CABORA BASSA FISH POPULATIONS BEFORE AND DURING THE FIRST FILLING PHASE

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ABSTRACT

Pre-impoundment surveys were made in 1973–4. The regulatory effect of continual water discharge from Kariba resulted in extensive dry-season aquatic, rooted, vegetal growth and a comparatively high small-fish population. Of a maximum of 38 species found one, *Sarotherodon andersoni*, was a new Middle Zambezi record. Lotic and shallow-water species were abundant; gill-nets showed moderately high catches per unit effort. In early November 1974 two-month-old *Hydrocynus vittatus* juveniles were present indicating an abnormal spawning time. Post-impoundment data from closure on 5 December 1974, to mid-August 1975 are given. The dam filled extremely rapidly to within 10 m of retention level but was thereafter drawn down by heavy floodgate discharge, resulting in continuous slow water-flow and the absence of any stratification or explosive plankton reproduction. Small lotic species, previously abundant, immediately disappeared or became scarce. There was a very high survival of new-spawned young of many migratory species. Growth rates, and abnormal feeding habits caused by post-impoundment stresses, of some of these are described. There was relatively poor reproduction of cichlid species. Soon after closure the first year-class predominated over all other age-groups; these juveniles, and small adult species, concentrated under mats of *Eichhornia crassipes*. One further species new to the area, *Haplochromis carlottae*, is recorded.

INTRODUCTION

That the damming of a river to form a large lake will result in marked changes in the fish fauna, and create new ecological niches, especially in the pelagic zone, was first stated, in so far as African waters are concerned, by Jackson (1959) for the case of the newly impounded Zambezi dam at Kariba. Since then these changes have been extensively studied for the Kariba Dam, closed in December 1958. Much work has also been done on the Volta dam in Ghana, closed in May 1964, and the Kainji dam in Nigeria, closed in December 1968, with some published results from other large impoundments such as Lake Nasser in Egypt, which was closed in its new form in 1966 but which is not expected to reach full retention level until the 1980's (Raheja 1973).

The latest of the large African man-made lakes is Cabora Bassa (Figure 1), which was closed in December 1974. Pre-impoundment work in the dam basin in 1973/74 is summarized here with changes in the fish populations during the dam's first eight months and some comparisons are drawn from experience on other large African impoundments. Any new dam is of

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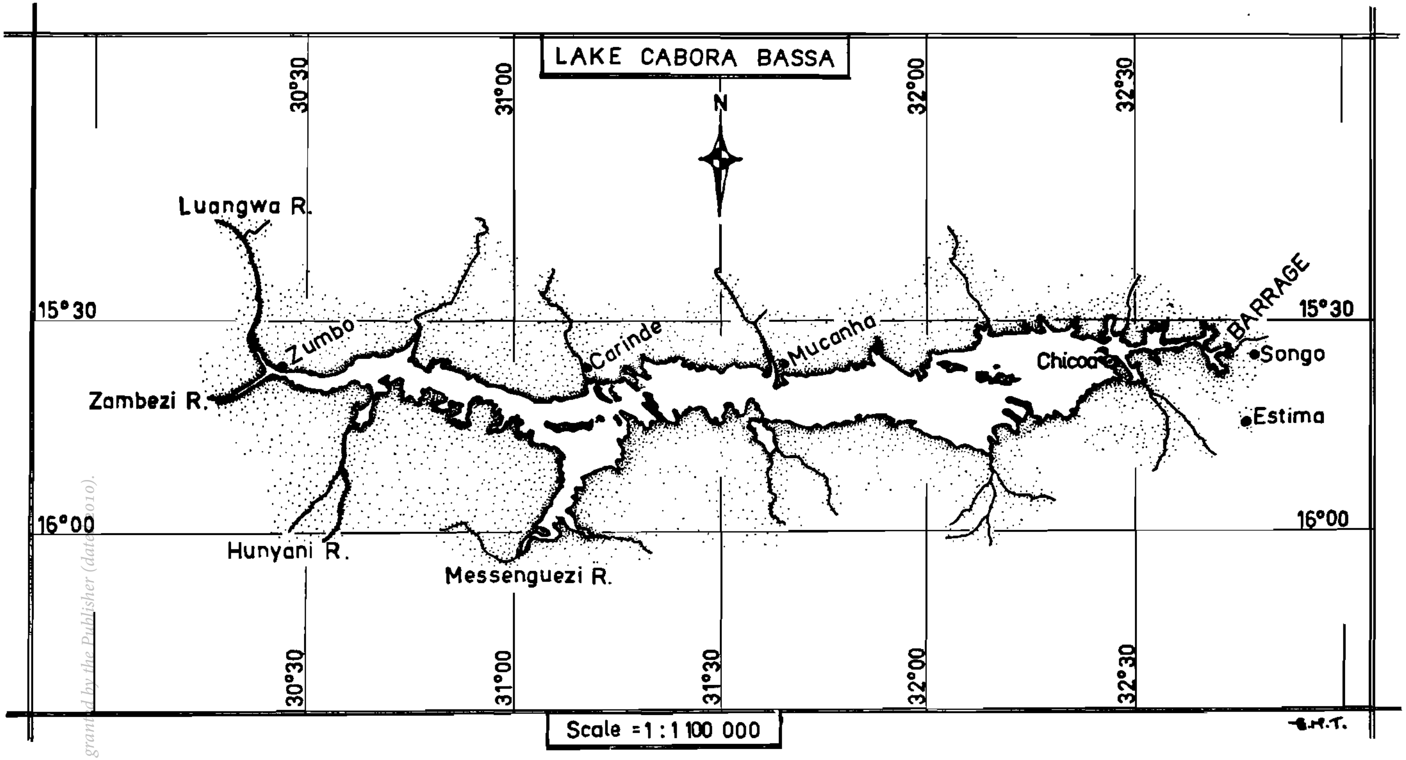


FIGURE 1
The Cabora Bassa Dam, Moçambique, at mean retention level of 326 m AMSL.
(Drawn by E. M. Tarr.)

course mainly colonized and populated by the progeny of the fish stocks of the old river. Their successful reproduction is critical to the new commercial fishery which should soon be one of the major assets of the new dam. The provenance, growth and survival rates of juvenile fish is therefore a main study-need which is emphasized here.

THE FISH POPULATION OF THE MIDDLE ZAMBEZI IMMEDIATELY BEFORE IMPOUNDMENT

Results of pre-impoundment fish-population studies in the Cabora Bassa basin are given by Morais (1974) and Davies *et al.* (1975). These are summarized, with certain additional data collected by one of us (PBNJ), below.

The influence of Kariba

In considering the fauna at this time, the regulatory effect of the Kariba Dam on the Zambezi, in contrast to extremes of low water and high flood which previously prevailed, assumes great importance. Before Kariba, especially because of the extremely low water during the dry season, there was an almost complete absence of rooted aquatic macrophytes except for a few stands of hardy forms such as *Phragmites mauretania* (Jackson 1961). The river-bed consisted mostly of bare sand-banks or rock. But at the height of the 1973 and 1974 dry seasons, work in the future Cabora Bassa area revealed a much stronger water-flow than was the pre-Kariba case; the water was much more turbid and the sand-banks and river edges were covered by a dense vegetation of *Ludwigia* sp., the grass *Panicum repens* and many other aquatic and semi-aquatic plants, including the two pest exotics *Salvinia molesta* and *Eichhornia crassipes*. The main reason for this dramatic environmental change is that Kariba, with its continual discharge of electricity-generating water even at the driest time of the year, has turned the Middle Zambezi from a sand-bank into a reservoir river.

Jubb (1954) was the first to draw a clear distinction between the Middle and Upper Zambezi, the former lying between the Victoria Falls and the Cabora Bassa rapids. Due to Kariba's impact Bell-Cross (1972) redefined the Middle Zambezi to include the Zambezi River and its tributaries (excluding the Upper Kafue) between the Kariba Dam wall and the Cabora Bassa Dam wall, a shorter length of about 560 km. The improved habitat of the Kariba Dam now allows the entry of species of Upper Zambezi or Kafue origin. The various faunas of the Zambezi system are discussed in detail by Bell-Cross (1972); here it suffices to say that the pre-impoundment survey of the Middle Zambezi in the Kariba area showed the presence of only 28 fish species within the area to be impounded (Jackson 1961), but 42 species are now known from the Kariba Dam (Junor 1975).

The pre-impoundment fish population

The same phenomenon of an improved environment caused by an artificial impoundment will probably result in an ever-increasing number of fish species becoming established in Cabora Bassa. Thus the concept of the Middle Zambezi as a distinct zoogeographical entity may soon become obsolete, save in a few tributary rivers such as the Luangwa, where the biota and its

TABLE 1

List of species recorded by Morais (1974:24) from within the Zambezi and the immediately surrounding area later inundated by the dam, and thus in the Cabora Bassa basin before impoundment. Species recorded from elsewhere, e.g. the upper reaches of inflowing rivers, are excluded. A single asterisk (*) denotes species not seen by either of the present authors, while a dagger (†) indicates species whose taxonomic status within the Zambezi below the Victoria Falls is presently under review.

Protopterus annectens brieni Poll, 1961
Anguilla mossambica Peter, 1852*
Anguilla nebulosa labiata Peters, 1852
Mormyrops deliciosus (Leach, 1818)
Hippopotamyrus discorhynchus (Peters, 1852)
Marcusenius macrolepidotus (Peters, 1852)
Mormyrus longirostris Peters, 1852
Hydrocynus vittatus Castelnau, 1861
Alestes imberi Peters, 1852
Alestes lateralis Boulenger, 1900*†
Micralestes acutidens (Peters, 1852)
Distichodus mosammbicus Peters, 1852
Distichodus schenga Peters, 1852
Barbus fasciolatus Gunther, 1868
Barbus unitaeniatus Gunther, 1866
Barbus marequensis A. Smith, 1841
Barbus lineomaculatus Boulenger, 1903
Labeo cylindricus Peters, 1852
Labeo molybdinus Du Plessis, 1963*†
Labeo rubropunctatus Gilchrist and Thompson, 1913*†
Labeo congoro Peters, 1852
Labeo altivelis Peters, 1852
Barilius zambesensis Peters, 1852
Leptoglanis rotundiceps Hilgendorf, 1905
Eutropius depressirostris (Peters, 1852)
Chiloglanis neumanni Boulenger, 1911
Clarias gariepinus (Burchell, 1822)
Heterobranchus longifilis C & V, 1840
Malapterurus electricus (Gmelin, 1789)
Synodontis zambesensis Peters, 1852
Synodontis nebulosus Peters, 1852
Aplocheilichthys johnstonii (Gunther, 1893)
Sarotherodon mortimeri (Trewavas, 1966)
Sarotherodon andersonii (Castelnau, 1861)
Tilapia rendalli rendalli Boulenger, 1896
Haplochromis codringtoni (Boulenger, 1908)
Haplochromis darlingi (Boulenger, 1911)
Pseudocrenilabrus philander (Weber, 1897)

seasonal changes remain, as before, unaffected by impoundments. This will be a classic example of the profound changes that modern man's manipulation of the environment can cause to anciently established ecosystems.

A total number of 58 fish species was recognized from the Middle Zambezi, i.e. from the Kariba Wall to the Cabora Bassa Gorge, before the closure of Cabora Bassa. However, the fact established in the Kariba pre-impoundment surveys, that many of these species find ecological conditions, particularly during the dry season, too harsh to enable them to survive in the main river, but only in upland streams within the system (Jackson 1961), held good here as well. In order to clarify the Cabora Bassa pre-impoundment situation as much as possible for future comparison with the new lake that now inundates the area, the list of species found by Morais (1974), who worked partly by himself and partly with one of us (PBNJ), in the Middle Zambezi within the future lake basin, but *excluding upland streams*, is reproduced here (Table 1). In addition two eel species known to inhabit the river at least seasonally are included. This total of 38 species may be considered the maximum found to occur in the *main river*, as opposed to the *system*, in the Middle Zambezi before impoundment by Cabora Bassa. However some species were not seen by either of the present authors, while the taxonomic status of others is at present under examination. Where applicable, these are so designated in Table 1.

In a survey of this nature it is impossible to obtain an accurate picture of species composition, since the various habitats such as large deep stretches, shallow weedy bays or rocky cataracts each have their own relative abundance of species, while seasonal changes, such as an abundance of new-spawned young, or the upstream passage of many thousand migrating elvers, can change the picture markedly if only temporarily. It is profitable, however, to assess population with gear such as gill-nets for comparison with similar estimations in the past or in the future. In the few areas in a large flowing river where their use is possible, seine nets and a fish toxicant such as rotenone give more accurate population samples than does the gill-net with its bias towards the capture of actively moving species. Employment of all these methods serves to give a fair picture of the faunal composition of the area. The prevailing political situation in the region made work both difficult and dangerous, and, in particular, sampling with explosives, as was done in the Kariba pre-impoundment work (Jackson 1961), was not possible.

Table 2 gives the results of sampling with a gill-net fleet of sizes 1½ to 4 inches stretched mesh. A sample of 2 397 fish was obtained. This method though tending, like all gill-netting work, to catch more of the actively moving and open-water species such as tiger-fish (*Hydrocynus vittatus*) and fewer of the more sedentary and cunning such as *Tilapia rendalli*, is sufficiently large for comparison with past and future work and also, if due allowance is made for such bias, to give an idea of the population structure of fish amenable to capture by this method.

It can be seen that 42,9 per cent, or nearly half the total number (Table 2) consists of two species of the family Characidae, the small carnivorous *Alestes imberi* and the piscivorous *Hydrocynus vittatus*. Similar high figures for characids caught in gill-nets before impoundment were found by Jackson (1961) for the Middle Zambezi in the Kariba basin, and Banks *et al.* (1966) for the Niger in the Kainji basin. No pre-impoundment fish survey was made of the Volta River before impoundment, but figures published by Petr (1969), of catches before the Volta Dam had much effect, show similar trends.

Characidae and Citharinidae together make up half the catch; this again is in line with the population structure found in other African dam basins before impoundment. The commercially important tilapiine species make up about 3 per cent of the total, but it should be remembered that juvenile tilapiines in their sheltered nursery areas are less liable to be caught in small-mesh gill-nets than, say, tiger-fish of the same age.

Small-meshed seine nets are used to sample a different environment, one where the water is often very much more shallow than that in which gill-nets are set. The areas seined are usually bays, weedy shallow areas or shallow running water, in contrast to the deep still backwaters

TABLE 2

Relative abundance of all fish species caught with 1½, 2½, 3 and 4 inch stretched-mesh gill-net at Zumbo, Mague and Chicoa, 1973–74, Middle Zambezi, in Cabora Bassa basin before impoundment.

Species	*Gill-net sizes* 1½ in.	2½ in.	3 in.	4 in.	*Total all nets*	*Percentage of total*
Alestes imberi	526	49	0	2	577	24,0
Hydrocynus vittatus	349	56	9	37	451	18,8
Eutropius depressirostris	339	63	4	13	419	17,5
Labeo altivelis	128	119	33	22	302	12,6
Synodontis zambesensis	7	48	5	130	190	7,9
Distichodus schenga	90	34	3	7	134	5,6
Hippopotamyrus discorhynchus	17	49	4	4	74	3,1
Sarotherodon mortimeri	15	22	27	1	65	2,7
Clarias gariepinus	2	24	28	1	55	2,3
Distichodus mossambicus	23	12	4	1	40	1,7
Labeo congoro	19	12	2	0	33	1,4
Mormyrops deliciosus	6	9	2	0	17	0,7
Tilapia rendalli	2	3	4	1	10	0,4
Mormyrus longirostris	0	1	6	2	9	0,4
Haplochromis codringtoni	0	4	4	0	8	0,3
Labeo cylindricus	2	4	1	0	7	0,3
Heterobranchus longifilis	0	5	1	0	6	0,2
Marcusenius macrolepidotus	2	1	0	0	3	—
Barbus marequensis	0	0	2	0	2	—
Sarotherodon andersoni	0	0	1	0	1	—
Totals	1 527	515	140	215	2 397	99,9

in which gill-nets are usually set. It follows that a different population is sampled, including the small current-loving forms such as *Barilius* and *Barbus* species, as well as the young juveniles of several families, notably Cichlidae and Citharinidae. Table 3 summarizes all catches made in the Cabora Bassa area by small-mesh seine nets and the use of rotenone.

Of the 19 species taken in this way, the eight marked with an asterisk, or 19 per cent of the total, are those which are small when adult and permanently inhabit the predominantly shallow areas. None of them are caught in gill-nets (see Table 2). The remainder, or 2 829 specimens out of a total of 3 499 are larger species which use these habitats only when juvenile, migrating to

TABLE 3

Small and juvenile fish caught with small-mesh seines and rotenone in the Middle Zambezi River, Cabora Bassa basin, before impoundment (1973–74).

Species	*Total*	*Percentage of total*
Distichodus schenga	2 084	59,6
Sarotherodon mortimeri	487	13,9
*Barilius zambesensis**	278	7,9
*Aplocheilichthys johnstonii**	176	5,0
Eutropius depressirostris	110	3,1
Labeo altivelis	101	2,9
*Haplochromis darlingi**	89	2,5
*Micralestes acutidens**	66	1,9
*Barbus unitaeniatus**	48	1,4
Tilapia rendalli	18	0,5
Distichodus mossambicus	11	0,3
Haplochromis codringtoni	9	0,3
Hydrocynus vittatus	5	0,15
*Alestes lateralis**	5	0,15
Labeo congoro	3	0,1
Synodontis zambesensis	3	0,1
*Barbus lineomaculatus**	3	0,1
Labeo cylindricus	2	—
*Barbus fasciolatus**	1	—
Total	3 499	99,8

* Species small when adult.

deeper and more open water at a size of 14–18 cm. Sampling of such areas is for this reason very variable. Juveniles of large adults tended to be especially abundant in early months of the year after most species have bred with the onset of the rains in December. For this reason the above summary is slanted unduly in favour of *Distichodus schenga* on the strength of an exceptionally large proportion of juveniles in one sample collected by Morais, and commented on by him (1974) as dominating that particular catch.

Table 4 breaks down a single sample of 507 juvenile fish collected on 12 November 1973, just before the breeding season when the juveniles of large species with a single rainy-season breeding season were at their minimum. Despite the greater vegetal cover caused by the regulatory effect of Kariba, this is a typically riverine fish fauna of the late dry season, dominated by the shallow-water flow-loving *Barilius zambesensis*, and with only the small minnow, *Barbus unitaeniatus*, additional to the species recorded from the river before impoundment by Kariba by Jackson (1961).

Barilius zambesensis, *Haplochromis darlingi*, *Barbus unitaeniatus* and *Aplocheilichthys johnstonii* are dwarf species and comprised 64,7 per cent of the total sample. This accurately reflects typical late dry-season composition in the Middle Zambezi River, while the high proportion of Cichlidae (42 per cent) indicates equally well the extended spawning period of these species, independent of the seasonal floods.

TABLE 4

Fish collected from small-mesh seining in shallow weedy areas at Zumbo, Middle Zambezi, on 12 November 1973

Species	*Fork length extremes (mm)*	*Number of fish*	*Percentage of total*
Barilius zambesensis	14– 53	277	54,6
Sarotherodon mortimeri	16– 49	152	30,0
Haplochromis darlingi	16– 71	37	7,3
Tilapia rendalli	15– 33	16	3,2
Barbus unitaeniatus	34– 56	11	2,2
Haplochromis codringtoni	24–167	8	1,5
Aplocheilichthys johnstonii	26– 31	3	0,6
Distichodus schenga	49–65	2	0,4
Labeo altivelis	48	1	0,2
Total		507	100,0

Fish species influenced by Kariba

On 11 November 1973, a single specimen of *Sarotherodon andersoni* (Castelnau) was taken at Zumbo in a three-inch gill-net. This is the first record for this species for the Middle Zambezi. Bell-Cross & Kaoma (1971) list a first record for this species from Kariba on 20 March 1969. That this Upper Zambezi and Kafue species might establish itself in the Middle Zambezi is undoubtedly due to the more favourable ecological conditions now prevailing the year round in this area, and approximates more closely the reservoir-river habitat to which this fish is endemic.

On 1 November 1974, before any wet-season rains had fallen, seven juvenile *Hydrocynus vittatus* were taken by rotenone in a shallow weedy bay adjoining and connected to the main river at Chicoa. These ranged from 46–55 mm (fork length) and had clearly been spawned only a few months before at the height of the dry season. Breeding at this time of the year is a previously unknown phenomenon for tiger-fish. The reasons are probably in part the continuous discharge from the Kariba tail-races which keep a consistently larger water quantity than was previously the case, and partly the fact that an unseasonal heavy rainstorm was experienced in the area in the previous July (Morais 1974).

THE SITUATION AFTER CLOSURE

Limnology

A detailed study of limnological changes during the first year after closure is in preparation. Here it is sufficient to say that the dam, after first closure on 5 December 1974, filled extremely rapidly, so that by 5 April 1975, a bare four months later, the dam was within 10 m of average retention level; there was 153 m depth at the wall and over 2 000 km^2 of land was flooded. This unprecedented rate of filling was caused by an especially large volume of water from Kariba being sent down the river in addition to the normal floods at this time of the year, a graphic demonstration of how even such a large river as the Zambezi can be controlled and manipulated by man.

At this stage, in early April 1975 the dam flood-gates were fully opened, sending a huge quantity of water down the lower Zambezi, which rapidly stopped the water rise and drew the water down again to 306 m AMSL (Figure 2). By the end of May the gates were being closed during the day and opened at night. The result of these manipulations by the engineers, without consultation with any biologist (Davies 1975), was that at no time within the first six months was the water body stagnant. The pattern was at all times that of a vast mass of raw flood water in constant, though very slow, motion down the dam. There was thus no stratification, nor was there any great outburst of growth of planktonic organisms, since the slow-moving water-mass had no time to leach much nutrient from the substrate. Up to 5 August 1975, therefore, the dam paralleled the situation found in Kariba (Harding 1961) and Kainji (Turner 1970) where there was no early water stratification, but was in contrast to Volta where early deoxygenation of bottom layers caused some fish kills in the first months (Ewer 1966).

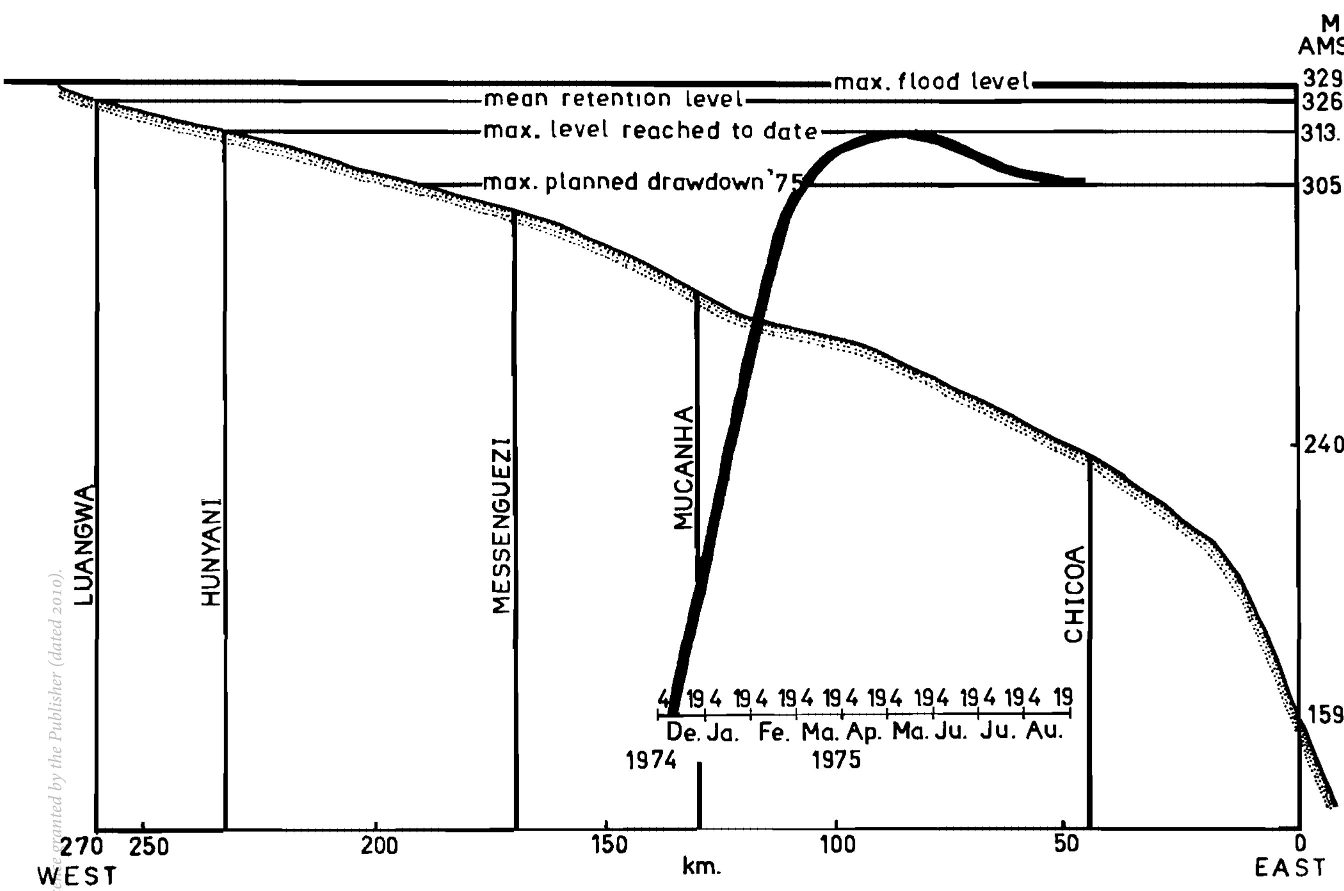


Figure 2
Profile of the Zambezi River in the Cabora Bassa area showing elevations above sea level with the rise and fall of water after closure on 5/12/74 to 19/8/75. Drawing E.M.T.

The recruitment of new-spawned juveniles

General. There was, on the other hand, a very high survival of juvenile fish of most of those species which migrate into flooded rivers and estuaries to spawn. The reasons for this have long been known (Jackson 1960); the conditions for survival of young fish in the newly flooded environment are far superior to those in the shrinking dry-season river. Such conditions are short-lived and other population changes occur as the new lake stabilizes (Begg 1974). But this initial low mortality of new-spawned juveniles is very marked when, as with both Kariba and Cabora Bassa, dam closure coincides with normal flood-season breeding.

Growth and abundance of Labeo congoro and L. altivelis. On 28 February 1975, two-and-a-half months after closure, quantities of very young *Labeo congoro* were feeding at the surface of the rapidly rising lake, among submerging land vegetation at Nova Chicoa. These had a modal fork length of 2,8 cm (Figure 3A). A sample taken on 13 April 1975 had a mode of 6,5 cm (Figure 3B) while another on 28 June was modal at 11 cm (Figure 3C). These indicate approximate growth rates of 3,7 cm in 45 days and 8,2 cm in 121 days. By August 1975 this O + year-class had grown big enough to enter the catches of the smaller-mesh components of the gill-net fleet (Figure 3D). Figure 4 shows a similar rapid growth in the case of *Labeo altivelis*, about 3 cm in five weeks and 9,5 cm in 18 weeks, all from the same locality at Nova Chicoa. These fish had probably all spawned in the neighbouring Inhacapiriri River (Figure 1).

Allowance must be made for the fact that, while these *Labeo* species have a mass migration at early flood, late migrations and presumably spawnings are possible (Bowmaker 1973). This is reflected in the scatter in some of these histograms. In spite of this the growth rates are remarkably rapid.

Similar indications of the high survival and great abundance of these *Labeo* species were present at the Mucanha River, some 135 km upstream from Chicoa (Figure 1). Here the O + year-class of *Labeo congoro* was enormously abundant. Two hauls of a small seine net ($\frac{1}{2}$ inch × 10 m) on the cleared area at Mucanha adjacent to the river produced over 1 800 specimens ranging between 6 and 8 cm in fork length. Many tens of thousands of others were clearly visible in shoals at the surface, both here and, though not so abundantly, at Nova Chicoa.

It is clear that the 1974/75 spawning season resulted in an exceptionally large survival of juvenile *L. congoro* and *L. altivelis* due to the impoundment of the Zambezi at that time. It remains to be seen whether this large year-class of these valuable commercial species will remain in the dam and whether future spawnings will be as successful.

Species composition, relative abundance and ichthyomass of juveniles. Juvenile fish were sampled at various localities with the use of small-mesh seine nets, gill-nets and rotenone. Each method has drawbacks; seining is usually extremely unsatisfactory in the new dam conditions of rock and submerged vegetation; gill-nets do not catch the smaller juveniles; and rotenoning is only possible in a few enclosed areas where the escape of fish can be prevented. Considered together, however, these techniques enable a fairly accurate picture of the juveniles to be built up, while in a few favourable localities a complete collection of the fish was possible.

Such a favourable area was a cove of smooth sloping rock in the gorge of the small eastern

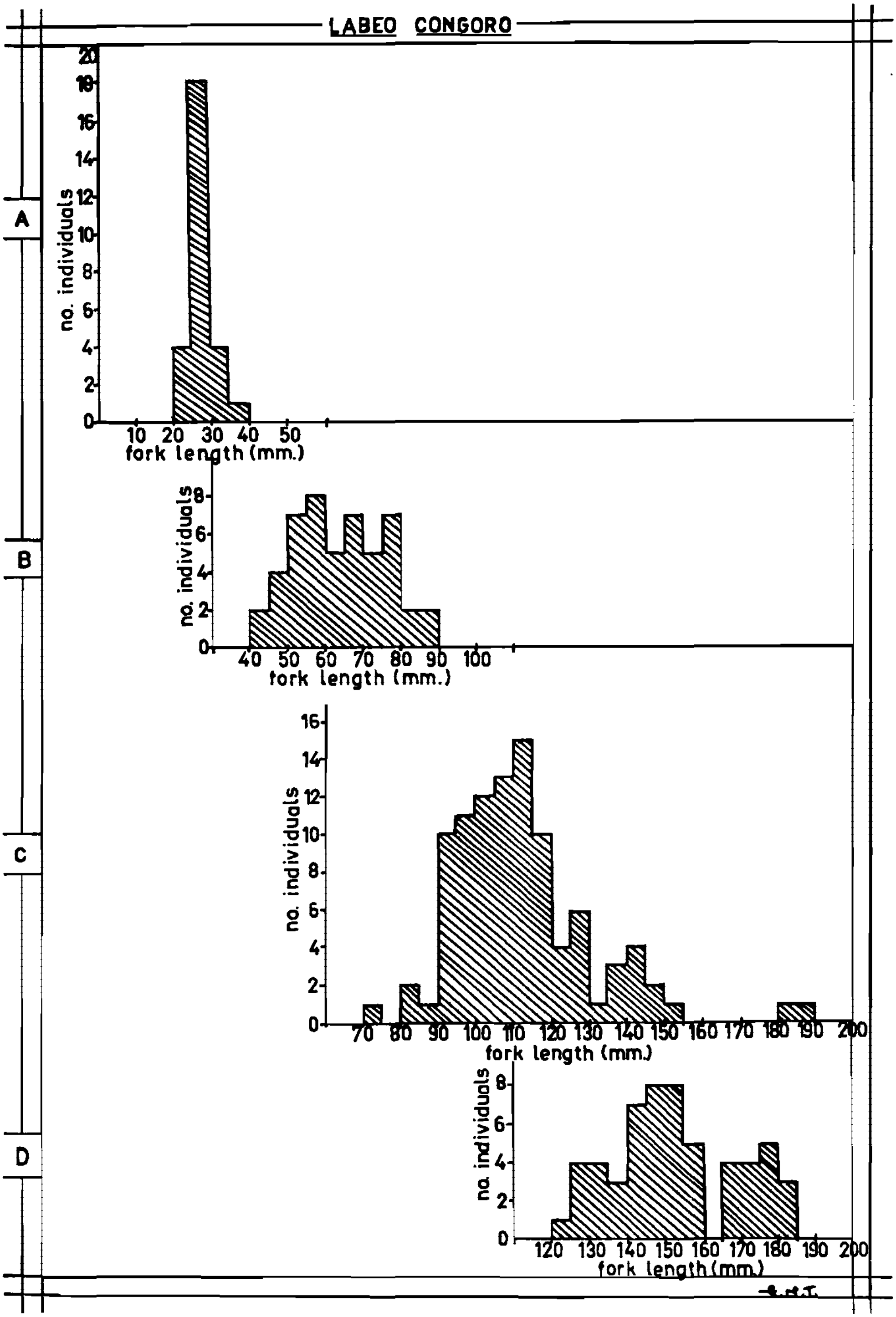

LABEO CONGORO
A
B
C
D
no. individuals
fork length (mm.)

TABLE 5

Species composition and relative abundance of juvenile fish in a small cove, Cabora Bassa, 8 June 1975.

Species	Number in sample	Abundance %
Labeo congoro	45	23,56
Distichodus schenga	45	23,56
Alestes imberi	27	14,14
Synodontis zambesensis	25	13,09
Distichodus mossambicus	22	11,52
Labeo cylindricus	11	5,76
Hydrocynus vittatus	6	3,14
Labeo altivelis	5	2,62
Clarias gariepinus	4	2,09
Pseudocrenilabrus philander	1	0,52
Total	191	100,00

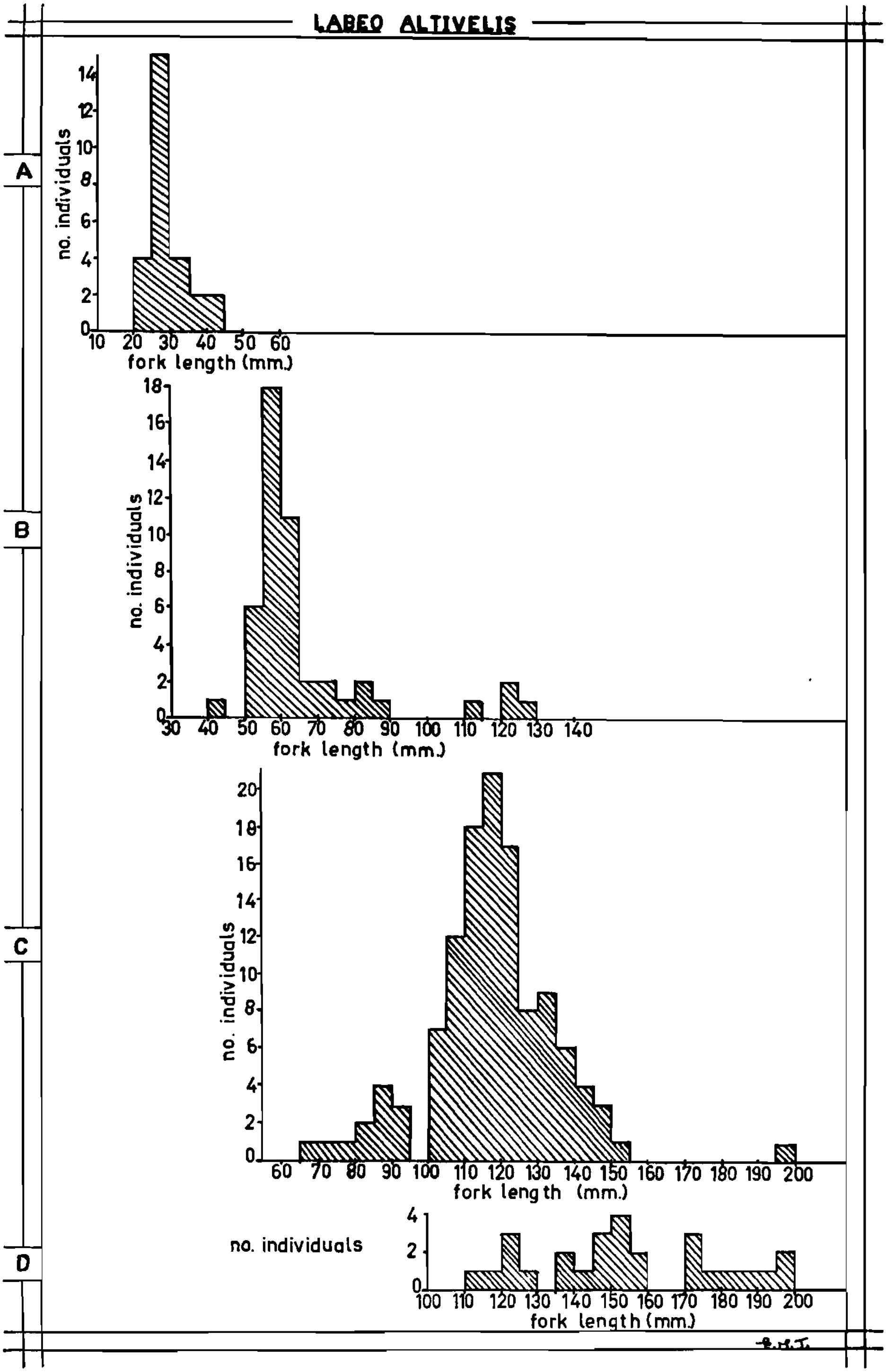
Mucangadze River which enters the Cabora Bassa gorge from the south near the dam wall. This small cove, approximately 60 m² in surface area, is approximately 4 km south-west of the dam wall. It was covered by a mat of floating weed, predominantly *Eichhornia crassipes*, which clearly afforded shelter and cover from predators for juvenile fish, since these were more abundant here than on the adjacent open shore. The seine was drawn in such a way that the entire population in the 60 m² of the cove was obtained. The sample consisted of 191 fish, all of them juveniles, of 10 species, their relative abundance being given in Table 5. The haul was made on 8 June 1975, six months after closure.

Table 6 summarizes catches of juvenile fish made with small-mesh seine nets, hand nets and rotenone at various times from February to July 1975 at three localities from near the top of the dam, i.e. the Panhame (Hunyani)/Zambezi confluence to the gorge near the dam wall. The habitats sampled are as follows:

1. *Panhame* (*Hunyani*) *mouth and Zambezi*. Shallow backwaters (maximum depth ca. 30 cm) with a little weed, mostly *Pistia stratiotes*, and flood debris. Shallow flowing water at river

FIGURE 3

Length-frequency histograms of *Labeo congoro* sampled (A) on 28 February 1975, (B) on 13 April 1975, (C) on 28 June 1975 and (D) on 9–10 August 1975.


LABEO ALTIVELIS
A
no. individuals
0
2
4
6
8
10
12
14
10 20 30 40 50 60
fork length (mm.)
B
no. individuals
0
2
4
6
8
10
12
14
16
18
30 40 50 60 70 80 90 100 110 120 130 140
fork length (mm.)
C
no. individuals
0
2
4
6
8
10
12
14
16
18
20
60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
fork length (mm.)
D
no. individuals
0
2
4
100 110 120 130 140 150 160 170 180 190 200
fork length (mm.)

edge; most *Chiloglanis neumanni* caught with hand nets among debris here.

2. *Chicoa area*. Drowned trees and grass, stagnant water.

3. *Cabora Bassa gorge*. Over 90 per cent of fish caught were associated with weed mats, predominantly *Eichhornia crassipes*. Steeply shelving shores, with water, on the average, deeper than the other habitats.

It is of interest to notice, in comparison with the pre-impoundment situation, the complete absence in any of the catches of *Barilius zambesensis*, any of the small *Barbus* species and *Haplochromis darlingi*, so well represented in pre-impoundment samples. The unequal distribution of cichlid young is also of interest; these are poorly represented in the main dam, but *S. mortimeri*, and to a lesser extent *Tilapia rendalli*, were relatively abundant at the Panhame mouth. At the time of sampling (July 1975) this area had previously been flooded, but with the rapid drawing down of the dam again by the engineers (Figure 2), had reverted to river, with banks scarcely 1 km apart, thus concentrating the fish far more than in the main lake areas of Mucanha and Chicoa. Included in Table 6 are samples of the fish from a shoal of an estimated 150 young *S. mortimeri* of mean fork length of 2,7 cm, caught in the Zambezi River at the Panhame confluence.

Other areas sampled for juvenile fish included the mouth of the Mucanha River and the Messenguezi on the southern shore south-west of Carinde (Figure 1). This river, formed by the confluence of the Ladzi and Mecumbura Rivers, will form a large bay in the southern shore at Longitude 31°15′E, and the only small *Barbus* species found since closure, were taken here.

At Mucanha two hauls of the small seine on 14 April produced over 1 800 specimens of *Labeo congoro* and *L. altivelis* of mean length 6,5 cm, and lesser quantities of young *Clarias gariepinus*, *Synodontis zambesensis*, *Hydrocynus vittatus*, *Eutropius depressirostris*, *Alestes imberi*, *Distichodus schenga* and *D. mossambicus*, but no Cichlidae, either juvenile or adult. The two *Labeo* species dominated the catch (over 90 per cent). Three hauls in the same place on 18 July produced only 53 *L. congoro* and 22 *L. altivelis* with mean fork lengths of 11,2 and 10,1 cm respectively. The thick cover of drowned grass present in April had disappeared by July, when the lake level was some 8 m lower. The discrepancy in the two samples may be explained by greater agility of the larger fishes avoiding the net, by migration out of the area as a larger size is attained, or by high mortality resulting from the absence of cover. Probably it is caused by all three factors. Cichlidae were again virtually absent from the hauls, with only two *S. mortimeri* of 10,4 and 8,4 cm.

At the Messengueze site on 20 July, 26 specimens of a shoal of more than 200 *Micralestes acutidens* were taken by hand net, and also three juvenile *Barbus trimaculatus* (2,5 cm fork length), six *B. unitaeniatus* (juvenile), and one *B. lineomaculatus* (2 cm). These all came off a sandy, debris-strewn bottom.

One reliable ichthyomass figure is at present available, from a cove-rotenoning undertaken from 20–23 June near Nova Chocoa. A small well-defined cove of 450 m^2, reaching a maximum depth of 1,3 m, was screened off with netting, rotenoned and the fish collected until all were

FIGURE 4
Length-frequency histograms of *Labeo altivelis* sampled on the same dates as those in Figure 3.

TABLE 6

Relative abundance of small and juvenile fish caught by small-mesh seine net, hand net and rotenone in the Chicoa basin and the Cabora Bassa gorge as compared to that of fish in the Panhame and Zambezi Rivers.

Species	*Panhame and Zambezi July*	*Chicoa Basin February–June*	*Cabora Bassa Gorge May/June*
Alestes imberi	(1) 20,7	(6) 4,7	(5) 7,9
Sarotherodon mortimeri	(2) 18,0	(7) 4,6	(11) 1,2
Distichodus schenga	(3) 15,7	(5) 8,1	(1) 30,4
Labeo altivelis	(4) 13,6	(1) 31,4	(6) 5,5
Labeo congoro	(5) 8,9	(2) 24,5	(2) 19,5
Hydrocynus vittatus	(6) 4,6	(4) 8,7	(9) 2,1
Eutropius depressirostris	(7) 3,3	—	(15) 0,3*
Marcusenius macrolepidotus	(8) 2,6	—	—
Pseudocrenilabrus philander	(9) 2,3	—	(8) 3,6
Chiloglanis neumanni	(10) 2,1	—	—
Tilapia rendalli	(11) 2,0	(12) 0,2	(13) 0,6
Aplocheilichthys johnstonii	(12) 1,5	(9) 1,2	(12) 0,6
Synodontis nebulosus	(13) 1,5	—	—
Syndontis zambesensis	(14) 1,2	(3) 13,3	(4) 8,5
Clarias gariepinus	(15) 0,7	(10) 0,9	(10) 1,5
Distichodus mossambicus	(16) 0,5	(14) *	(3) 13,1
Malopterurus electricus	(17) 0,5	—	—
Hippopotamyrus discorynchus	(18) *	—	—
Micralestes acutidens	(19) *	(11) 0,4	—
Labeo cylindricus	(20) —	(8) 1,8	(7) 4,9
Heterobranchus longifilis	(21) —	—	(14) 0,3*
Barbus marequensis	(22) —	(13) *	—
Total	99,7	101,6	100
Total number of fish in sample	605	1 061	329

Note. * indicates one specimen only. Figures in parenthesis indicate order of abundance.

removed by the third day. The results are given in Table 7.

A theoretical ichthyomass of 241,7 kg/ha is reflected in these figures, largely of juvenile fish.

A gill-net fleet immediately offshore of this area in water 2–3 m deep yielded among others a second *Barbus marequensis* of similar size, and a large *Tilapia rendalli* (856,3 gm) with testes in active-ripe condition.

Feeding habit changes

A supply of food commensurate with the greatly increased numbers of juvenile fish must have been available to allow for their survival. In the genus *Labeo*, one of the most numerous fish in the new lake, no food problem existed because of the extremely rapid growth of the epiphytic algae, which form the main diet of the genus, on all substrates of tree-trunk, branch and rock over the whole littoral area. Larger *Labeo* were readily seen in the shallowest water, grazing on such attached algae, while in the early months large shoals of the recently spawned juveniles swam commonly on the surface in sheltered areas, feeding on material in the surface film.

Carnivorous species had no such regular and abundant food supply, and several shifts in diet had to be resorted to for survival. The case of the catfish *Eutropius depressirostris* may be considered.

TABLE 7

Species composition and ichthyomass resulting from rotenoning a cove of 450 m^2 surface area near Chicoa, 20–23 June 1975.

Species	*Number of individuals*	*Percentage abundance*	*Total mass (g)*
Labeo altivelis	208	36,56	5 437,9
Synodontis zambesensis	131	23,02	659,9
Labeo congoro	106	18,63	2 202,2
Sarotherodon mortimeri	35	6,15	296,3
Distichodus schenga	25	4,39	299,0
Hydrocynus vittatus	20	3,51	444,0
Alestes imberi	19	3,34	357,0
Labeo cylindricus	15	2,64	48,1
Clarias gariepinus	9	1,58	874,9
Barbus marequensis	1	0,18	257,4
Total	569	100,00	10 876,7

Small-mesh seine nettings at Mucanha in April 1975 yielded numerous examples of small *E. depressirostris* (11,5–14,0 cm fork length). Several of these had recently swallowed young *Labeo congoro* up to 65 per cent of their own length. This abnormally large prey resulted in gross abdominal distension with the predator's body being bent in a semi-circle, and the swimming ability of the fish being considerably impaired. Typical examples are given in Table 8.

The great abundance of *Labeo congoro* made their capture at this time an easy matter, but their rapid growth apparently soon made it impossible for them to be swallowed even by the most voracious *Eutropius*. Three months later the diet had changed completely. Thus in July 1975 of 17 *Eutropius* caught six had empty stomachs, four had regurgitated food and the stomachs of six contained chironomid larvae and mud.

It appears probable that a shortage of normal-sized fish prey in the confused conditions of the new lake had forced the *Eutropius* to attack numerous but abnormally large prey-fish and then, when prey-growth made even this impossible, the catfish had to resort to grubbing for insect larvae in the bottom mud.

At Chicoa, which is not on the mouth of a river and where the juveniles of migratory fish are therefore less abundant, terrestrial insects were taken by *Eutropius* during the initial filling phase, but these declined as fewer drowned insects became available after the first flooding of the land. The data are summarized in Table 9.

Little change in the normal fish diet of *Hydrocynus vittatus* was observed during this period, and at no time was the taking of terrestrial insects observed.

Terrestrial animals were, however, taken during early flooding by *Synodontis zambesensis*, *Clarias gariepinus* and *Alestes imberi*, further evidence of the well-known catholicity of diet of these species. They are listed in Table 10. The abundance of mantids is interesting and unexpected.

The order Reptilia was represented by two unidentifiable snakes of about 40 cm in length, having been eaten by one female *Clarias gariepinus*.

Of terrestrial plants, the most common component was dicotyledonous leaves, both green and dead. Grass leaves were represented, and the most common seeds were of the grass *Heteropogon* sp. *Alestes imberi*, in particular, are often seen attacking heads of grass on the water surface.

Gill-netting data

Due to the above-mentioned difficulties of sampling by seine net, fish toxicant, etc., in the boulder-strewn and tree-studded environment of a recently formed man-made lake, the use of a graded fleet of gill-nets remains the main sampling tool for post-juvenile and adult fish. At Cabora Bassa, a standard fleet of multifilament nylon nets was used of 1½, 2, 2½, 3, 4 and 5⅝ inch stretched mesh, all hung by the third. During this period locally manufactured nets were used; these came in erratic lengths so that the hung lengths of net had to be standardized at 35 m instead of the more usual 50 m. Regular nettings commenced in February 1975 at the research base at Nova Chicoa (Figure 1), and from mid-April to the end of July at the other localities mentioned.

The distribution of adult fish as reflected in gill-netting data. Table 11 summarizes percentages by number of the species taken to the end of July 1975. The Chicoa data, from February to the end of April, are treated separately to allow of comparison between all localities for the

TABLE 8

Abnormally large fish eaten by *Eutropius depressirostris* at Mucanha, 14 April 1975.

Fork length of predator (E. depressirostris) (cm)	*Fork length of prey (L. congoro) (cm)*
11,5	7,5
14,0	two fish 5,0 and 5,5
12,5	4,5
12,0	5,5

TABLE 9

Diet of 63 *E. depressirostris* of sizes 12–31,5 cm fork length in February and March 1975 (rapid flooding of savannah woodland) and of 33 fish 17–18 cm fork length April to June (stable water level), as percentage of the total at Chicoa.

	Stomach contents			
Date	*Fish* %	*Terrestrial Animals* %	*Terrestrial Plants* %	*Empty* %
19/2/75 to 29/3/75	49,3	26,0	2,7	16,4
4/4/75 to 22/6/75	41,9	6,5	0,0	51,6

May–July period. Partly also, this is because the rapidly rising water levels of this time meant that nets at first set among drowned trees on steeply rising ground with a depth of 8–25 m, were in the second period set in water with a level substrate at the edge of the drowned tree-line with a depth of 2–10 m. As gill-nets in all cases were fished at the water surface to avoid entanglement with submerged trees and bush, this may have had some effect on the capture of bottom-frequenting species such as tilapiines. A complete list of the habitats fished in the gill netting operations is given in Table 12.

The final column in Table 11 summarizes the capture of fish in the Cabora Bassa gorge immediately below the wall, when shutting off of the water flow reduced the water to pools in the river bed which were sampled with rotenone.

Several points of interest, enumerated below, arise from consideration of Table 11:

(*a*) The low abundance of adult *Labeo* species (as opposed to juveniles) in the flooded stagnant-water areas of the dam, and the high abundance (higher than pre-impoundment figures) in the Panhame/Zambezi area. It is possible that this may be caused by adult *Labeo*, with their preference for lotic conditions, migrating away from flooded areas to those where running water conditions still prevail. Begg (1974) showed the abundance of *Labeo* in the upper or more riverine basins of Kariba.

(*b*) Conversely, scavenger-predators such as *Clarias* and *Eutropius* are abundant in the dam area. This may have correlations with the presently numerous populations of O + year-class fish around the estuaries of tributaries where they have spawned, as well as the early prevalence of drowned terrestrial animals.

TABLE 10

The main orders and families of terrestrial insects taken by *S. zambesensis*, *C. gariepinus* and *A. imberi*, in order of abundance.

	Order	*Family (ies)*
1.	Orthoptera	Locustidae
2.	Dictyoptera	Mantidae
3.	Coleoptera	Scarabidae, Tenebrionidae, etc.
4.	Hymenoptera	Formicidae, Sphecidae
5.	Isoptera	

TABLE 11

Relative abundance of fish caught by gill-nets at five stations in the Cabora Bassa basin, 1975, after flooding commenced in December 1974. Included is the relative abundance of fish caught with the aid of rotenone in the Zambezi River below the dam wall.

Species	July	July	April & July	May–June	Feb–April	June July	May
	Pan Zam	Mes	Muc	Chi (2)	Chi (1)	Gorge Basin	Zamb Gorge
Hydrocynus vittatus	22,5	20,0	20,1	48,7	45,5	62,3	—
Eutropius depressirostris	8,7	39,9	45,4	10,8	20,4	13,8	—
Mormyrops deliciosus	0,6	—	—	—	—	—	84,6
Clarias gariepinus	0,6	8,3	18,2	20,5	3,9	1,8	—
Labeo congoro	31,3	3,7	0,8	4,3	1,5	3,6	2,7
Labeo altivelis	24,5	8,1	2,1	2,3	2,2	8,7	—
Synodontis zambesensis	2,6	16,9	3,7	3,7	9,7	0,7	2,7
Alestes imberi	4,1	0,8	2,6	5,4	8,5	6,5	—
Sarotherodon mortimeri	3,3	1,2	2,8	3,3	—	1,1	—
Labeo cylindricus	—	—	0,2	—	3,6	0,4	5,1
Distichodus mossambicus	0,2*	0,5	2,0	0,2	3,4	0,4	—
Distichodus schenga	0,9	0,2	1,1	0,2	1,0	0,4	—
Anquilla nebulosa labiata	—	—	—	—	—	—	8,3
Heterobranchus longifilis	—	0,3	0,6	0,4	—	—	1,3*
Marcusenius macrolepidotus	0,9	—	0,09*	0,09*	—	—	—
Mormyrus longirostris	0,4	—	—	0,09*	—	0,4	—
Haplochromis codrintonii	—	—	0,4	—	—	—	—
Protopterus annectens	—	—	—	—	0,1*	—	—
Hippopotomyrus discorhynchus	—	—	—	—	0,1*	—	—
Tilapia rendalli	—	—	—	0,09*	—	—	—
Barbus marequensis	—	—	—	0,09*	—	—	—
Haplochromis carlottae	—	—	0,09*	—	—	—	—
Labeo molybdinus	—	—	0,09*	—	—	—	—
TOTALS	100,6	99,9	100,18	100,15	99,9	100,1	100,2
No. of samples	1	1	2	4	5	2	1

LEGEND
- * = One specimen only
- Pan Zam = Zambezi River near Panhame (Hunyani) River confluence
- Mes = Messenguezi River estuary
- Muc = Mucanha River estuary
- Chi (1) = Nova Chicoa area (Feb–Apr)
- Chi (2) = Nova Chicoa area (May–June)
- Gorge basin = Flooded Cabora Bassa Gorge
- Zamb Gorge = Zambezi Gorge below dam wall

(*c*) The roving, primarily piscivorous predator *Hydrocynus vittatus* has a much higher abundance at Chicoa and in the gorge. These areas, nearest to the barrage, have been flooded the longest.

(*d*) The marked difference in the fish population in the gorge above and below the dam wall is noteworthy. Even including the presence of eels, not of course capturable in gill-nets, only six species were taken below the dam.

(*e*) The lack of Mormyridae in the dam is very marked, while the abundance of *Mormyrops deliciosus* in the gorge below the dam perhaps underlines the known preference of this family for rocky, flowing areas. During this sampling large *M. deliciosus* were observed swimming upstream from one pool to another. Possibly there has been a deliberate migration of mormyrids out of the dam into the flowing rivers above it.

(*f*) *Heterobranchus longifilis*, the well-known vundu, is also little represented in the catches. Mr F. J. R. Junor (in litt. to PBNJ) confirms that, in Kariba, this is a relatively rare fish in the lake proper. Of 3 469 fish caught from 1970–73 in 2–7 inch monofilament gill-nets at Lakeside, Kariba, an area remote from any river, only one was of this species. However, the species is more abundant in river mouths.

(*g*) The generally low abundance of tilapiines parallels the early situation in Kariba where Jackson (1959) caught only 0,75 per cent of *Tilapia mossambica* in 1959. Eighteen months later, however, Harding (1962) had greatly improved catches of 24 per cent of *Tilapia mossambica* in his fleet of gill-nets due to improved breeding as the lake stabilized.

(*h*) One specimen of *Haplochromis carlottae* was caught in a 3 inch gill-net at Mucanha on 14 April 1975. This female specimen of 760 g is the first record of this species in the Zambezi below Kariba.

Catches per unit of effort. Table 13 summarizes the catches by mass of the gill-net fleet in the various localities fished. As mentioned above, all nets were standardized to be 35 m long when hung on the head and foot ropes.

The nets being set at the surface to avoid entanglement, the differences caused by a steeper substrate at Chicoa for the relative abundancy figures are applicable here as well.

The effect of the estuaries as 'focal points' for fish concentrations is again marked. This is because migratory fish used the estuaries to spawn at, or shortly after, the time of closure and the rising waters ensured high survival of this year-class. At present the estuarine fish and their predators are also abundant, resulting in high catches. A trend for catches to become progressively greater the further away from the dam wall is also noticeable.

At this preliminary stage catch efforts for individual species are not given, but are being prepared for a later paper. In general, however, they were, at this early stage in the dam's history, considerably higher for those cyprinids, characids and siluroids with a spawning migration and short breeding season than for the nest-building cichlids.

TABLE 12

Main habitats in which gill-nets were set.

Pan Zam area	Not in main current but in area with slower flow. Depth ± 2 m. Some weed, mostly *Eichhornia* along banks
Messengueze	Flooded river banks amongst drowned trees. Depth 2,5–5 m, no weed.
Mucanha	Cleared area of depth 2–3 m, and flooded river gorge 10–20 m deep. No weed.
Chicoa (1)	*Mostly* along edge of drowned trees. Depth 8–25 m. No weed.
Chicoa (2)	*Mostly* amongst drowned trees. Depth 2–10 m. No weed.
Gorge Basin	Deep water 15+ m. Nets set along edge of weed-mats.
Zambezi Gorge	Fish caught in pools formed after gates were closed. Rotenone thrown in at top end of pool and fish caught as they congregated at downstream end.

TABLE 13

Mean catch per unit of effort at five stations: kg mass of fish caught per 14-hour setting of gill-net 35 m in hung length, multiplied by a factor of 2,857 to convert to unit length of 100 m.

Station	Dates 1975	1½″	2″	2½″	3″	4″	5½″	Number of Settings
Gorge basin	Jun/Jul	6,71	30,74	19,14	19,97	2,83	3,43	2
Chicoa basin	Feb/Apr	6,49	22,43	—	20,71	0,17	—	5
Chicoa basin	May/Jun	9,26	42,43	40,54	28,74	8,37	3,09	4
Mucanha estuary	Apr & Jul	18,00	40,46	68,28	205,53	35,03	88,42	2
Messeguezi estuary	July	46,63	121,22	87,91	186,45	50,37	114,28	1
Zambezi River	July	23,80	74,00	—	55,43	13,26	26,34	1

CONCLUSIONS

The data presented here were recorded up to mid-August 1975, or for the first eight months after closure of the dam. By this time a clear pattern of the rapid disappearance of the lotic habitat species, the high survival rate and consequent rapid population increase of certain siluroids, characids and cyprinids, and the comparatively slower increase of cichlid fish, had become apparent. These population changes taking place in the first year after closure have not been much studied, though both Harding (1962) for Lake Kariba and Ita (1973) for Lake Kainji reported rapid fish population increases taking place in the second year after closure of these dams.

Comparison of Cabora Bassa with both Kariba and Kainji is relevant; with the first because of the similarity of the fish fauna and with the second because of the very high ratio (about 1 : 1) of water flow to stored volume reflected in the rapid filling rate of both dams. Their fish fauna, however, does not appear comparable, as in Kainji the major post-impoundment increase was in the Citharinidae (Ita 1973), and this is unlikely to be the case in Cabora Bassa. There are, however, some physical features peculiar to Cabora Bassa. One is the fact that three major rivers, the Zambezi, the Hunyani (Panhame) and the Luangwa (Arangua) enter at the top of the dam, and these, because of normal draw-down, will have flowing water within the dam basin for at least half of the year. This will probably mean a higher population of the 'riverine' fish species, and will also influence considerably those potadromous components which undertake a spawning migration. Relatively higher populations of these than at Kariba may be expected. Then again Cabora Bassa is likely to be more turbulent, with greater wave action, than other African man-made lakes because it lies due east and west. The dry-season south-east monsoon wind tends to blow down the long axis of the dam, the resulting long fetch generating, especially at the western end, larger and rougher waves than is the case of Kariba, which receives the same wind at right angles.

This storminess of the lake may have some effect on the fish, but a more severe effect is likely to be that of the exotic infestant plants. These are to be discussed in greater detail elsewhere, but it can be said briefly that while Cabora Bassa is the only large African water to harbour both *Eichhornia crassipes* and *Salvinia molesta*, it has been found in practice that the *Eichhornia* completely overshadows and dominates the *Salvinia*, which is small and insignificant in comparison. While growing rapidly, the *Eichhornia* had not, however, reached epidemic proportions at the end of the eight months under consideration. Moreover, some 50 per cent of its total biomass was destroyed by being stranded on banks and trees during the very rapid draw-down illustrated in Figure 2. As described above a marked effect of *Eichhornia* thus far has been the aggregating under it of small and juvenile fish.

Finally it may be mentioned that although Cabora Bassa has only 55 per cent of the surface area of Kariba, it nevertheless has a large open-water area of over 100 km in length eminently suitable for stocking with the Lake Tanganyika sardine *Limnothrissa miodon*. No sign of any *Limnothrissa* has yet been observed, and this fish probably is unlikely to colonize the dam naturally for the reasons given by Kenmuir (1975). Recommendations have therefore been made to the Moçambique Government that artificial stocking should take place in the near future to take advantage of the high productivity of the dam's early years.

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