectly they affected the reproductive migrations in the delta zone of the Shari. Moreover, in the aim of considering the rivers influence on changes in lake communities we regularly followed, from 1974, the descent of young fish in the El Beid; they took this outlet of the flooded plains to rejoin the south basin of the lake.

Two phases could be distinguished: that of drying up (1972–1974) and that of 'Lesser Chad' (1975–1977) which only affected the south basin.

10.3.1 Drying up of the north basin

Towards the end of the first half of 1973, the drying up of the 'Great Barrier' (Fig. 1) transformed the north basin into a closed basin without inflows other than the low supply of the Yobé because the small floods of 1973 and 1974 did not reach the north of the lake. The mean depth at Kindjéria changed from 3.3 m in September 1973 to 0.5 m in December 1974 (Fig. 10). The transparency was reduced by seven over the same period. The existence of an increasingly abundant seston and phytoplankton involved a large nightly variation in

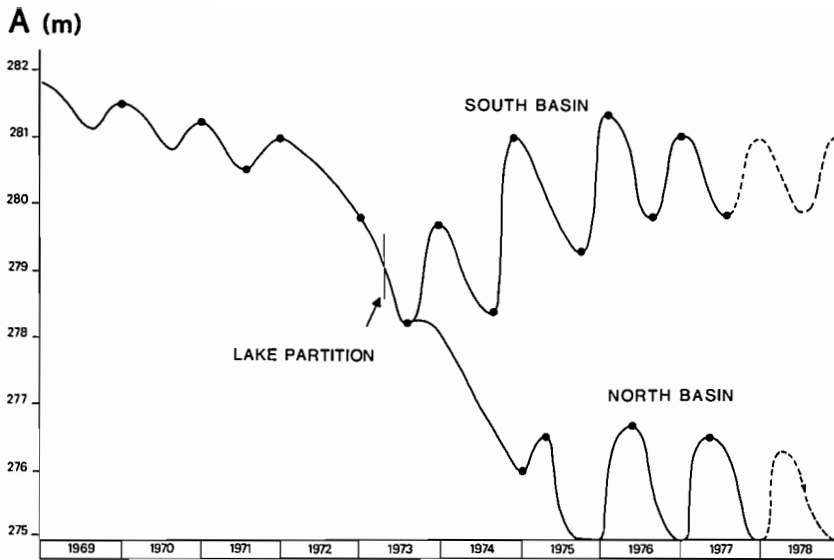


Fig. 10 Between year variation in water level (altitude, above sea level) for the lake, and for each of the two basins after August 1973 (lake partition).

oxygen concentration from 0 to 20 mg l⁻¹ in 12 hours at 10 cm under the surface (Bénech et al. 1976). The conductivity increased from 900 to 3500 $\mu\text{S cm}^{-1}$ between March and December 1974.

An important barrier of marshy vegetation developed on the exposed ground of the 'Great Barrier' and hindered the outflow of flood waters towards the north in 1974–75. The losses by evaporation were not compensated for and the entire north basin dried completely in November 1975.

At the time of its isolation from the rest of the lake, the fish stocks of the north basin as well as their distribution were practically the same as in 1971, the year of reference for the ichthyology of the northern part of the lake before the drought. No migrations or mass movements were observed towards the south basin before the division of the lake. On the contrary it appeared likely that some stocks in the south basin like *Alestes baremoze* were sheltered in the north to take advantage of a more stable environment (Durand 1978). The concentration of fish then attracted almost all the professional fishermen previously distributed over the delta regions and the southern border of the lake. The development of fishing activity caused a strong increase mortality due to fishing. Also, the degradation of ecological characteristics throughout the basin increased the natural mortality. These two phenomena together contributed to the establishment of a very high total mortality for almost all the species present during the period of 'Normal Chad'. Mortalities were a principal factor in the

change in the populations between the isolation of the basin and the second half of the year 1974.

This change was expressed by the progressive disappearance of species like *Heterotis niloticus*, *Hydrocynus brevis*, *Citharinus citharus*, *Tetraodon fahaka*, *Pollimyrus isidori*, *Mormyrus rume*. Some mass mortalities following tornadoes were also observed (Bénech et al. 1976). When the water level fell below a critical threshold of about two meters the sediment could be perturbed under the effect of very violent winds. Then there was an explosive development of phytoplankton, a lowering of the transparency and the oxygen content. The fish died directly due to an oxygen deficiency or due to the mechanical action of suspended particles on the branchial tissues. This phenomenon was repeated several times in different places during the rainy season. In September 1974, on the windward banks of several islands, some fringes 0.5 to 1 meter wide and several hundred meters long of dead fish could be seen.

Whatever sampling point was chosen, at the end of 1974, the influence of the drought and the turbulence favored the same group of species, namely *Polypterus*, the *Mochocidae* and *Sarotherodon*, although they reacted very differently to the changes in their environments.

— The Mochocidae (*S. schall* and *B. batensoda*) did not reproduce, and although they suffered considerable mortality, their relative resistance to the reduction in water area included an increase in their density — more so than for the other species (Fig. 11).

— *Polypterus*, represented especially by *P. senegalus* could respire oxygen from air and thus suffered less from anoxia. Due to a lack of data on their reproduction (the gill nets catch few young *Polypterus*) we can only note their growing importance over the course of this period.

— In spite of the considerable losses suffered during the storms the populations of *Sarotherodon* were maintained and proliferated because of their high reproductive capacities. The young became dominant from June 1974 before the growth following the rainy season as shown by the change in the catches (Fig. 12).

During the drought, the increase of *Sarotherodon galilaeus* was much less perceptible than that of *S. niloticus* and especially of *S. aureus* whose development was considerable. The differential success in adapting to the conditions imposed by the drought, was related to the oxygen requirements of the three species. The needs of young *S. aureus* were 30% of *S. galilaeus* while *S. niloticus* was intermediate (Welcomme 1964).

If the same groups of species were favored by the drought, the changes in the fish communities were not identical over the whole basin. The spatial variations became evident in the results of a correspondence analysis which deals with a table regrouping the catch per unit effort from three nets (GN 15, 30 and 50) for the main species caught in four stations of the north basin between 1971 and the end of 1974 (stations A, B, C, D; Fig. 1).

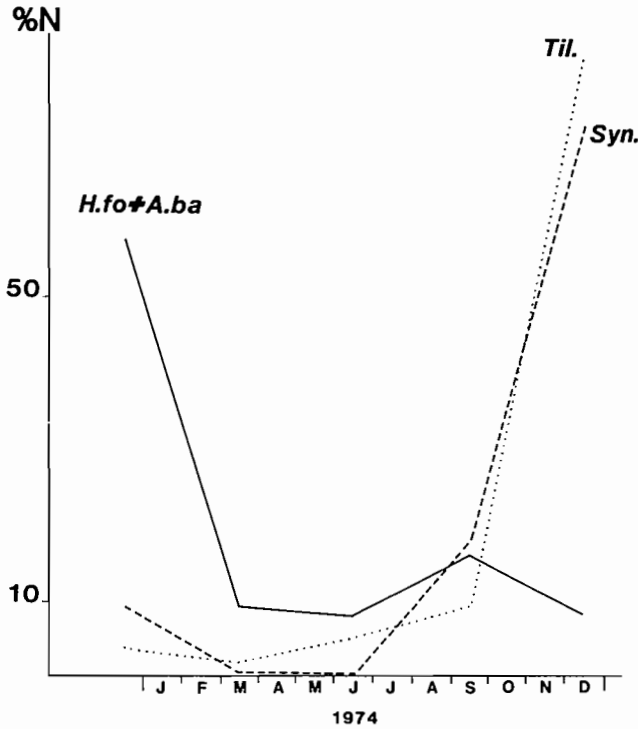


Fig. 11 Variation in the catch per unit effort for a few species at Kindjéria (N is the sum of individuals in groups of species or genera considered during the period described). H.fo = *Hydrocynus forskalii*; A.ba = *Alestes baremoze*; Til = *Tilapia* species and *Sarotherodon* species; Syn = *Synodontis* species.

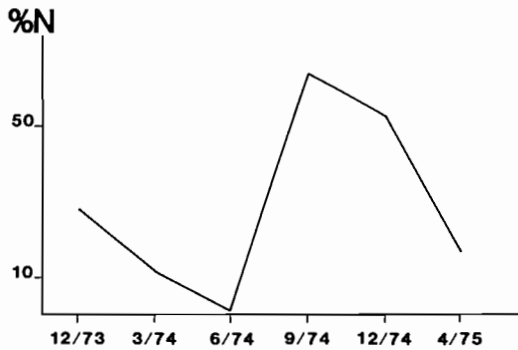


Fig. 12 Experimental fishings at Kindjéria (north basin, GN 11, 15, 35, 40). The number of individuals of young *Tilapia* and *Sarotherodon*, caught in both GN 11 and 15 is expressed as a percentage of the total number of individuals of the same species caught in the whole gill net set.

— In 1971, before the period of drought, few young were found at Station A which was located in the region of the Northern Open Water (Fig. 1). The catches were then primarily made up of large *Hyperopisus bebe*, *Lates niloticus* and *Synodontis frontosus* as well as several *Eutropius*. The community changed fairly little until the beginning of 1974, when the populations flowing back from the archipelago enriched the diversity and the species richness of catches made at the station which was slightly deeper than the eastern border of the lake. *Synodontis* spp. were then dominant, while the importance of *Tilapia-Sarotherodon* increased although it was still not predominant.

— Stations D and C were located in the Northern Archipelago at the northern extremity of the lake and at the limit of the reed islands respectively. In 1971, they had comparable communities composed principally of young *Hydrocynus forskalii*, *Eutropius niloticus*, *Alestes baremoze* and large *Lates niloticus* and *Sarotherodon galilaeus*. As in station A, these communities changed in 1973 and all retained their main characteristics. Over the course of 1974, the disappearance of *Alestes*, *Lates* then of *Hydrocynus* and *Eutropius* was seen in the northern part (station D). The same phenomenon occurred at station C but with a slight delay. All this happened as first *Alestes* and *Lates* and then *Hydrocynus* and *Eutropius* moved back towards the center of the basin abandoning the place to *Tilapia* which made up most of the fish community until the drying up of these stations towards the end of 1974.

— Station B was located in the deepest region of the lake. As in the other stations the fish community at point B was not modified between 1971 and 1973. By contrast, there was a large decrease in *Alestes* between March 1973 and March 1974 probably because of the considerable fishing effort to which it was subjected throughout the basin. Similarly the apparent development of large *Schilbe* and *Synodontis schall* was noted. The change was regular and the December 1973 samples showed one stage, but after March 1974 the change took place in a different manner and appeared more and more diversified. A rise in abundance was noted for *Eutropius*, *Alestes baremoze* and *A. dentex* of large size. The large *B. batensoda*, usually rare in the region, appeared as well as the large *Sarotherodon aureus* and *S. niloticus*. Some large *Lates* were even caught during 1974. It was thus evident that these fish came from shallower drying up regions of the lake.

In spite of this apparent recovery, the fish community of station B showed the beginning of its final stage from November–December 1974. The presence of *Brienomyrus niger*, the slow development of *Polypterus* stocks, the appearance of a notable number of *Clarias* as well as the multiplication of *Sarotherodon* were the signs of the installation of a marshy fish community. It developed in 1975 until the drying up of the station and it recovered as a result of the brief inundations caused by the floods. After 1975 and the total drying up of the basin, the northern part of the lake was partially flooded each year (Chapter 2). It was then a marshy region like some flooded areas of a particular type

colonized by a community with a high productivity mainly based on *Clarias*.

10.3.2 Southeastern Archipelago

The Southeastern Archipelago was isolated in April 1973 during the drying up of the reed island region (Chapter 2). The water level then declined very rapidly and the archipelago region would probably have followed the changes found in the north basin if the following flood wave had not reached Bol. It was filtered during passage through the thick band of semi-aquatic vegetation which had developed on the dried ground in April. After 1974, the archipelago was no longer isolated from the open water by a dry ridge but the plant formations, which were installed there (Fotius and Lemoalle 1976) formed a definite obstacle to the free circulation of fish between these two regions.

The study of catches from a gill net battery expressed as presence-absence (Table 6) distinguished two stages in the change of the Southeastern Archipelago communities. The first (1973–74) drying period during which the archipelago was isolated for part of the year corresponded to the lowest water level (Fig. 14). This isolation no longer existed over the second period (1975–77) during which the 'Lesser Chad' was established.

10.3.2.1 *The drying phase (1973–1974)*. The first half of 1973 was still a period of high water. However an increase in the number of fish caught was then observed because the reduction in the water area (90%) caused a concentration of fish and increased the vulnerability of species that were previously caught to a lesser extent by gill nets.

From July to September 1973 at the time of the lowest water, before the arrival of the flood, some species disappeared: *Hydrocynus forskalii*, *Citharinus citharus*, *Hemisynodontis membranaceus*, *Lates niloticus*, *Alestes dentex* and *Labeo senegalensis*. The species appearing with the reduction in water area also disappeared except *Bagrus bayad* which persisted until November 1973. There may have been a possible emigration during the flood. This fish community change must have been related to some mass mortalities following storms observed in the 1972 rainy season. The sudden decrease of the species number always coincided with the period of storms in June and July (Fig. 14).

The 1974 floods submerged a large number of decomposing plants and caused an oxygen deficit which persisted for at least three months. The appearance of dissolved free CO₂ accompanied the reflooding. This event marked the disappearance of most of the common species from the high water community which had survived the conditions of low water. The Mochocidae which represented 45% of the catches a month before, disappeared in a few days (Fig. 13), while the number of species changed from 23 in September to 8 in October, reaching a minimum of 5 in December (Fig. 14). Only the species

Table 6 Evolution of the species composition of catches by gill nets in the southern archipelago of Lake Chad from 1973 to 1977. (1) Species with supplementary respiratory organs.

Species	1973							1974							1975				1976				1977					
	F	M	A	J	J	O	N	D	J	M	A	M	J	S	O	D	F	Mi	At	D	M	A	At	O	J	F	Mi	
<i>Mormyrus rume</i>				■	■	■																						
<i>Mormyrops deliciosus</i>		■																										
<i>Hippopotamyrus harringtoni</i>	■	■	■	■	■																							
<i>Hydrocynus brevis</i>	■	■	■	■																								
<i>Alestes macrolepidotus</i>	■	■	■																									
<i>Labeo coubie</i>				■																								
<i>Bagrus bayad</i>	■	■	■	■	■	■	■																					
<i>Chrysichthys auratus</i>	■	■	■	■																								
<i>Hydrocynus forskalii</i>	■	■	■	■	■	■			■																			
<i>Citharus citharus</i>				■																								
<i>Hemisynodontis membranaceus</i>	■	■	■	■		■																						
<i>Lates niloticus</i>		■	■	■								■	■															
<i>Hyperopsis bebe</i>	■	■	■	■		■	■	■			■	■	■	■														
<i>Marcusenius cyprinoides</i>	■	■	■	■	■	■	■			■	■	■	■	■														
<i>Petrocephalus bane</i>	■	■	■	■	■	■	■			■	■																	
<i>Pollimyrus isidori</i>	■	■	■	■	■	■		■		■	■	■	■															
<i>Labeo senegalensis</i>	■	■	■	■		■				■	■	■	■		■													
<i>Eutropius niloticus</i>	■	■	■	■	■	■	■	■	■	■	■	■	■	■														
<i>Synodontis clarias</i>	■	■	■	■		■	■	■		■	■																	
<i>Schilbe uranoscopus</i>	■	■	■	■	■	■	■			■	■	■	■	■			■	■	■		■			■				
<i>Brachsynodontis batensoda</i>	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■						
<i>Synodontis frontosus</i>	■	■	■	■	■	■	■			■	■		■	■	■			■			■							
<i>Synodontis schall-gambiensis</i>	■	■	■	■	■	■	■	■		■	■	■	■	■			■	■	■	■	■	■	■		■	■	■	
<i>Alestes dentex</i>	■	■	■	■	■						■	■		■				■	■		■	■	■		■	■	■	
<i>Alestes baremoze</i>	■	■	■	■	■	■	■	■	■	■	■	■		■			■	■	■	■	■	■	■		■	■	■	

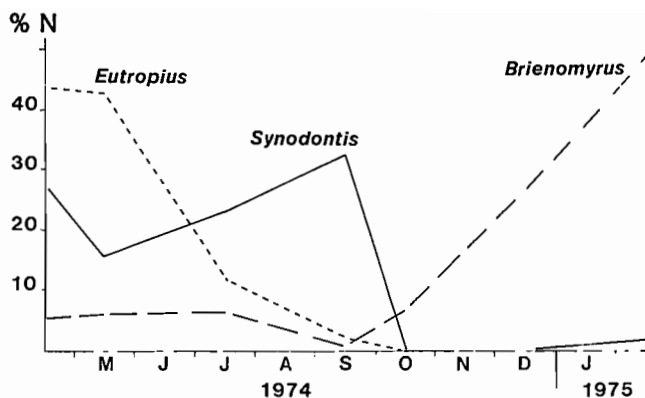


Fig. 13 Variation in the catch per unit effort (in number) for a few species at Bol-Berim (N is the sum of monthly c.p.u.e. for each genus during the period described).

possessing organs of aerial respiration persisted: *Polypterus senegalus*, *Clarias* spp. and *Brienomyrus niger* as well as some individuals of other species: *Alestes nurse-dageti*, *Distichodus rostratus*, *Brachysynodontis batensoda* and *Sarotherodon niloticus* whose traces were found in the October or December, 1974 catches (Table 6).

The two types of severe mortalities recorded at the time of storms or the arrival of flood water were due to hypoxic conditions provoked at first by a dispersion in the water mass of reducing sedimentary compounds and then by the arrival of a considerable mass of anoxic water. The species which disappeared in 1973, endured the hypoxic conditions with much difficulty as shown experimentally for *Alestes baremoze* and *Labeo senegalensis*. Inversely, the species whose few individuals persisted in the very hypoxic water of the 1974 flood, experimentally showed a very good resistance to hypoxia: *Distichodus rostratus* and especially *Sarotherodon niloticus* and *Brachysynodontis batensoda* (Bénech and Lek 1981). A diffuse mortality shown by experimental fishing was superimposed onto the severe and apparent mortality. The normal conditions of existence no longer being assured, the mortality rate rose. The pelagic species of high water disappeared first, then the predators: *Lates niloticus*, *Hydrocynus forskalii*, *H. brevis* and the plankton feeders: *Alestes dentex*, *Hemisynodontis membranaceus*. In this last category *Brachysynodontis batensoda* succeeded in surviving partly due to a more adaptable diet; in 1973 the stomach of these animals contained a considerable proportion of detritus (Im 1977), a starvation diet which halted growth in length (Bénech 1975).

Until the end of 1974, the eventual exchanges with the rest of the lake did not play an important role in the changes in the archipelago fish community because it was isolated at first by the drying of the reed islands zone, then by a cordon of plants several kilometers deep. All the species which abounded in the

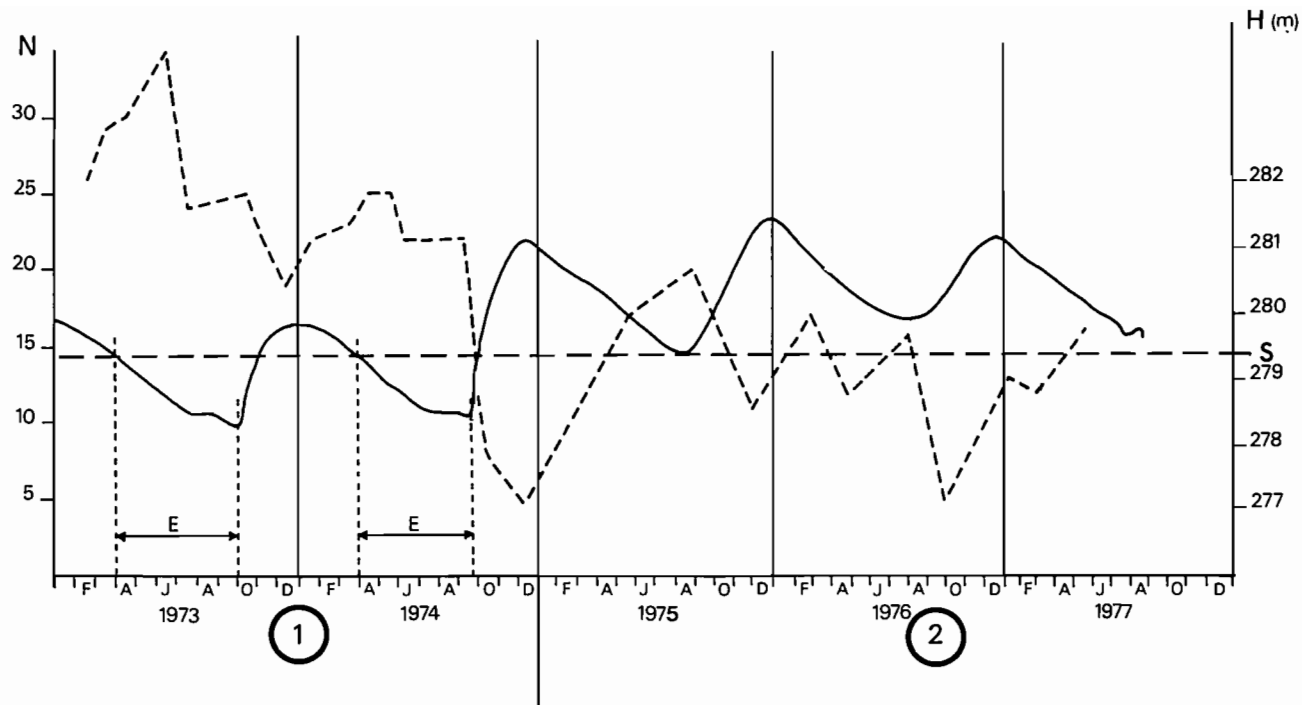


Fig. 14 Changes in the water level (H =continuous line) and in the number of species (N =dashed line) of fish caught by a set of gill nets at Bol in the Southeastern Archipelago.

S =level at which the reed islands zone is above water; E =period at which the reed islands zone is above water; 1,2=first and second period (see explanation in the text).

new environment had already been reported in the region, but the 1973 flood may have favored the immigration of some species (*Siluranodon auritus*, *Brienomyrus niger*, *Clarias* spp. and *Heterotis niloticus*) who appeared simultaneously.

10.3.2.2 *The 'Lesser Chad'*. During 'Lesser Chad', two factors prevented the resuspension of the archipelago sediments: the very high water level and the development of vegetation belts which limited the action of winds on the open water zones. The only disturbance of the environment was the arrival of hypoxic flood water which eliminated the species sensitive to an oxygen deficit. The reappearance of the latter must be attributed to migrations from the Southeastern Open Water. This colonization was facilitated by the appearance, during 1975, of a navigable channel between Bol and the Shari delta. These recolonizations were by species that developed in the archipelago after the transformation of the environment in 1973: *Sarotherodon* spp., *Schilbe mystus*, *Siluranodon auritus*, *Distichodus rostratus*, *Alestes nurse-daget* as well as two pelagic species from 'Normal Chad': *Alestes baremoze* and *A. dentex*.

The composition of the characteristic fish community of 'Lesser Chad', consisting of about 15 species (Table 6), appeared well established in spite of a particular seasonal disturbance of the community. All the correlation coefficients (Pearson's Φ coefficient) showed some affinities between all the samples of 1975, 1976 and 1977 except August 1975 and October 1976 which corresponded respectively to the maximum and the minimum of species caught during this period. March showed few affinities with the rest and was the last sample in which three species from 'Normal Chad' were found prior to their disappearance (*Schilbe uranoscopus*, *Brachysynodontis batensoda*, and *Synodontis frontosus*).

From 1975 the fish community of the archipelago henceforth had less than 20 species whereas 34 were represented in the 1973 catches. With the new appearance of the lake, a seasonal change took form, such that the species richness of the archipelago decreased drastically at the time of the arrival of the flood then increased until the end of the following low water. The arrival of the 1975 flood certainly produced the same effects as that of 1974 (Fig. 14) but the decrease in the number of species caught was less marked in 1975 because of the sampling being much later that year. This was confirmed by the 1976 data as the sampling carried out at the beginning of the flood showed that, as in 1974, the surviving species were those which could use oxygen from the air.

10.3.3 *The zone of contact with the river system*

10.3.3.1 *The Southeastern Open Water*. In comparison to other lake environments the south basin exhibited two original features beginning in the second half of 1973:

- a constant connection with the river system and the fish stocks it contained. It should be recalled here, that there were no endemic species of the lake which could be considered as an extension of the river system (Daget 1967), at least in relation to the fish fauna of the basin;
- a change towards a new appearance of the lake characterized by an extension of open water surrounded by a thick vegetation belt unfavourable to sheltering the fish species sensitive to hypoxia.

The change of the fish community of this part of the lake after the drought of 1972–73 must be interpreted in view of these characteristics. As in the South-eastern Archipelago this change included two periods towards the end of 1974.

(a) The subsidence of the lake (1973–1974)

From a hydrological point of view this period corresponded to a considerable reduction in water areas. These conditions also caused an increase in mortality that was less important than in the Southeastern Archipelago or in the north basin due to four reasons:

- at the time of its separation from the northern basin, the southern part of the lake enclosed a majority of open water species and fish stocks less important than those of the other lake regions. The reducing water volume thus led to lower fish concentrations;
- the connections with the Shari being maintained in 1973, some species migrated towards the river system where they found temporary refuge;
- the nature of the sediments also played an important role here as the bottom of the basin was mostly composed of sand and pseudo-sand. There was no notable increase in turbidity with the simultaneous reduction of dissolved oxygen and proliferation of the phytoplankton;
- the region of the Southeastern Open Water was not subjected to the considerable fishing effort seen at the same time in other regions of the lake, especially in the north basin.

From March 1973, the fish community sampled close to the island of Kalom was dominated by *Brachysynodontis batensoda*, mostly adults caught by GN 30 and GN 35. There was also an abundance of *Pollimyrus isidori* and *Eutropius niloticus*. *Alestes baremoze*, *A. dentex*, *Hydrocynus forskalii*, *Chrysichthys auratus* and other characteristic species of the archipelago fish communities were rare. But this rarity was attributable as much to their low abundance in this region at the time of its isolation as to an increase in mortality due to the drought. The proof lies in these species becoming more abundant from 1974 although the conditions of the lake did not improve.

(b) The 'Lesser Chad'

After 1975, the zone of open water increased and arms of open water appeared in the vegetation which was progressively broken down by the maintenance of a

relatively high water level in the basin. At the same time the floodplains in the river system recovered a normal flooding, a favourable factor in restoration of migratory stocks (cf. Section 3.4).

Although the information provided here sometimes contained gaps such as the recent changes in the south basin it appeared that a new type of fish community was being established. Thus Shannon's diversity index calculated from relative frequencies of the 16 most abundant species in the annual samples taken between 1973 and 1977, indicated a recovery of the species richness from 1975 (Table 7). This experimental fishing, done close to the island of Kalom also indicated a rejuvenation and a progressive return to equilibrium of the age structure of some populations such as those of *Hydrocynus forskalii*, *Synodontis clarias* or *Labeo senegalensis* despite their being deeply affected by the drought (Table 8).

10.3.3.2 *The Shari delta.* The samples taken in this region of the Shari provided information on the availability of the breeders present in the lake for species which made anadromous spawning migrations. To illustrate the disturbances suffered by the lake populations during the period of 'Normal Chad' and the building up of a fish community of 'Lesser Chad', we will also consider two sets of data collected over the drying up phase in 1972-73 and after the drought in 1976-77.

(a) Drying period (1972-1973)

The data considered here were collected between September 1972 and December 1973 at the time of observations on the delta fisheries (cf. Chapter 13, Section 5). The tendency for change in the sampled fish community appears clearly on the first factorial plane of a correspondence analysis (Fig. 15) on the numerical catch per unit effort of the 15 most abundant species (97.81% of the total catches) (Quensière 1976).

Data for the months September to December 1972 showed a fairly loose group of species that were dominant during this period: *Alestes baremoze*, *A. dentex*, *Marcusenius cyprinoides*, *Brachysynodontis batensoda*; they were joined

Table 7 Diversity and equitability index of samples taken close to the island of Kalom in the southeastern open waters.

Year	I	I/I _{max}
1973	1.420	0.384
1974	1.044	0.267
1975	0.920	0.230
1976	1.331	0.341
1977	1.888	0.510

Table 8 Importance of three species in different mesh size gill nets as % (in number of individuals) of the total catch in the Open waters of Lake Chad (East of Kofia).

Species	GN	11	15	20	22	25	30	35	40
<i>Hydrocynus forskaiti</i>	1973	0	12.0	6.0	50.0	24.4	7.5	0	0
	1974	7.0	2.6	15.7	15.7	18.9	24.1	14.5	1.7
	1975	2.6	1.8	8.3	8.3	13.0	35.8	18.4	11.9
	1976	5.8	7.7	12.1	6.8	11.1	38.7	15.4	2.4
	1977	4.6	2.3	24.1	9.2	19.5	23.0	16.1	1.2
<i>Labeo senegalensis</i>	1973	0	0	0	0	0	100	0	0
	1974	0	0	1.2	2.1	6.6	12.0	46.3	31.8
	1975	0	0	16.3	28.6	22.5	20.4	2.0	10.2
	1976	0	0.4	1.9	5.4	18.1	53.5	19.3	1.5
<i>Synodontis clarias</i>	1973	0	0	3.0	6.8	9.8	51.8	37.2	3
	1974	1.6	5.2	27.8	16.4	34.6	8.9	4.2	1.3
	1975	4.5	16.0	25.0	22.4	4.5	13.5	7.1	7.1
	1976	6.2	7.9	36.4	40.4	1.1	4.0	3.4	0.6

by *Hemisynodontis membranaceus* in October and November. The month of January was clearly differentiated from the preceding ones by a greater abundance of *Alestes baremoze* which formed 78.1% of the catch. A very clear shift was then seen from a community of dominant *A. dentex* and *A. baremoze* towards a community of dominant *Synodontis*: *Synodontis clarias*, *S. frontosus*, *Polypterus bichir*, *S. schall* and *S. gambiensis*. This phenomenon was not linked to the development of these species but simply to the disappearance of *A. dentex* and *A. baremoze* whose abundance masked it during the preceding months. This is shown clearly by the change in yields from small mesh gill nets (from 25 to 35 mm) that are shown in Fig. 16.

A comparison with yields taken in the preceding months (Loubens 1973) showed a progressive slump in catch per unit effort as a consequence of the drought. In 1972 the exceptionally low flood appeared a month later, but the spawning places and particularly the Yaéré were not flooded.

The chemical water composition before entering into the lake was notably different from other years (Lemoalle 1974) and probably caused some changes in migratory behaviour. Finally the disturbances caused by the lower level of the lake itself (Bénech et al. 1976) caused fish to move towards the north basin which had more stable conditions than the south basin (Durand 1978). This reduction of yield, which was linked to the increasingly difficult fishing conditions in the delta region, incited the fishermen to look for more favorable zones. The month of May 1973 marked the suspension of all professional

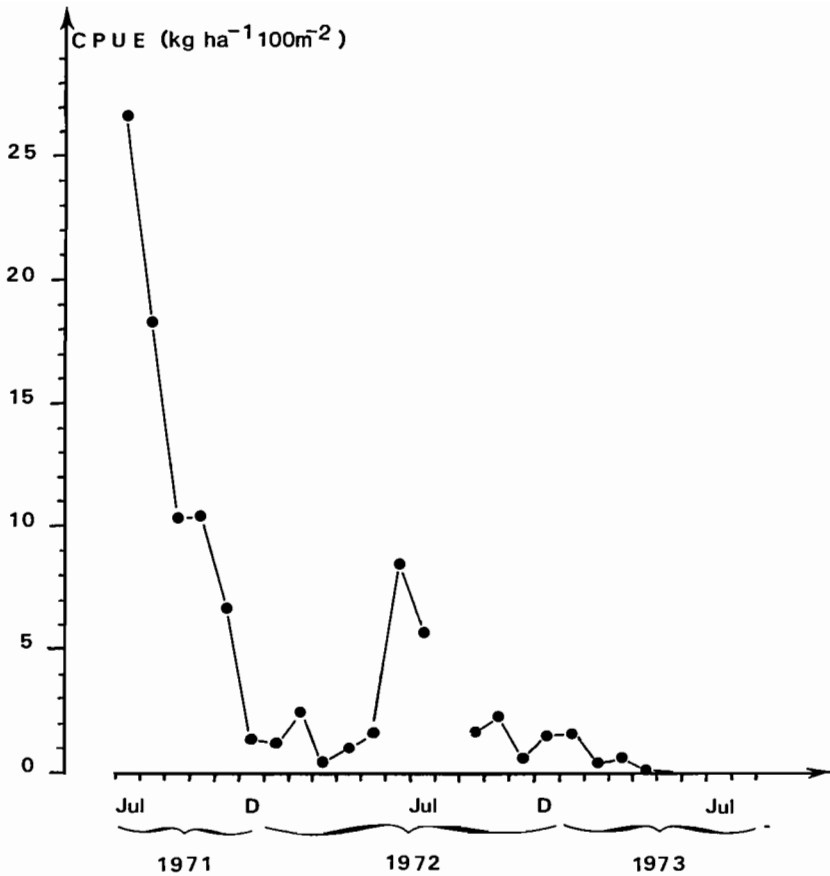


Fig. 16 Changes in the catch per unit effort for traditional fisheries with small mesh drift net in the Shari delta from July 1971 to May 1973.

fishing activity in the delta (Chapter 13); *Alestes baremoze* and *A. dentex* completely disappeared from samples after October. The species diversity thus varied strongly from one month to another due to the mass migrations of Mochocidae: *B. batensoda* in October and *H. membranaceus* in November.

The comparison of the fish communities observed in 1972–73 with those of 1971–72 showed some significant differences between the two periods. *Distichodus rostratus*, *Citharinus citharus*, *Labeo senegalensis*, *Hydrocynus brevis*, *Bagrus bayad* and *C. latus* no longer occurred among the 15 most abundant species and were replaced by the formerly rarer species such as *Marcusenius cyprinoides*, *Synodontis frontosus*, *S. clarias* and *Petrocephalus bane*. The second major difference between the two series of samples was the progressive disappearance of *A. baremoze* and *A. dentex* beginning in the middle of 1973.

The change of catches in the delta fisheries during 1972–73 thus signified the profound disorders then present throughout the lacustrine fish communities. It showed the poverty of stocks sheltered by the south basin at the time of the fragmentation of the lake and the selective pressure the hitherto dominant species were subjected to.

(b) 'Lesser Chad' (1976–1977)

The almost continuous observations made throughout the 1976–77 hydrological cycle showed the orientations of the new lacustrine fish community which became established as the lake remained reduced ('Lesser Chad'). The data considered here correspond to the catches made for each of the 40 weekly samples by a battery of 20 gill nets (GN 10 to GN 100). With a weekly average fishing effort of 2000 units ($100 \text{ m}^2 \text{ night}^{-1}$) over the entire period considered, 72 species were caught, of which the 20 most abundant (Table 9), represented

Table 9 Abundance expressed in total number of individuals caught and in percentage of total catches for 20 species represented in the delta fisheries during 1976–77 season.

Species	Number of fish caught	% of total catches
<i>Pollimyrus isidori</i>	25 426	43.78
<i>Schilbe mystus</i>	4370	7.52
<i>Siluranodon auritus</i>	4021	6.92
<i>Petrocephalus bovei</i>	3974	6.84
<i>Alestes nurse</i>	2720	4.68
<i>Brachysynodontis batensoda</i>	2378	4.09
<i>Eutropius niloticus</i>	1690	2.90
<i>Ichthyborus besse</i>	1605	2.76
<i>Petrocephalus bane</i>	1511	2.60
<i>Brienomyrus niger</i>	1108	1.91
<i>Marcusenius cyprinoïdes</i>	993	1.70
<i>Hydrocynus forskalii</i>	809	1.39
<i>Schilbe uranoscopus</i>	796	1.37
<i>Chrysichthys auratus</i>	710	1.22
<i>Alestes baremoze</i>	585	1.01
<i>Distichodus rostratus</i>	585	1.00
<i>Hyperopisus bebe</i>	528	0.91
<i>Polypterus bichir</i>	491	0.85
<i>Synodontis schall</i>	414	0.71
<i>Synodontis clarias</i>	349	0.60
Total	55 058	94.79

94.8% of 58 082 individuals sampled. The results from all the batteries were not directly comparable with the above descriptions. Whereas the observations of Loubens (1973) and Quensière (1976) were for the period exploited by the delta fisheries, the present observations were for experimental fishing using a battery of much more diversified nets. A battery comparable with that used by the fishermen before 1973 (from GN 25 to GN 100) would only have caught 11.4% of the fish now sampled. A comparison of this part of the catch with the above homologous data showed three types of change according to the species in question (Table 10).

— The first type of change was that of species which were abundant during the period of 'Normal Chad' and became rare after 1973. This group included *Citharinus citharus*, *C. latus*; *Mormyrus rume*, *Bagrus bayad* and *Alestes dentex* which were part of the 17 most abundant species in 1971 and 1972 but had become a negligible part of the catch. Although more abundant than the species cited previously, *Hydrocynus brevis*, *Hemisynodontis membranaceus* and *Labeo senegalensis* also lost their passing importance. *Alestes baremoze* occupied a separate place in this group because although it was rare in the catches of a battery comparable to that of the 1971–73 fishermen it was still present in notable quantities in the catches of the experimental battery. The reason for this

Table 10 Rank of species classed by abundance in 1971–1972, 1972–1973 and 1976–1977. Shari delta fisheries.

Species	1971–1972	1972–1973	1976–1977
<i>Alestes baremoze</i>	1	1	> 30
<i>Schilbe mystus</i>	2	5	2
<i>Alestes dentex</i>	3	3	> 30
<i>Brachysynodontis batensoda</i>	4	4	1
<i>Hemisynodontis membranaceus</i>	5	2	20
<i>Synodontis schall</i>	6	12	14
<i>Hyperopisus bebe</i>	7	6	16
<i>Hydrocynus forskalii</i>	8	7	4
<i>Distichodus rostratus</i>	9	9	12
<i>Mormyrus rume</i>	10	13	> 30
<i>Polypterus bichir</i>	11	10	3
<i>Citharinus citharus</i>	12	27	> 30
<i>Labeo senegalensis</i>	13	16	18
<i>Eutropius niloticus</i>	14	11	9
<i>Hydrocynus brevis</i>	15	20	19
<i>Bagrus bayad</i>	16	> 30	> 30
<i>Citharinus latus</i>	17	29	> 30

was that the average size of the migrants had decreased considerably because of the lowering of the age of sexual maturation (Durand 1978).

— The second type of change was that of species described as less abundant in 1971–72 and which become predominant later on such as *Synodontis clarias*, *Schilbe uranoscopus*, *Distichodus brevipinnis*, *Chrysichthys auratus* and *Marcusenius cyprinoïdes* which become abundant from 1972–73. This was also the case of some formerly less abundant predators such as *Lates niloticus* or some species rarely reported in the delta fisheries like *Gymnarchus niloticus*. The success of the latter resulted from the establishment and maintenance of large areas of the lake that are poorly oxygenated and/or unstable. Finally, *Alestes nurse* and *Brienomyrus niger* which were very abundant in the fisheries of the entire experimental battery, remained among the 17 species mostly caught by the reduced battery (mesh bar: 25 mm and over) in spite of their small size.

— The third type of change corresponded to species that were abundant before the drought as well as in the catches of 1976–77. This may be because they did not suffer a recession like *B. batensoda* or because after a decrease in 1972–73 they appeared to reconstitute their stocks like *Synodontis schall*, *Hyperopisus bebe* or even *Hydrocynus forskalii*, *Polypterus bichir* and *Eutropius niloticus* whose importance in 1976–77 was higher than that of 1971–72.

If all the catches made by the complete experimental battery are now considered it is noted that some small sized species that were rare or accidental during the period of 'Normal Chad' became abundant in 1976–77. They were *Pollimyrus isidori*, *Siluranodon auritus*, *Ichthyborus besse*, *Brienomyrus niger* ... Some others became notably more frequent than before: *Petrocephalus bane*, *P. bovei* and the already cited *Alestes nurse*.

To compare the behaviour of migrants sampled in 1976–77 with those described by Loubens in 1971–72, we extracted the variability in seasonal abundance of 19 species that were most abundant between April 1976 and April 1977 (complete experimental battery). To do this, although the periodicity of sampling was not perfect we smoothed the curve of abundance of each species by the method of repetitive moving averages. From the hierarchical ascendant classification obtained (Fig. 17), two groups of species could be distinguished. The first group included those whose maximum abundance was located around low water and it was composed of three groups:

- the first included *Ichthyborus besse* and *Schilbe mystus* whose maximum abundance was at the end of the withdrawal. If the migratory behaviour of *S. mystus* was probable that of *I. besse* was less evident;
- the second group included *Siluranodon auritus*, *Alestes nurse* and *Chrysichthys auratus* whose migratory behaviour was not certain;
- the third group included *Pollimyrus isidori*, *Synodontis clarias*, *Hydrocynus forskalii*, *Alestes baremoze* and *Eutropius niloticus*. The presence of these species was almost constant throughout the year with a more marked abundance at the low water between April and July.

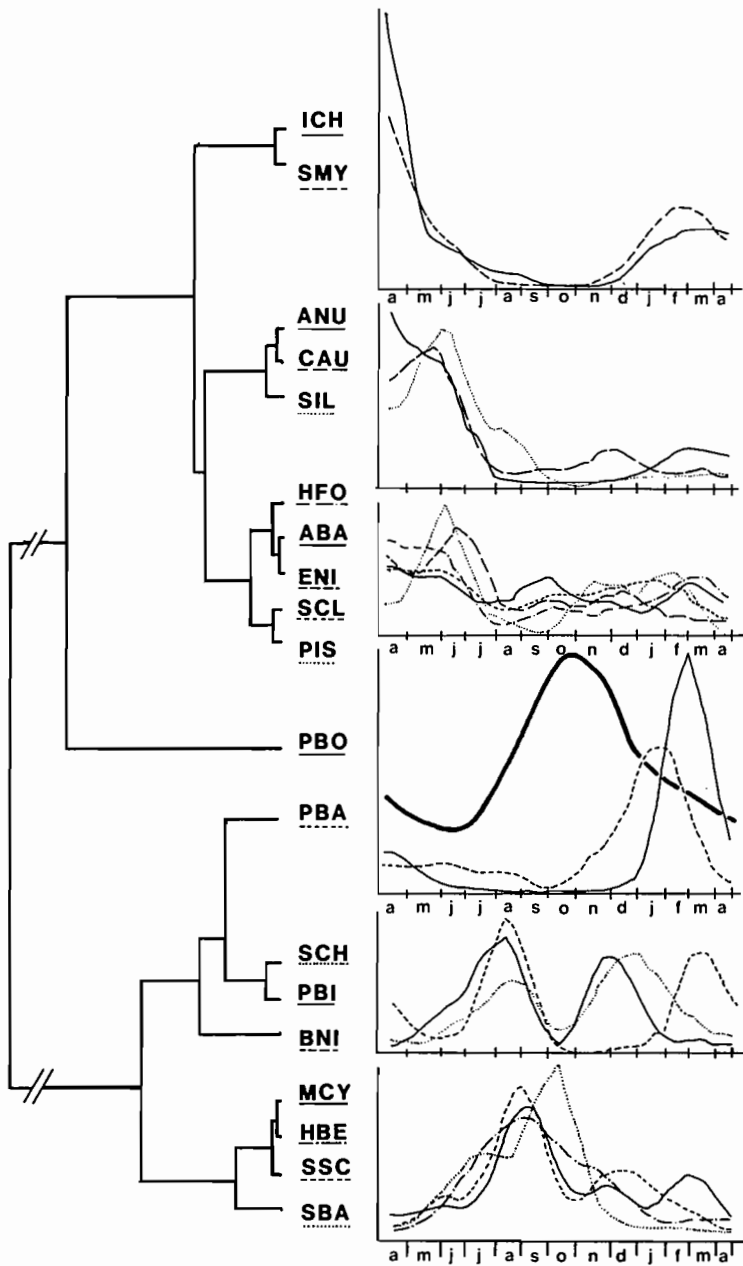


Fig. 17 Smoothed profiles of the catches of the 20 most abundant species in the Shari delta from April 1976 to April 1977 (experimental set GN 10, 11, 12, 13, 14, 15, 16, 18, 20, 22, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100). Species are gathered according to the results of a hierarchical ascending classification (to the left). For abbreviations, see Table 12. The thickest line shows the flood of the Shari river.

A. baremoze was an exception with three periods of very high abundance in May–June, September–October and in February–March corresponding fairly well to the observations of Loubens. The migratory period of *H. forskalii* appeared to be shifted slightly because it was found abundantly from January to May whereas Loubens limited its migration from November to March. There was even less agreement for *Eutropius niloticus* which showed two periods of abundance. The first from April to June almost corresponded to the 1971–72 descriptions and the second from December to February corresponded to the greatest scarcity of species.

The second group of species distinguished by the hierarchic classification included some species whose maximum abundance coincided with the flood period. It was composed of two groups:

- the first included *Synodontis schall*, *Hyperopisus bebe*, *Marcusenius cyprinoides* and *B. batensoda* characterized by a unimodal migrating tendency. The modes were located during the period of flood between July and October, corresponding for *S. schall* and *H. bebe* to the descriptions before the drought. By contrast, *B. batensoda*, 95% of whose catches occurred in May–June 1972 appeared to migrate towards the month of September–October from 1973;
- the second group, *Polypterus bichir*, *Schilbe uranoscopus* and *Brienomyrus niger* were characterized by some bimodal tendencies. The first mode were contemporary with the preceding group, whereas the second were located at the beginning or end of the subsidence.

Schilbe uranoscopus migration increased considerably in the periods indicated previously, but with an inversion of the magnitude of the passages, with the migration from November to January being more important than that from June to September. *P. bichir* made two migrations, shown by the analysis of data from 1971–72 and 1972–73. Finally, *Petrocephalus bovei* and *Petrocephalus bane* must be mentioned. Their resemblance is greater although it does not agree with the classification. Their high abundance at the end of the 1977 subsidence was not equivalent to the previous year but appeared to correspond to the catch variations of 1971–72.

10.3.4 *Surveys of the changes in recruitment*

The Yaère-El Beid complex (Fig. 1) played an important role in the stocking of Lake Chad. The overflow of the Logone in the Greater Yaéré of north Cameroon emptied mainly towards the lake by a natural drain: the El Beid (Bénech et al. 1982). The traditional fisheries of this river exploited the juvenile populations which followed the water movement. The composition of catches was an index of the renewing of the lake stocks. In order to understand well the restructuration of lake fish communities, we followed the composition of catches of the El Beid fisheries from the year of the recovery of normal floods (1974).

10.3.4.1 *General survey of catches.* A total presentation of results of four fishing seasons (1974–75, 1975–76, 1976–77, 1977–78) was provided by the projection on two factorial planes (from a correspondence analysis) of species and samples regrouped as a function of the fishing season (Fig. 18). The study of the projections on the factorial planes at first showed a marked opposition on the first axis between two groups of species. One was closely related to the high water period and the other to the period of withdrawal and low water. This distinction was found to be the same for all the years of observation, though 1974–75, the first year after the drought showed a smaller distance between the two groups. Axis 2, defined by the analysis, permitted a better separation between the different periods of subsidence and low water. Axis 3, on the contrary, discriminated between the different periods of high water. The yearly differences suggested by the analysis, corresponded more to the dissimilarity of importance of different floods than to a chronological succession after the drought. The samples of the years of average flood (1975–76 and 1976–77) regrouped in the same way the samples from the years of low flood (1974–75 and 1977–78), as well for the withdrawal periods (axis 2) as for the high waters periods (axis 3). The structure shown by this analysis of results was therefore essentially connected to the hydrology of the El Beid.

10.3.4.2 *Influence of the drought.* All the fish caught in the El Beid could be divided into two groups. The first was made up of less mobile species whose breeding adults made some small transverse migrations at the time of the flood. Most of these species were capable of maintaining themselves in the residual ponds of the plain between two floods. The second group consisted of species whose adults made longitudinal lake–river migrations to spawn close to the Yaéré. These species which were more mobile than the first group, tend to colonize environments that were more favourable to them, more quickly.

These differences can explain the evolution of catches of two small Mormyridae with a short cycle (reproduction at one year) and a similar diet: the migratory *Pollimyrus isidori* and the sedentary *Petrocephalus bovei*. In the catches of the El Beid these two species showed considerable development after the drought of 1972–73. The slowness of the recolonization from the lateral migrations of the river stock explains the shift from the abundance of *P. bovei* by comparison with *P. isidori*.

The same shift was seen for *Brienomyrus niger*, one of the main inhabitants of the Yaéré ponds. Some sedentary species however had a greater capacity for rapid recolonization, e.g. Cichlidae and especially *Sarotherodon niloticus*. The latter has a remarkable resistance to difficult environmental conditions due to its multiple spawning habit and the care given to the young, and can thus respond very quickly to favorable environmental conditions. This particular adaptation allowed them, at the time of the flood of 1974–75, to multiply

rapidly in the Yaéré thus occupying the place left vacant by the populations that normally colonized this biotope.

Among the large sized migratory species, different types of change could be noted according to the species which can more or less bear the perturbations caused by the drought. Three examples will illustrate this diversity: *Schilbe mystus*, *Citharinus citharus* and *Brachysynodontis batensoda*.

The catches of *Schilbe mystus* declined from 9.4% in 1968–69 (Durand 1970) to 2.6% in 1974–75 and were maintained during the following years at about 1% (Table 11). The lacustrine stocks of *Schilbe* suffered mortalities resulting from the lowering of the water level. Moreover, reproducing only in the rivers, two year classes were absent (1972 and 1973) corresponding to the low floods. In 1974–75 reproduction was still assured from the 1971 age class, then three years old, and spawned just before the dry period. From 1976, the reproduction corresponded to absent year classes. It is the explanation to the higher percentage of young found in 1974–75 than in the following years.

The influence of the drought was more marked for *Citharinus citharus*. It is probable that the lake stocks of this species were almost destroyed. The change in the percentage of young in the catches shows that the restoration of stocks was very slow (Table 11).

In contrast the *Brachysynodontis batensoda* stock recovered rapidly if the change in the El Beid catches was related to the abundance of mature lake fish. This species resists the drought quite well, probably because of its hardiness which was great as seen in the north of the lake as well as in the Southeastern Archipelago. It may also have been due to some of the adults being sheltered in the fluvial system from the end of 1973 as shown by some observations made in the delta region (Quensiére 1976).

In the context of 'Lesser Chad', the recruitments showed an unstable species composition. The species that suffered least from the drought or which had a potential for rapid recovery of their stock became important in turn. This was the result of a complex interspecific competition. *Sarotherodon niloticus* benefited from the absence of competitors in 1974–75 and similarly *Marcusenius cyprinoides* in 1975–76 and *B. batensoda* in 1977–78. Thus there was a

Table 11 Number of individuals of three species caught and their % composition in total catches during four fishing seasons at the Daga station (El Beid).

Species	1974–1975		1975–1976		1976–1977		1977–1978	
	N	% N	N	% N	N	% N	N	% N
<i>Schilbe</i> spp.	922	2.6	1348	1.2	1435	1.2	1063	1.0
<i>Citharinus citharus</i>	0	0	12	0.01	40	0.03	38	0.04
<i>Brachysynodontis batensoda</i>	984	2.8	2323	2.1	2790	2.3	10 678	10.4

successive random appearance of abundant species. In fact, since 1974–75 the species richness has increased and the relative abundance of various species has tended to progressively stabilize over the successive years.

10.3.5 *Conclusions*

After a slow retraction period between 1965 and 1971 the exceptionally low floods (on the scale of scientific observations of the basin) of the years 1972–73 and 1973–74 precipitated the hydrological change in the lake. In the space of two years it declined from a 'Normal Chad' to a 'Lesser Chad'. From an ichthyological point of view this evolution included two successive phases. The first corresponded to the drying up with a severe change in the Chad basin, from a stable lacustrine appearance ('Normal Chad') to an unstable marshy appearance. The second corresponded to the move towards the new equilibrium of 'Lesser Chad', different from the first, and with lacustrine and marshy characteristics at the same time. The observations made in the fluvial and lacustrine environments over the drying period showed that the reduction in lake water area acted upon fish communities three basic ways:

- the decrease in water volume caused a concentration of the fish present. It increased inter and intraspecific competition as well as vulnerability to the fishing gear;
- the increasing shallowness of the water layer allowed resuspension of sediments by wave action which caused some mass mortalities by affecting the branchial tissue or by fixing the dissolved oxygen (reducing compounds in the muds). However, the solubility of nutritive substances caused the explosive development of phytoplankton which led to an increase in the daily variability of the oxygen content and dissolved free CO₂;
- the drying up of the shallows at first caused isolation of the parts of the lake richest in fish (the north basin and the archipelago) through the cutting off of river supplies. Abundant marshy vegetation then developed which according to its thickness prevented the supply of flood water to isolated areas and the eventual escape of fish which became trapped there (north basin) or caused organic pollution of water through which they pass (Southeastern Archipelago). Thus some truly anoxic conditions were created that were toxic and increase the mortalities.

Moreover, the absence of water from the upper layers and floodable plains, which normally provided spawning places and/or shelter for the young, prevented the renewing of stocks.

The natural selection operating on the fish communities during the drying up period favoured the development of 'marshy' species endowed with adaptations of diet, reproduction and respiration that allowed them to survive in an unstable environment, at the expense of 'lacustrine' species that are generally migrators with strict preferences. This selection operated both on the lacustrine stocks and their renewal:

- on the stocks, by provoking an increase in natural mortality and indirectly by mortality through fishing;
- on the renewal of stocks, by isolating the spawning places as well as by opposing their filling by water. The development of the marshy fraction of the fish community was thus not only linked to the adaptations of these fractions but also to the absence of competition of the other part of the fish community which extinguishes in the lake.

During the second period, the 'Lesser Chad', which is the installation of a new lacustrine appearance, a 'marshy' fish community is maintained which developed over the previous stage. The 'Lacustrine' stocks are restored by the recovery of a normal hydrological balance well marked floods, flooding of spawning places ... and the diversification of lake environments. Here zones of open water and zones of vegetation banks coexist with some important mass residuals of marshy vegetation mostly composed of ambatches (*Aeschynomenes elaphoxylon*).

The study of the drought and its consequences on the lake brings out a major characteristic of the Chadian fish fauna which is the constant coexistence of two groups of species. One is more particularly adapted to low waters and the other to high waters (which we have qualified by 'marshy' and 'lacustrine', respectively). The replacement of the dominance of one group by another is very rapid when a change occurs in the lacustrine environment. As no species are restricted only to the lake, the reconstitution of stocks is always possible from river fish communities.

Table 12 List of the species with their codes and initials used in the figures.

Code	Abbreviation	Name
1	XNI	<i>Xenomystus nigri</i>
2	HET	<i>Heterotis niloticus</i>
3	HYP	<i>Hyperopisus bebe</i>
4	MHA	<i>Mormyrus hasselquisti</i>
5	MRU	<i>Mormyrus rume</i>
6	MDE	<i>Mormyrops deliciosus</i>
9	BNI	<i>Brienomyrus niger</i>
11	MCY	<i>Marcusenius cyprinoïdes</i>
12	PBO	<i>Petrocephalus bovei</i>
13	PBA	<i>Petrocephalus bane</i>
14	PIS	<i>Pollimyrus isidori</i>
15	GYM	<i>Gymnarchus niloticus</i>
19	HBR	<i>Hydrocynus brevis</i>
21	ADE	<i>Alestes dentex</i>
22	ABA	<i>Alestes baremoze</i>

Table 12 (continued).

Code	Abbreviation	Name
23	AMA	<i>Alestes macrolepidotus</i>
25	ANU	<i>Alestes nurse</i>
26	MAC	<i>Micralestes acutidens</i>
28	ICH	<i>Ichthyborus besse</i>
29	CIC	<i>Citharinus citharus</i>
33	DRO	<i>Distichodus rostratus</i>
34	DBR	<i>Distichodus brevipinnis</i>
37	LSE	<i>Labeo senegalensis</i>
38	LCO	<i>Labeo coubie</i>
39	BAR	<i>Barilius niloticus</i>
41	BBA	<i>Bagrus bayad</i>
42	CAU	<i>Chrysichthys auratus</i>
{ 44	ABI	<i>Auchenoglanis biscutatus</i>
{ 45	AOC	<i>Auchenoglanis occidentalis</i>
{ 46	CAN	<i>Clarias anguillaris</i>
{ 47	CLA	<i>Clarias lazera</i>
{ 48	CAL	<i>Clarias albipunctatus</i>
49		<i>Heterobranchus spp</i>
50	SCH	<i>Schilbe uranoscopus</i>
51	SMY	<i>Schilbe mystus</i>
52	ENI	<i>Eutropius niloticus</i>
53	SIL	<i>Siluranodon auritus</i>
55	SBA	<i>Brachysynodontis batensoda</i>
56	SME	<i>Hemisynodontis membranaceus</i>
57	SCL	<i>Synodontis clarias</i>
60	SNI	<i>Synodontis nigrata</i>
66	SSG	<i>Synodontis schall-gambiensis</i>
67	MAL	<i>Malapterurus electricus</i>
68	LAT	<i>Lates niloticus</i>
70	TNI	<i>Sarotherodon niloticus</i>
71	TAU	<i>Sarotherodon aureus</i>
72	TGA	<i>Sarotherodon galilaeus</i>
73	TZI	<i>Tilapia zillii</i>
{ 75	CMU	<i>Ctenopoma muriei</i>
{ 76	CPE	<i>Ctenopoma petherici</i>
79	PSE	<i>Polypterus senegalus</i>
80	PBI	<i>Polypterus bichir</i>
82	PAN	<i>Protopterus annectens</i>
83	AND	<i>Alestes nurse-dageti</i>

Table 12 (continued).

Code	Abbreviation	Name
84	TSP	<i>Tilapia and Sarotherodon</i> spp.
85	CSP	<i>Clarias</i> spp.
86	PET	<i>Petrocephalus</i> spp.
92	BAB	<i>Barbus</i> spp.
93	MOC	<i>Mochocus brevis</i>
94	EPI	<i>Epiplatys</i> spp.
96	—	<i>Mochocus niloticus</i>
97	—	<i>Aplocheilichtys</i> spp.
98	—	<i>Aplocheilichtys gambiensis</i>
99	—	<i>Hydrocynus</i> spp.
Regroupments		
25	ANU	<i>Alestes nurse</i>
44	AUC	<i>Auchenoglanis</i> spp.
75	CTE	<i>Ctenopoma</i> spp.
86	PET	<i>Petrocephalus</i> spp.
85	CSP	<i>Clarias</i> spp.

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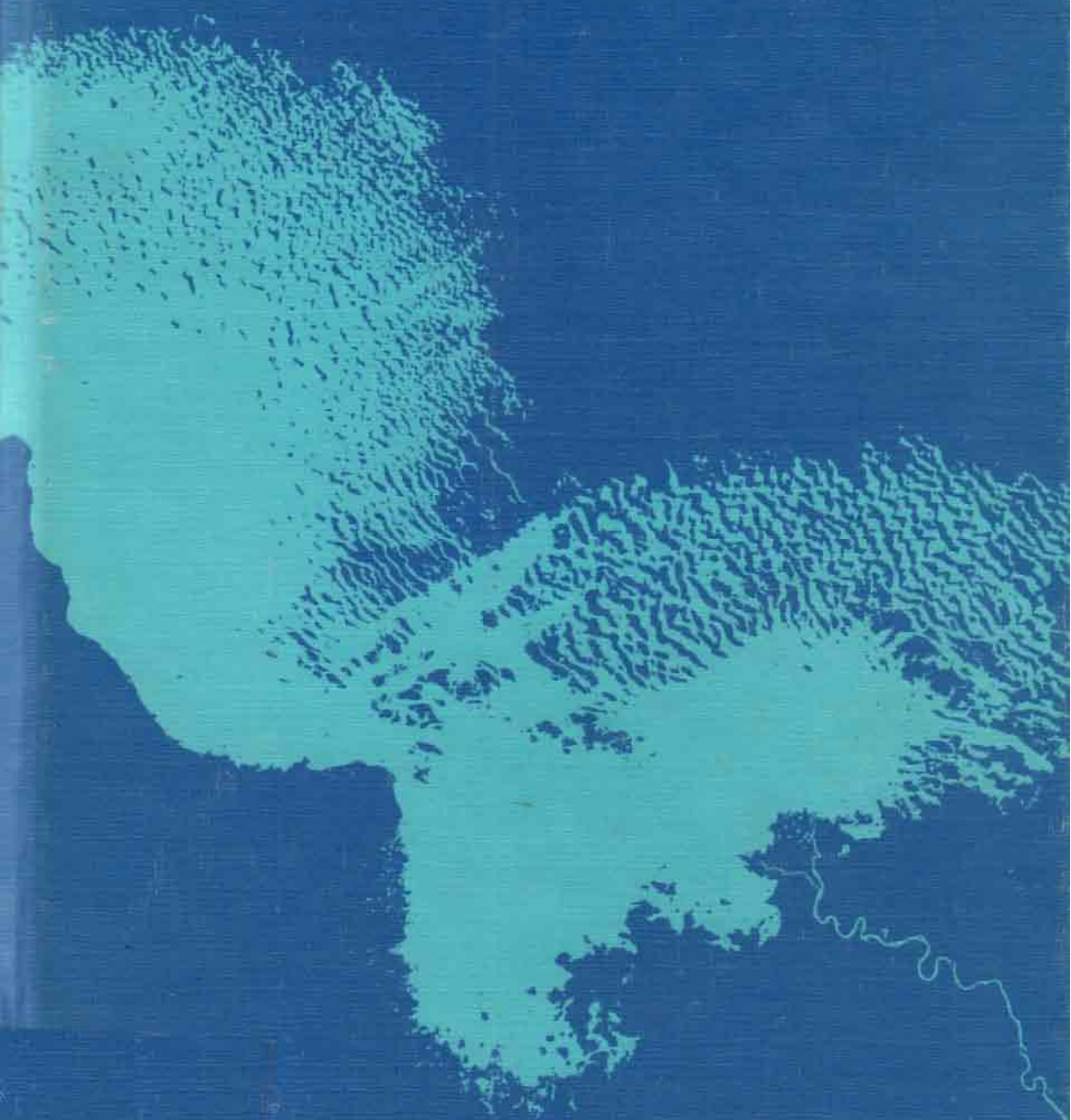
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28

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