placed into the same tube as the imagines. Emergence had usually ceased within ten weeks of collection. On cessation of emergence, tanks were cleared, cleaned and refilled. The water was then allowed to mature for approximately six weeks before the next sample was placed therein.

The five hydrophytes sampled reacted differently to being placed in aquaria, which were positioned where they were in direct sunlight for up to five hours each day. Ceratophyllum demersum and Lagarosiphon ilicifolius appeared not to be affected, and plants were as healthy at the cessation of emergence as when originally placed into the aquaria. Salvinia auriculata, on the other hand, usually deteriorated and was attacked by fungus so that within five weeks of collection they had turned brown, although there appeared to be little difference in the submerged part of the plant. Potamogeton pusillus initially reacted well to the aquaria, but within three weeks had begun to develop a heavy growth of periphytic algae. Four to five weeks after being placed in an aquarium this growth appeared to inhibit the plant which was usually reduced to a few strands by the end of the emergence period. This did not, however, seem to inhibit the insect population which continued to emerge up to the tenth week. Much the same sort of reaction was elicited in Chara sp. from the river pools.

No alternative to this method was practicable on consideration of the other commitments of the project. Various weaknesses are immediately obvious. These are:

1. That definite correlations between imagines and exuviae were sometimes obscured by multiple emergence. This difficulty was largely cancelled by earlier or later emergences of individuals of the same species.

2. That certain species could be more greatly affected by conditions in the polythene bag while in transit. Samples were examined carefully shortly after decanting into aqua- . and although occasional dead specimens were found, the vast majority of the population appeared to survive this period. Smaller dead specimens could, however, have escaped notice. Actual _in situ_ sampling would therefore give a better estimate of the population size and constituents though these lack accuracy somewhat at the specific level. Constituents estimated from emergence in the laboratory would therefore be more accurate at the specific level, but less accurate with regard to quantitative estimations.

3. That the final, emerged, sector of the population would bear little relationship to the original sample after enclosure and the effects of predation. Furthermore, an important aspect of predation, by fish, is removed entirely from the population. The effects of enclosure as such could have had, it is suggested, far less effect than the conditions while in transit, bearing in mind the relative size of the insects to the aquarium. The change in the situation regarding predation could have profound effects on the original sample. For these reasons any estimates of seasonal changes in the population constituents or numbers derived from breeding tanks must be regarded with caution. This is also true for estimates of the overall species constitution of the various substrates and the relative density between substrates, all of which can only be regarded as sound if confirmatory of _in situ_ larval sampling. On the other hand, it is thought that estimates of substrate preference for any single species based on relative emergence can be regarded with confidence.

It is considered that robust predatory groups such as the Odonata are less affected by the above treatment than others, and estimates of the original population based on emergence results can therefore be treated with greater confidence. Furthermore, in the same way that it has been proposed that *Hydrocynus vittatus*, as the peak fish predator, can be used to assess relative changes in the fish population, so, it is suggested, can the dragonfly nymphs be used to assess relative changes in the aquatic larval population, being their major insect predator. For these reasons the emergence data have been analysed even though the conclusions reached must be regarded with considerable reservation.

Table 8.19 shows the specific composition of all emergences. A total of 126 emergences of twelve species occurred, 70% of which were Zygoptera.

TABLE 8.19 SPECIES EMERGED FROM ALL SUBSTRATES AND THEIR RELATIVE IMPORTANCE BASED ON NUMBERS EMERGED

ANISOPTERA	NUMBER EMERGED	PERCENTAGE OF TOTAL
Trithemis hecate Ris	1	0.79
Trithemis annulata Beauv.	30	23.82
Trithemis arteriosa Burm.	1	0.79
Urothemis assignata Selys.	1	0.79
Orthetrum trinacria Selys.	1	0.79
Crocothemis erythraea Brulle	1	0.79
Aethriamanta rezia Kirby	1	0.79
Anax imperator var *mauricianus* Ramb.	1	0.79
ZYGOPTERA		
Pseudagrion massaicum Sjost.	41	32.55
Pseudagrion nubicum Selys.	22	17.47
Pseudagrion nigerrimum Pinhey	5	[illegible].38
Ischnura senegalensis Ramb.	23	10.26
TOTAL:	126	

11 SUBSTRATE SUITABILITY

Figure 8.7a demonstrates the relative production of Odonata by the various substrates by comparing histogramically the mean number

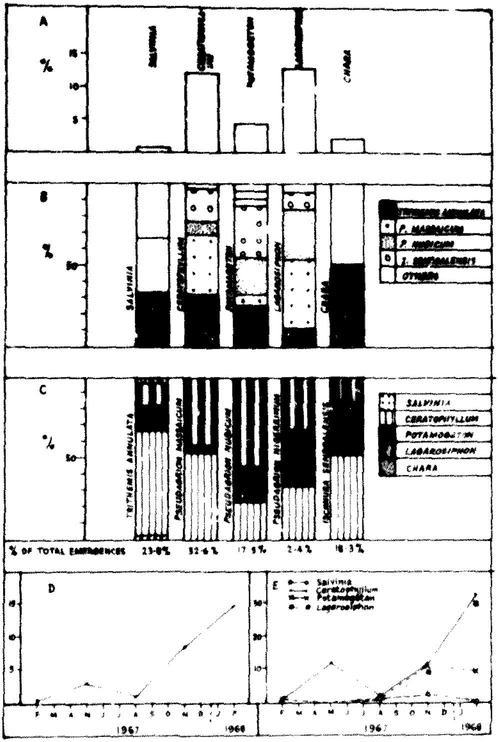


FIG. 8.7. Data on the emergence of Odonata from plant substrates

of emergences per sample, and Table 8.20 elaborates on these. The species composition of the substrates are tabulated in Table 8.21 and figured in Fig. 8.7b.

Lagarosiphon and Ceratophyllum would seem clearly to maintain far larger dragonfly populations than the other three substrates available at that time, and there appears to be little difference between these two substrates on these data as well.

TABLE 8.20 THE RELATIVE PRODUCTION AND NUMBER OF SPECIES FOUND ON EACH SUBSTRATE

SUBSTRATE PLANT	MEAN NUMBER OF IMAGINES EMERGED/SAMPLE		NUMBERS OF SPECIES EMERGED FROM ALL SAMPLES
	Nos.	%	
Salvinia	0.6	1.88	3
Ceratophyllum	12.0	37.56	6
Potamogeton	4.4	13.77	7
Lagarosiphon	13.0	40.69	6
Chara	2.0	6.26	2
TOTAL/MEAN:	6.4		12

Whereas Potamogeton would appear to be less suitable than Ceratophyllum or Lagarosiphon from the viewpoint of numbers of nymphs maintained at any given time, a slightly larger number of species emerged from it than from the latter two. Furthermore, these were found to be more equally distributed between species than on Ceratophyllum or Lagarosiphon, in each of which a preponderance of two species was found, constituting 68.4% of the dragonfly population in the former and 74.2% in the latter, one of which (P. massaicum) was common to both. Salvinia and Chara, with only three and two species respectively, showed a seeming lack of suitability in this respect also.

8.1.2 Species importance and distribution

Single specimens only of the following seven species emerged:

TABLE 8.21 THE SPECIES COMPOSITION OF THE DIFFERENT SUBSTRATES

	T. hecate		*T. annulata*		*T. arteriosa*		*U. assignata*		*O. trinacria*		*C. erythraea*		*A. rosia*		*A. mauricianus*		*P. massaicum*		*P. nubicum*		*I. nigerrimum*		*I. senegalense*		TOTAL
	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	
Salvinia	-	0	1	33.3	-	0	1	33.3	-	0	-	0	1	33.3	-	0	-	0	-	0	-	0	-	0	3
Ceratophyllum	-	0	19	31.7	-	0	-	0	1	1.7	-	0	-	0	-	0	22	36.7	5	8.3	1	1.7	12	20.0	60
Potamogeton	-	0	5	22.7	-	0	-	0	-	0	1	4.6	-	0	1	4.6	2	9.0	5	22.7	1	4.6	7	31.8	22
Lagarosiphon	1	2.6	4	10.3	-	0	-	0	-	0	-	0	-	0	-	0	17	43.6	12	30.8	1	2.6	4	10.3	39
Chara	-	0	1	50.0	1	50	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	2
	1	0.8	30	23.8	1	0.8	1	0.8	1	0.8	1	0.8	1	0.8	1	0.8	41	32.5	22	17.5	3	2.4	23	18.3	126

Trithemis hecate Ris from Lagarosiphon; Urothemis assignata Selys and Aethriamanta rezia Kirby from Salvinia; Orthetrum trinacria Selys from Ceratophyllum; Crocothemis erythraea Brulle and Anax imperator var mauricianus Ramb. from Potamogeton; and Trithemis arteriosa Burm. from Chara.

The most numerous species was Pseudagrion massaicum Sjost. (32.6% of total emergences), which showed very much the same degree of preference for Ceratophyllum as for Lagarosiphon from which substrates 95% of this species emerged. The species would seem therefore, to have either chosen or succeeded on a rather narrow substrate range within which it appears to have been very successful at the time of sampling.

The next most numerous species, Trithemis annulata Beauv. (23.8% of total emergences) emerged from all substrates sampled, but showed a definite preference for Ceratophyllum, from which 63.3% of all emergences of this species took place.

Pseudagrion nubicum Selys and Ischnura senegalensis Ramb. were of equal numerical importance (17.5 and 18.3% respectively). Neither emerged from Salvinia or Chara, but whereas P. nubicum showed a marked preference for Lagarosiphon (55% of emergences), I. senegalensis seemed to show a greater preference for Ceratophyllum (52% of emergences) and to a lesser extent Potamogeton (30.5%) on which substrate it was the single most important species (32%).

Only three emergences of P. nigerrimum occurred, from Ceratophyllum, Potamogeton and Lagarosiphon. There would seem to be therefore, some indication that the species is potentially ubiquitous, but as it only occurred in the final sample, and had seemingly only recently invaded the area, no conclusions may be drawn.

8.1.3 Seasonal variation

The data presented in Table 8.22 and Figure 8.7d and 8.7e indicate a marked increase in the dragonfly population of the aquatic plants during the course of sampling, both in numbers and species. This increase would seem not to be associated with seasonal changes, for the results obtained in February 1967, and February 1968, are markedly different. A high rate of mortality in 1967 cannot explain this difference, bearing in mind that inspection would have undoubtedly revealed a mortality of this magnitude. Some of the difference must have resulted from the introduction of *Lagarosiphon* sampling, but this would not explain the increased emergence from *Ceratophyllum* (Fig. 8.7f). Should the increase observed not have been due to sampling error, as seems likely, the only alternative explanation is that the increase in dragonfly numbers resulted from a maturation or stabilisation of the environment. It seems improbable that, in a single year some ten years after closure, Lake Kariba fauna should undergo such startling changes, unless these changes could be attributed to major environmental differences. It has been shown that these occurred at the time in the aquatic hydrophytes (Chapter 4). Briefly, isolated individuals of both *Ceratophyllum* and *Potamogeton* were found to occur in November 1966, and were well established in isolated large stands by May 1967, when the second series of samples were placed in aquaria. The situation was unchanged by July 1967, when the third series were taken, except for the appearance of a single large stand of *Lagarosiphon* which was sampled for the first time. Thereafter *Lagarosiphon* increased exponentially, replacing some of the *Cerato-phyllum* and nearly all the *Potamogeton* so that the latter had virtually disappeared by November 1968.

TABLE 8.22 THE ODONATA EMERGENCE DATA

	NUMBERS EMERGED					MEAN EMERGENCE PER SAMPLE	NUMBER OF SPECIES BETWEEN SEASONS	NUMBER OF NEW SPECIES	NUMBER OF NEW SPECIES PER SUB-STRATE
	Salvinia	Cerato-phyllum	Potamo-geton	Lagaro-siphon	Chara				
February 1967	0	1	1	ND	ND	0.5	2	-	-
May 1967	0	12	0	ND	ND	3.0	4	3	0.33
August 1967	1	2	1	0	ND	1.0	3	0	0
November 1967	2	12	11	9	ND	8.5	6	2	0.5
February 1968	0	33	9	30	2	14.9	9	4	0.8
TOTAL/MEAN	3	65	16	36	2	5.6	12	-	-

ND - No sample

It would therefore seem likely that the increase and diversification of dragonfly nymphs is associated with the increase in coverage and diversification of the aquatic plants. There are, furthermore, indications that the increase of the overall nymphal population was not just proportional to the increase in substrate, but was more of a logarithmic nature, for as the plants increased, so did the nymphal population per unit plant. The marked increase in emergence from _Ceratophyllum_ and _Lagarosiphon_, and decrease in emergences from _Potamogeton_ between November 1967 and 1968, when considered in the light of the dynamics of the plants themselves indicate, perhaps, that the reverse of this observation is also possible. Namely, as the substrate diminishes, so does the fauna per unit substrate. The lack of emergences from _Lagarosiphon_, when initially sampled, also tends to support this view, though this could have been a seasonal effect.

The general conclusion which may be drawn from this, subject to the reservations mentioned earlier, is that the odonate fauna may only utilize a habitat in full once this habitat is widely established. Also, at some critical stage in the diminution of a substrate, utilisation by nymphs appears to decrease rapidly.

8.1.4 _Discussion_

The lack of knowledge of the aquatic immature stages of tropical insects leads one to suppose that the method described could be of value in assessing accurately the species composition of various substrates, once the technique has been perfected. With further perfection the dynamics of these species could be ascertained with some confidence. Inaccuracy inherent to the method arises from (i) the difficulty of obtaining accurate quantitative samples (i.e., replication problems), (ii) possible mortality during transposition from a natural to a laboratory environment, and (iii) changing the predatory regime; and it is these factors which need to be overcome. The first is common to all non-relative quantitative sampling, the second can be overcome with care and it would be necessary, by comparison with natural populations with the use of emergence traps, to try and ascertain a constant for the third.

Should the tentative conclusions drawn regarding the dynamics of the dragonfly population in relation to the dynamics of their substrate be true, some reason or reasons for this phenomenon must exist. It could be due either to the increased or decreased protection from predation by fish, or to the ovipositional behaviour of adults. In the first instance, established weed beds are extremely dense, whereas free access to fish is given to most plants on initial establishment or when the vegetation type is on the wane. The indications are, however, that this is not the major factor, for when _Potamogeton_ was being replaced by _Lagarosiphon_ in February 1968, the protection offered by vegetation density was relatively constant, yet the Odonata on _Potamogeton_ appeared to decrease relative to other substrates. It would therefore seem possible that the ovipositional behaviour of adults, linked with the availability of substrate, results in the phenomenon.

The question which also arises, linked with ovipositional behaviour of adults, is: are the adults selective for specific plants or, alternatively, are the eggs laid haphazardly on any type of vegetation and the selection for specific substrates, seemingly apparent in these results, is in fact due to the survival of certain species in certain substrates as a result of differences in nymphal adaptations? It is generally accepted that the Odonata seem to be innately bound in their behaviour associated with ovipositing. Certainly some species are, but whether there is an actual choice of specific vegetation and not just a vegetation type (i.e., submerged aquatic with their tips protruding from the water) is still an open question. On the basis of these results, Trithemis annulata would seem to show no specific selectivity, yet the differences in distribution of Pseudagrion massaicum, Pseudagrion nubicum and Ischnura senegalensis which are all limited to three plant species, but in different proportions, could indicate differences in ovipositional behaviour, and selection towards specific plants. Yet equally, oviposition could be linked with a vegetation type and the differences in distribution result from selective nymphal survival.

8.2 Adult Collections and Their Significance

Collection of adult and recognizable nymphal material in the same area, inclusive of bred-out specimens, yielded 28 species of which 12 have been found to utilize the aquatic plant substrate. As yet the nymphal material from benthic collections has not been named, but it is known that the nymphs of Paragomphus hageni (Selys) and Lestinogomphus africanus Fraser burrow under the sandy bottoms of the river pools and that the former is particularly numerous; the large nymphs of Ictinogomphus ferox Ramb. are cryptic and slow-moving and are usually associated with detritus on the bottom of both the river pools and the lake; and the long-legged nymphs of Macromia regina le Roi and possibly Macromia picta (Hagen) are also benthic and favour the river pools. Thus of the 28 species collected, the habitat of the nymphs of eleven of these is not as yet known (Table 8.23). The low frequency of emergence of some of the bred-out material from aquatic vegetation could be an indication that these are not ideal substrates for these species and that optimum conditions are to be found elsewhere, though this is more likely to be a function of the small size of samples taken.

TABLE 8.23 LIST OF SPECIES PRESENT AT LAKE KARIBA WHOSE NYMPHAL HABITAT IS UNKNOWN

Ceriagrion glabrum Burm.
Orthetrum chrysostigma Burm.
Orthetrum falsum Longf.
Orthetrum stemmale kalai Longf.
Palpopleura lucia Drury
Acisoma panorpoides ascalaphoides Ramb.
Brachythemis lacustris Kirby
Brachythemis leucosticta Burm.
Zygonyx torrida Kirby
Pantala flavescens Fraser
Urothemis edwardsi Selys

Balinsky (1967) made extensive collections of dragonflies before Kariba Dam was closed, during flooding and after filling in 1965. He collected 42 different species and a decrease was found to occur in the number of species present during the formation of the lake. Thirty-two species were present on the banks of the Zambesi River, 22 were collected during flooding and 24 were collected after filling in 1965. My own collection of imagines, and those collected by P.R. Alp, are only partly comparable with Balinsky's results for our collection included the river and its pools and were made throughout the year, and any changes of fauna during maturation could be masked by this.

Seven species have occurred in our collection which were not found by Balinsky. These include *Pseudagrion massaicum* which is now relatively common and must have invaded recently. The increase in emergence of this species during the course of sampling would indicate that *P. massaicum*'s invasion was closely linked with the development of submerged aquatic hydrophytes and, also, the unsuitability of *Salvinia* as a substrate for this species. *Orthetrum falsum*

Longf. had also appeared since 1965 and is found along the lake shore. Trithemis hecate Ris. and Aethriamanta rezia Kirby have been bred from aquatic vegetation samples and were very rare during 1967/1968. Only the nymphs of two further species not recorded by Balinsky were collected, that of Lestinogomphus africanus Fraser and Anax imperator var. mauricianus Ramb. Zygonyx torrida Kirby was also collected for the first time in the area, but is understandably not in Balinsky's collection as it appeared to be purely riverine.

Five further species collected by us were found by Balinsky before and during flooding and not thereafter. These were Palpopleura lucia (Drury), Paragomphus hageni (Selys), Macromia picta (?) (Hagen), Urothemis edwardsi (Selys) and Pantala flavescens (Fabr.). All these species were collected by us along the river margins, so in the light of Balinsky's findings would seem to be essentially riverine.

Six species were collected by us in 1967, and by Balinsky after the formation of the lake. These were Pseudagrion nubicum Selys, Ictinogomphus ferox (Ramb.), Orthetrum stemmale kalai Longf., Acisoma panorpoides ascalaphoides Ramb., Crocothemis erythraea (Brulle) and Macromia reginae le Roi, so that it would seem that these species are able to utilize the lacustrine environment. Balinsky (1967) has suggested that the appearance of the previously rare Pseudagrion nubicum was closely linked with the explosive development of Salvinia and that it utilised Salvinia as a nymphal substrate. This may well have been the case prior to the development of the rooted macrophytes, but it would seem from breeding results that Pseudagrion nubicum definitely preferred the latter as a substrate.

A further ten species found by us were found in all Balinsky's collections. The indication would therefore be that these species are able to tolerate widely differing nymphal environments. They are: *Ceriagrion glabrum* (Burm.), *Pseudagrion nigerrimum* Pinhey, *Ischnura senegalensis* Ramb., *Orthetrum chrysostigma* (Burm.), *Orthetrum trinacria* (Selys), *Brachythemis lacustris* (Kirby), *Brachythemis leucosticta* (Burm.), *Trithemis annulata* (Beauv.), *Trithemis arteriosa* (Burm.) and *Urothemis assignata* (Selys).

Nine species were found by Balinsky in 1965 and were not collected by us. This is insufficient in itself to suggest that these species are dying out as the lake matures and further collections will have to be made before any conclusions may be drawn. However, a further thirteen species were collected by Balinsky before and during flooding, but not after the lake's formation, and it would seem that these have not been able to utilize the lake after its formation, as they were not collected by us.

I am extremely grateful to Professor Dr. B.I. Balinsky who identified the individual emerged Odonata.

CHAPTER 9

THE FISHES : DISTRIBUTION IN THE LAKE AND RIVER

1. METHODS OF SAMPLING

Hand nets, seine nets, fish poisons, electrical gear, traps and gillnets were used to sample fishes, the latter method being the most frequent and regularly used to sample the lacustrine portion of the study area.

1. Hand Nets

Hand nets were used irregularly to capture juvenile and small fish species, particularly in association with vegetation. They were also used in conjunction with rotenone and electrical gear.

2. Seine Nets

A 30 metre long by 3 metre deep seine net without a cod and with relatively fine mesh (13 mm stretched set by the half) was used extensively in the riverine pools, usually in conjunction with poisoning. It was not possible to use this net in the lake due to the lack of clear pitches.

3. Fish Poison

Rotenone, at a concentration of 2 ppm, was used to sample the fish population in the riverine pools during the dry season. The usual procedure was to add rotenone to a pool until the working concentration was reached and then collect surfacing fish by hand net until surface activity ceased. The pool was then seined repeatedly until the catch was reduced to a few fish. In the rocky pools a certain proportion of fish were not collected, as witnessed by subsequent surfacing of putrefied fish. Fish could be cleared easily from those pools without snags however, such as Surprise Pool and Champs Pool (the pool at the head of the Champs Elysees).

4. Electrical Fishing

A portable AC/DC generator, delivering both 110 and 220 volts, was coupled to various electrodes in an attempt to collect fish by shocking. Trials were undertaken and the most effective combination was found to be 110 volts DC. Although the method was used on several occasions in the river and the highest point of backflooding by the lake and produced some interesting juvenile fishes, it was found to be both dangerous and cumbersome in general use and was unsatisfactory in turbid water. In the latter instance many fish were lost before they could be netted.

5. Traps

Three traps approximately 1.2 x 1.2 x 1.5 m, covered with 2.5 cm wire mesh and with funnel entrances, were used in the study, both baited in static water and in conjunction with rough stone barrier walls to capture migrating fish in the flowing river, during the lower flow periods.

6. Gillnets

Gillnets were used extensively in the survey. The standard net used was of a "multimesh" type and the dimensions when set were 91.5 m long by 2.1 m deep (100 yards by 7 feet). Netting was mounted "by the half" (e.g., 10 m stretched mesh mounted to 5 m head and foot ropes) and was composed of 10 panels 9.2 m long when set, the smallest mesh being 38 mm stretched, increasing by 13 mm (½ inch) increments to 150 mm (6 inches). Some nets were balanced to fish on the bottom and others at the surface. Surface and bottom nettings were always carried out simultaneously at any station, except in water shallower than 5 m when most of the water column was fished. All nets were anchored at each end with heavy concrete blocks and buoyed with orange polystyrene floats which were attractive to crocodiles and required frequent replacement. Nets were set in the evening and raised the following morning, usually fishing for 12 hours. Variations which occurred in the fishing period were corrected to 12 hours. Nets were only fished if in perfect condition, which could be restrictive as damage caused by crocodiles to surface nets was occasionally considerable. Results were corrected for any loss of panels which occurred.

Nets were usually lifted before 0600 hours. Catches were separated into mesh panel groups (Fig. 9.1) and weighed before being further separated by species. Individual fish were weighed (to the nearest 1 g if lighter than 1 Kg and the nearest 5 g if heavier) and measured (fork length in millimetres). The procedure thereafter was to test for a "ripe running" condition by stroking firmly along the side of the belly from pectoral fin to vent and then to open the fish ventrally from gut to operculum for observation of sex, breeding condition and stomach contents. Breeding condition was allocated one of seven categories as follows:

I - Inactive; IA - Intermediate between Inactive and Active;

A - Active; AR - Intermediate between Active and Ripe;

R - Ripe; RR - Ripe-running; S - Spent.

This categorisation followed standard procedure used by the Joint Fisheries Research Organisation of Northern Rhodesia and Nyasaland and is somewhat subjective, being based initially on gonad size relative to the fish, gonad colour and development of the gonadial blood vessels. At later stages of activity the gonad is cut and examined for ripeness. The "Ripe" category in females refers to fish with ova free and unconnected by tissue within the ovary, and in males to a copious exudate

Fig. 3.1 Typical gillnet catches. The fish are from two nettings, separated by mesh panels. Both nettings are from Station 4, set on the night of 21/1/68. The left-hand row is from a bottom setting and the central and right-hand row are from the surface.

of milt from the incision made in the testis. In the cat fishes the development of the accessory glands in the male were also used as indicators of readiness to breed. "Ripe-running" fish were those which emitted ova or milt on being stroked. The "Spent" condition was only discernable in female fish, where the ovary was contused, empty and flaccid. The infrequency with which this condition was found suggests that ovarian recovery, after breeding, was rapid and fish categorised as "Inactive" could have bred only a few days previously. Only R, RR and S conditions have been considered for analysis in this instance as they are the least subjective and are therefore sound indicators of the imminence or recent occurrence of breeding. The other categories are therefore not described. Whenever possible the gut contents were analysed immediately. On occasions, however, due to their complexity, they were stored in 10% formalin for later examination. Scales were removed from the shoulder of each fish, washed and stored in an envelope with relevant data.

A modification of the gillnet used to sample movement of fish in the river was a trammel net 30 m long by 2.1 m deep, composed of large and small mesh netting hung on the same head and foot rope. The smaller mesh was always set upstream and was loosely hung to bag through the larger mesh. Various combinations were tested and the most successful was found to be the 127 mm/63 mm meshes. The advantage of this net was that a wide range of fish sizes were liable to capture. Trammel nets were usually swum for 15 minutes and the direction of movement of each fish, apart from the other information for individual analysis mentioned above, was noted. These nets proved reasonably adequate sampling tools in the river, but above a certain flow level were unsatisfactory when the nets were lifted by the current and lay along the water surface.

Prior to the present study, attempts to fish gillnets within a permanent Salvinia mat had proved unsuccessful. An assessment of fishes associated with the mat was vital to an understanding of its effects and attempts were made to develop a satisfactory method which included vertically hung nets. The most satisfactory method developed and that used in this study involved a rapid shooting of nets off a stern platform of a launch powerful enough to pass rapidly through the mat. A suitable platform was constructed on the stern of M.V. Erica. Nets were carefully laid to shoot freely from this platform. The procedure followed thereafter was to enter the mat at 10 knots, maintaining this speed while shooting the nets. When the netting station was reached, the anchor and buoy were dropped and the net was pulled off the shooting platform, entering the water where the mat had been parted by the boat and settling into a fishing position before the gap left by the passage of the boat closed. The net was therefore laid extremely rapidly and preparatory folding had to be perfect. Lifting nets through the Salvinia proved particularly arduous and no efficient method to accomplish this was developed.

As the study progressed so did the efficiency of sampling. The number of "net nights" at all stations during the different sampling periods are given below:

Jan/Feb 1967	:	12
April/May 1967	:	24
July/Aug 1967	:	24
Oct/Nov 1967	:	28
Jan/Feb 1968	:	26

An attempt was made to carry out at least three nettings at each station both at the surface and on the bottom. This series constituted the seasonal survey, or the first phase of gillnetting. The second series involved bottom settings only at Station 3 (Parrot Bend) which had shown itself to be, in the first series, a key position in the "estuary", particularly in association with the congregation of fish prior to and during the rains. During the second series 600 metres of netting was set over two nights at fortnightly intervals, coinciding with new and full moon periods. This programme was initiated in June 1968 and terminated ten months later in April 1969, having been devised with several aims in view; primarily to monitor the body of fish congregating at the river mouth before and after running upstream and to gather more detailed information on behavioural differences of the species involved; secondly to ascertain whether there was any marked lunar effect on catches and to provide further information for analysis of mesh efficiency and selectivity. A further difference between the seasonal and fortnightly programmes involved the procedure with the catch. In the second phase, catches were separated according to mesh panel and species and were only weighed. Detailed biological data were not collected. A third netting series involving Station 3 and other stations further into the lake was initiated in August 1969, but is not reported on here.

Although the gillnet is a convenient sampling device, it is clearly selective towards errant as opposed to sedentary species and does not usually capture juvenile fish. Furthermore, some of the errant species are less prone to capture by this method than others, particularly in the case of the Barbel, Clarias gariepinus, which were observed to feel nets with their barbels and avoid them. At no time during the course of this study did the comparatively small number of Clarias caught reflect the numerous large shoals feeding at the water surface. In view of this obvious bias, the data presented only reflect the fish population as captured by gillnet, or the "gillnet population", as opposed to the true population.

Sampling of the fish fauna of the pools by seine net and poisoning was undertaken at five pools between October 1966 and November 1968, during the rainy season between February 1967 and February 1969.

1.1 Mesh Selectivity

In order that some idea of the selectivity of the multimesh fleet could be gained, data from the fortnightly 1968/69 gillnet programme have been analysed and are figured (Fig. 9.2). Intermediate zero readings for Clarias gariepinus and Labeo lunatus have been ignored in drawing the curves as it is considered that these result from sample sparsity. As it stands the data would appear to give some indication of selectivity for these two species, thus they have been included. The efficiency of the multimesh gillnet in sampling the various species is apparent from the curves (Fig. 9.2) and four types may be distinguished. The first of these, illustrated by that of Cyphomyrus, indicates that a major portion of the population is not sampled as meshes are not sufficiently small. The second type, illustrated by Synodontis, Hydrocynus, Eutropius, Mormyrops, Labeo lunatus and Labeo altivelis, approximates to a normal distribution curve indicating that the major portions of the population are sampled by the 58 to 150 mm mesh range used. The third type, as seen in Labeo congoro and Clarias, indicates than an important part of the population is perhaps not sampled due to the 150 mm mesh being too small to take this part. The data are sparse, however, and questionable. The fourth type, illustrated by Mormyrus, definitely indicates that a major portion of the population is not sampled, the mesh range not including sufficiently large meshes.

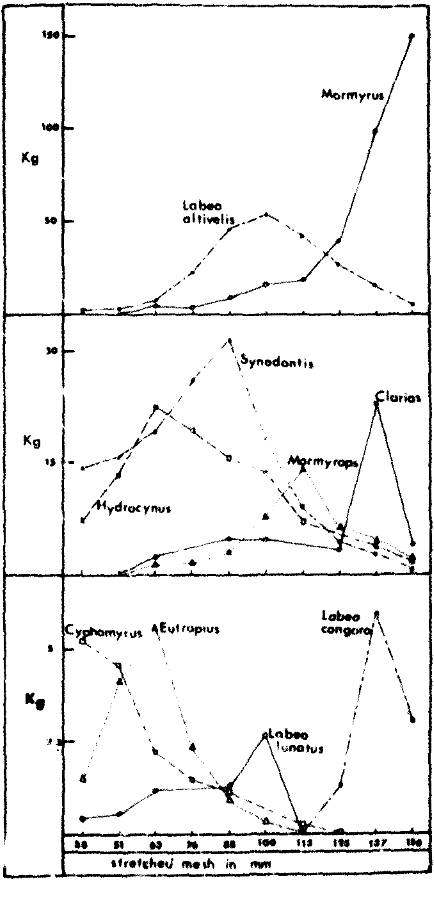


Fig. 9.2. Total catches of various meshes by species (specific selectivity curves).

2. RESULTS FROM THE QUARTERLY GILLNET PROGRAMME (1967/68)

2.1 Species Composition as Reflected by Gillnets

Sixteen of the possible 69 species present in Lake Kariba (Bell Cross, 1972) were caught by gillnets in the proportions by weight shown in Table 9.1. The single most important species was *Labeo altivelis*, by itself constituting 1/3 of the fish population. *Hydrocynus vittatus* was also a dominant constituent, making up 1/4 of the population. *Mormyrus longirostris* was an important part of the population, providing 1/10 of the biomass. Other species which were present in some density, in more or less the same proportions, of approximately 1/20 each, were *Mormyrops deliciosus*, *Clarias gariepinus* and *Synodontis zambezensis*.

2.2 Variations in Gillnet Catches

The overall mean catch by gillnets was found to be 6.5 Kg/91.5m/12 hours, the results from surface and bottom sets being remarkably similar (7.0 and 6.0 Kg/91.5m/12 hours respectively). Data are presented in Table 9.2 and Figure 9.3.

Seasonal Changes (9.3A, D). The seasonal trend in catches was followed closely by both surface and bottom set nets, high densities occurring during the rains and low densities in winter. The increase in density during the rains was most apparent at Station 3 in 1967 and Station 4 in 1968, coinciding with proximity to the mat edge which moved inwards during 1967. There would therefore seem to have been a major concentration of fish in association with surface waters against the mat edge in both 1967 and 1968 during the rains. Species involvement will be considered below.

Spatial abundance (9.3A, C). Overall mean density data considered by stations indicate lowest densities of fish susceptible to capture by gillnets occurred in the open bay, increasing inwards to the section

TABLE 9.1 THE FISH SPECIES TAKEN BY GILLNET AND THEIR OVERALL PERCENTAGE COMPOSITION BY WEIGHT FROM APRIL 1967 TO FEBRUARY 1968

	%	%
MORMYRIDAE		19.9
Mormyrops deliciosus	5.8	
Cyphomyrus discorhynchus	2.5	
Mormyrus longirostris	11.6	
CHARACIDAE		26.6
Hydrocynus vittatus	26.2	
Alestes imberi	0.4	
DISTICHODONTIDAE		P
Distichodus mossambicus	P	
CYPRINIDAE		35.7
Labeo altivelis	34.5	
L. congoro	1.2	
L. cylindricus	P	
SCHILBEIDAE		1.9
Eutropius depressirostris	1.9	
CLARIIDAE		6.7
Clarias gariepinus	6.3	
Heterobranchus longifilis	0.4	
MOCHOKIDAE		7.1
Synodontis zambezensis	7.1	
CICHLIDAE		2.1
Tilapia rendalli rendalli	0.1	
T. mortimeri	1.9	
Haplochromis codringtoni	0.1	

P : Present

TABLE 9.2 THE MEAN SEASONAL GILLNET CATCH AT DIFFERENT STATIONS (in Kg/91.5m/12 hours)

STATION/SEASON	JAN/FEB 1967	APRIL/MAY 1967	JULY/AUG 1967	OCT/NOV 1967	JAN/FEB 1968	OVERALL
SURFACE						
1 (*Ceratophyllum*)	-	14.8	13.7	18.8	7.1	5.5
1 (Open water)	10.0	7.4	2.3	5.7	5.2	[illegible].0
2 (Open water)	26.1	5.2	5.5	3.7	7.8	6.8
3 (Open water)	39.7	10.7	9.5	14.2	19.4	11.8
4 (*Salvinia* and open water)*	7.8	5.5	3.2	19.6	55.8	12.7
5 (Under *Salvinia*)	-	-	1.2	7.6	11.7	4.3
TOTAL	83.2	43.6	35.4	69.6	107.0	
MEAN	20.8	[illegible].9	5.9	11.6	17.8	7.0
BOTTOM						
1 (Open water)	-	6.7	5.3	2.[illegible]	4.5	2.8
2 (Open water)	-	15.6	4.9	1.6	13.6	7.3
3 (Open water)	28.6	18.8	15.6	13.4	34.9	12.7
4 (*Salvinia* and open water)*	-	-	2.8	21.7	13.0	5.3
5 (Under *Salvinia*)	-	-	4.2	21.3	15.0	6.4
TOTAL	28.6	41.1	32.8	60.0	81.1	
MEAN	(28.6)	13.7	6.6	12.0	16.2	6.0
OVERALL						
TOTAL	111.8	84.7	68.2	129.6	188.1	
MEAN	22.9	10.6	6.2	11.8	18.0	6.5

*Station 4 became free of *Salvinia* by November 1967.

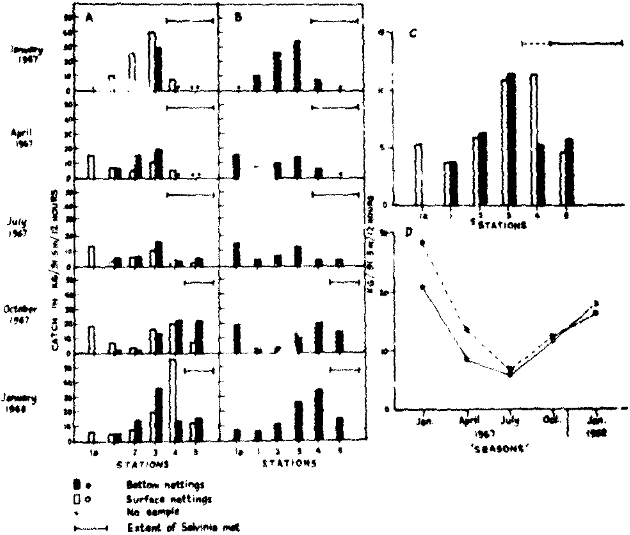


Fig. 9.3. The distribution and abundance of fish as reflected by gillnets.

A : Mean catches at surface and bottom.
B : Mean combined surface and bottom catches.
C : Overall mean catch at different stations.
D : Overall mean seasonal catch in surface and bottom nettings.

between Stations 3 and 4 and decreasing again under the permanent mat at Station 3. The mean values for surface and bottom nettings were similar between Stations 1 and 3. This trend was found not to persist into the "estuary" as witnessed by the considerable difference between surface and bottom catches at Station 4, although a similarity was again apparent at Station 5. The density of nettable species underneath the Salvinia mat was similar to those found in the open bay. The high density of fish at the surface at Station 4 can be attributed to the extraordinarily high catches during the 1968 rainy season where the mean catch rose to 56 Kg/91.5m/12 hours (123 lbs / 100yds/12 hours). Catches at Station 3, on the other hand, were consistently higher than in the open bay, particularly in association with the bottom, which could be a function of depth (10 m at Stn 3, 18 - 21 m at Stns 1 and 2). Catches on the bay margin in the Ceratophyllum beds were consistently more productive than at the open water stations and showed a decrease during the 1968 rains, due perhaps to a movement of fish to the river mouth as reflected in the synchronous increase in catch here.

2.3 Vertical Distribution of Species

A clear impression of differences in specific composition between surface and bottom catches was gained during the course of field work. The mean catch of each species, at the surface, on the bottom and in the Salvinia mat and Ceratophyllum beds was therefore analysed (Fig. 9.4). Ignoring for the moment the portion taken in vegetation, only Mormyrus longirostris and Synodontis zambezensis appear clearly as essentially bottom dwelling fish. Apart from Alestes imberi which appears on these data to be surface dwelling, all other species were more or less evenly distributed between surface and bottom. When surface distribution in relation to vegetation is considered however, a major propor-

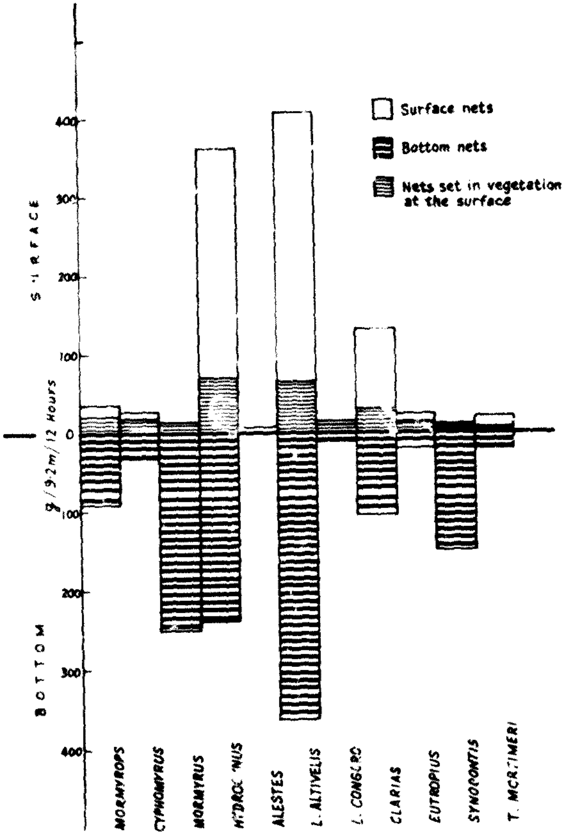


Fig. 9.4. The overall mean catch of different fish species separated according to vertical distribution.

tion of the *Mormyrus* and *Synodontis* (which seem clearly bottom dwelling) caught on the surface were caught in association with vegetation. This would indicate an affinity of these bottom dwellers for the surface only if vegetation is present. If this should be the case, the *Mormyrops*, *Cyphomyrus*, *Labeo congoro* and *Eutropius* should also be included in the benthic category, as a major proportion of the surface catch of these species was taken in vegetation, and a larger proportion still was taken by bottom set nets. These four species obviously would not be as markedly bottom dwelling as were *Synodontis* and *Mormyrus*. The density distribution of *Hydrocynus*, *Labeo altivelis*, *Clarias* and *Tilapia mortimeri* showed little variation between surface and bottom.

2.4 Spatial Differences in Species Composition

Stations 2 and 4 have been omitted from the analysis of species composition presented here to render the data more easily understandable. Species composition at Stations 1 and 2 were in any case similar, while the removal of *Salvinia* at Station 4 halfway through the programme renders overall analysis of the results from this station unsatisfactory. Station 1 results are therefore presented as representative of the open waters of the bay, Station 3 as the open waters of the "estuary" and Station 5 as the *Salvinia*-covered "estuarine" habitat. The faunal composition of the *Ceratophyllum* beds are included as a separate habitat (Fig. 9.5).

The fish population of surface waters in the bay were clearly dominated by *Hydrocynus* (86% by weight) and although several other species occurred there, they did so infrequently and were relatively insignificant as population constituents. At the bottom, however, *Hydrocynus* was of little importance (17%). Typical here were *Synodontis* (27%) and Mormyrus (40%). The other mormyrids, *Eutropius* and *Labeo*

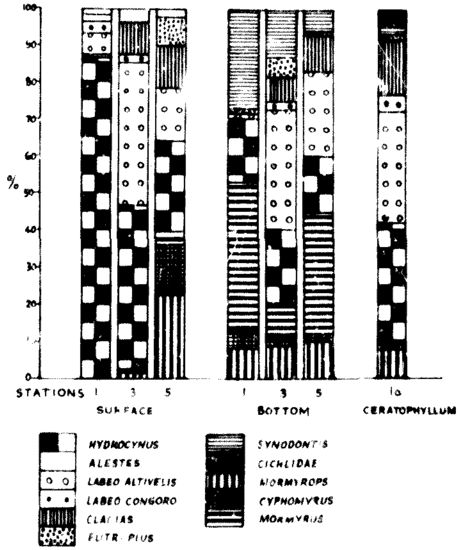


FIG. 9.5. The species composition in the open lake (1), the Salvinia free waters of the "estuary" (3) and the Salvinia covered portion of the "estuary" (5), at surface and bottom; and the Ceratophyllum bed.

altivelis also occurred.

In the *Salvinia*-free surface waters of the estuary, *Labeo altivelis* (39%) appeared as a more or less equally dominant constituent as *Hydrocynus* (44%) and *Clarias* increased in importance (15%). Along the bottom, at a depth of 10 metres a far more equally proportioned population was found; most species being significantly represented, although *Labeo altivelis* was the single most important species (32%).

Although the depth of water where netting took place in the *Salvinia* mat was only 5 m, the differences in population composition between surface and bottom, on consideration of overall results, were marked. *Mormyrus* and *Synodontis*, for example, were only found in any concentration on the bottom, the former being a more significant constituent there than in the open waters of the estuary (33% as against 10%), although the actual catch/unit effort returns were similar. At the surface, *Mormyrops* (25%), *Cyphomyrus* (13%) and *Eutropius* (8%) were significant, unlike the bottom. *Clarias*, *Hydrocynus* and *Labeo altivelis* showed little difference in surface and bottom results. These species were significant as constituents of the *Ceratophyllum* beds along the shoreline near Station 1. Here again the population was dominated by *Labeo altivelis* and *Hydrocynus*, each constituting about 30% of the population by weight. *Mormyrops* was found to be the dominating mormyrid (7%). *Labeo congoro* and *Clarias* were more significant as population constituents here than elsewhere. The cichlids *Tilapia mortimeri* and *Haplochromis codringtoni* only occurred with any significance at this netting station.

2.5 Seasonal Differences in Species Composition

Mean seasonal catches of the different species from all stations are presented in Table 9.3. Three definite groups with characteristic overall seasonal fluctuation are apparent.

1. Those species which were caught in low numbers during the rains, increased in April and May, dropped in July and August and increased again in October and November. This group includes *Mormyrus*, *Cyphomyrus*, *Tilapia mortimeri* and *Eutropius*. A higher October than April peak was common to all of these species.
2. Those species showing a consistent trend of decrease from a peak during the rains to a winter low and increasing consistently again to the rainy season peak. Included here are *Hydrocynus*, *Labeo altivelis*, *Synodontis* and, possibly, *Labeo congoro*. The high May density of *Synodontis* which is atypical of this group is explicable in terms of the very high density of this fish which appeared following unseasonal floods in May 1967 ($\bar{x}$ before flood: 30g/9.2m/12 hrs; after flood: 420g/9.2m/12 hrs). *Labeo congoro* was somewhat atypical in that values from April to November were consistently low, higher densities having only been found during the rains. The great discrepancy between densities during the rains of 1967 and 1968 also separates this species from the rest of the group.
3. Those species showing a peak in May and July, and low values from October and through the rains. Only one species, *Clarias gariepinus*, was found to vary in this way.

Alestes and *Mormyrops* showed somewhat erratic variation peculiar to themselves and the other species listed in the table occurred too infrequently to warrant comment.

TABLE 9.3 THE SEASONAL MEAN ABUNDANCE OF FISH SPECIES AT ALL STATIONS IN g/9.2m/12 hours

SEASONS / SPECIES	A	B	C	D	E
Mormyrops deliciosus	96	101	55	95	18
Cyphomyrus discorhynchus	9	30	14	41	25
Mormyrus longirostris	85	145	51	205	81
Hydrocynus vittatus	1151	266	164	305	452
Alestes imberi	25	40	1	6	8
Distichodus mossambicus	3	0	0	0	0
Labeo altivelis	509	263	154	411	745
Labeo congoro	140	15	10	12	30
Labeo cylindricus	0	0	0	P	1
Heterobranchus longifilis	0	6	0	0	0
Clarias gariepinus	86	185	161	41	76
Eutropius depressirostris	20	26	7	41	10
Synodontis zambesensis	126	108	51	40	124
Tilapia rendalli rendalli	0	0	0	0	1
Tilapia mortimeri	11	19	5	26	20
Haplochromis codringtoni	0	0	1	4	P

A: January and February 1967
B: April and May 1967
C: July and August 1967
D: October and November 1967
E: January and February 1968

2.6 Seasonal Changes in Spatial Distribution of Species

Data on seasonal variation in spatial distribution of the seven most important species, in terms of surface and bottom catches at each station, have been used to prepare Fig. 9.6.

The distribution of *Mormyrops* in surface water indicated a preference by this species for vegetation, whether *Ceratophyllum* or *Salvinia*. In bottom waters (seemingly preferred by *Mormyrops*) the area within Station 3 yielded the greatest catches. There appeared to be no marked seasonal movement by *Mormyrops*. Although consideration earlier of composite surface and bottom seasonal changes (Table 9.3)

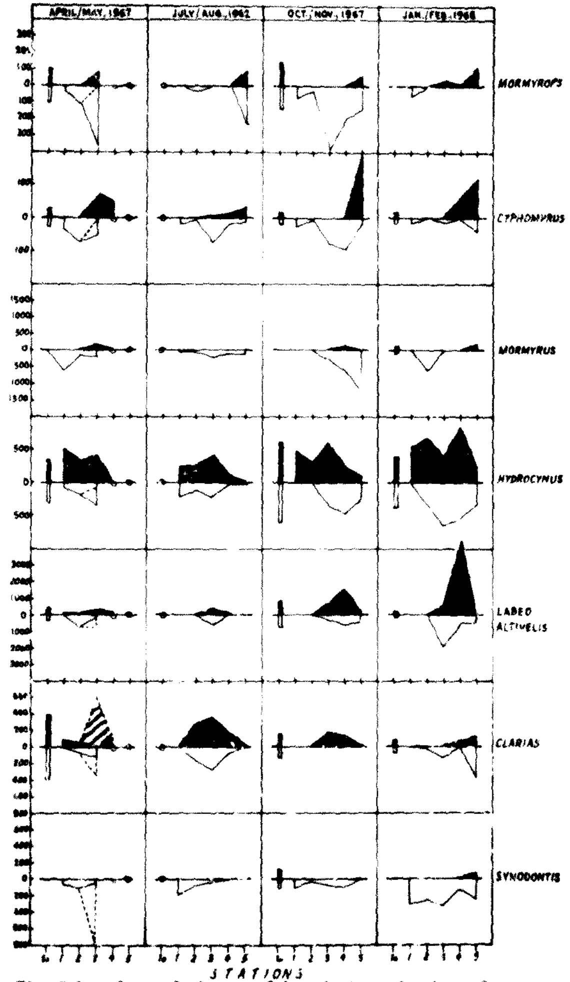


Fig. 9.6. Seasonal changes of important species in surface and bottom nettings at the various stations.

-♦- - No data

Surface : blocked in
Bottom : outline
Stippled : after unseasonal flood

did not indicate it, the increased catches of bottom set nets within Station 3 in October 1967 may be an indication of immigration into the "estuary" at this time.

Cyphomyrus catches indicated a preference by this species for the waters inside the estuary, particularly at the surface in association with Salvinia, throughout the year, and at both surface and bottom within the "estuary" in October. During the rains the numbers caught dropped considerably and Cyphomyrus was more evenly dispersed through the study area (January 1968). There were some indications that this species was more commonly found in the bottom waters of the bay in April and May 1967.

Mormyrus, a clearly benthic species on these data, showed an October concentration within the "estuary" similar to the other mormyrids. The data available indicate also that with Cyphomyrus, Mormyrus shares a preference for open bay waters in April.

Hydrocynus showed a pattern from July to January of both increase in density within the estuary coupled with an increase towards its higher reaches. This distribution would seem to be associated with breeding behaviour, which will be discussed later.

Although Labeo altivelis was at all times an important population constituent in the "estuarine" area, the majority of the population seemed to have dispersed away from the estuary between April and August. Thereafter there was a considerable increase, particularly within the estuary, where during the rains phenomenal concentrations of these fish occurred (ca. 45Kg/100m/12 hrs), particularly at the edge of the weed mat. It is of interest to note that the major proportion of the population was found at the surface against the mat edge and no fish were taken at the surface within the mat, whereas the population on the bottom was the same, irrespective of the mat.

Prior to increased flooding in May 1967, concentrations of Clarias within the study area were low and had increased to a peak by July when they were found both at the surface and on the bottom, having been most concentrated from Station 2 to Station 4. By October, all fish occurred at the water surface, in greatest concentrations within the estuary at Stations 3 and 4 against the mat edge. During the rains, largest catches occurred in association with the _Salvinia_ mat, both at the surface and on the bottom.

Synodontis, in common with _Hydrocynus_ and _Labeo altivelis_, showed an increase throughout the estuary just prior to the rains. During winter the greatest concentration occurred at outermost stations. The extraordinary increase following flooding in May will be discussed in the next section.

2.7 The Effects of Unseasonal Flooding

Netting took place at Station 3 before and after unseasonal floods on 2nd May 1967. The effects of this on the fish fauna could throw some light on the seasonal differences in distribution and abundance of faunal components and are, therefore, included (Table 9.4).

A great change in population composition, and to a lesser extent an increase in density, occurred when the river flooded. The result of flooding was to drop water temperatures 7°C very suddenly. _Mormyrops_ and _Cyphomyrus_, which were present before the flood, virtually disappeared after it. The _Mormyrus_ population seemed unaffected by flooding, although fish were caught atypically at the surface after the flood. A slight decrease occurred in the _Hydrocynus_ population following flooding and the data suggest a movement away from the bottom. The number of _Alestes_ increased somewhat following flooding, particularly at the ... surface. _Labeo altivelis_ and _Synodontis_ increased spectacularly after the flood, particularly in the cold bottom waters. _Eutropius_ occurred in a slightly greater density along

TABLE 5.4 THE EFFECTS OF UNSEASONAL FLOODING ON THE FISHES AT STATION 3 (May 1967)

SPECIES	BEFORE FLOODING			AFTER FLOODING		
	SURFACE	BOTTOM	TOTAL	SURFACE	BOTTOM	TOTAL
Mormyrops deliciosus	96	362	458	0	0	0
Cyphomyrus discorhynchus	70	50	120	7	0	7
Mormyrus longirostris	0	229	229	113	270	383
Hydrocynus vittatus	390	347	737	321	115	436
Alestes imberi	0	6	6	14	5	19
Labeo altivelis	224	189	413	218	681	899
Clarias gariepinus	0	148	148	616	347	963
Eutropius depressirostris	12	19	31	30	30	124
Synodontis [illegible]	29	51	80	0	839	839
TOTAL	821	1401	2222	1319	2351	3670

the bottom following the flood.

3. DISCUSSION OF THE QUARTERLY GILLNET PROGRAMME (1967/68)

The point has been made in the introduction to this work that perhaps because of their lotic origin, the fish population of Lake Kariba before the introduction of the pelagic Lake Tanganyika sardine would appear to be confined to the marginal areas of the lake. It was in such an area that the sampling took place. Apart from the area being marginal, the situation was somewhat complicated by the fact that the fish population of a river mouth would have been affected to some degree by the river's flow and the fluctuations of potamodromous species. The population is clearly dominated by the potamodromous *Labeo altivelis*, *Hydrocynus vittatus*, *Mormyrus longirostris*, *Synodontis zambezensis* and *Clarias gariepinus*, which together constituted 36% of the weight of all species taken. The population is obviously different from the situation found by Coke (1967) in the Sanyati cleared area some distance away from a river mouth, where only 26% of the catch were potamodromous and 69% were cichlids (as opposed to 2% at the Mwenda River mouth). Begg (in press) has recently shown that the composition of the fish population of commercial gillnet catches in the different basins of Lake Kariba show differences in composition which can be related to the proximity of the Zambezi River. *Labeo congoro*, for example, forms the single most important constituent in catches at the Zambezi end of the lake whereas in the Sanyati Basin it is most infrequent. The cichlid distribution is the exact opposite, forming a higher component in the Sanyati Basin and being infrequently found at the head of the lake. This situation cannot necessarily be explained by reference to breeding requirements of fish, in that *Labeo congoro* was so sparse at Mwenda, implying a restriction in distribution of this fish to the flowing Zambezi River at the head of the lake.

Perhaps reference to feeding and physical habitat requirements of this fish would yield a more logical answer. Coke's (1967) catch data show an overall mean yield of a cleared area in the Sanyati Basin to a depth of 14 m to be in the region of 3.3 Kg/91.5m/night. In relation to the present data, this is better only than the open water bay station and indicates the concentration of fish at the Mwenda River mouth. The mean catch at Station 5 is particularly high in comparison (12.5 Kg).

The seasonal fluctuation in the fish population, with the winter low building up to a peak in the rains, must also be attributable to the accumulation of fish occurring before and after breeding, although this could also partly be explained, in certain instances, to feeding accumulation stimulated by allochtonous food from the river. The population accumulation which was apparent during the rainy season was particularly noticeable at the stations in open waters of the "estuary" and showed a decrease both inwards underneath the _Salvinia_ mat and outwards towards the open bay. Fisheries production underneath the _Salvinia_ was approximately equivalent to that found in the open bay. Production in the _Ceratophyllum_ bed netted was consistently high and only decreased during the rains.

In the open bay, _Hydrocynus_ was overwhelmingly dominant in surface waters whereas _Mormyrus_ and _Synodontis_ dominated the bottom fishes and here there was also significant representation by several other species. The general trend apparent in the specific variations found at the Mwenda River mouth was the essential simplicity of clear dominance by few species in open, deeper, water compared with a greater faunal complexity generated by a more equable representation of an increasing number of species in shallower waters, particularly in association with vegetation. This is understandable on consideration of increased habitat complexity which occurred inshore. Distributional data are summarised in Table 9.5.

TABLE 9.5 THE IMPORTANCE OF FISH SUSCEPTIBLE TO GILLNETS RELATIVE TO THEIR OWN DISTRIBUTION AND THAT OF OTHER FISH SPECIES

	CERATOPHYLLUM	BAY		SALVINIA FREE ESTUARY		SALVINIA MAT	
		SURFACE	BOTTOM	SURFACE	BOTTOM	SURFACE	BOTTOM
Mormyrops deliciosus	X		X	X	XX	XXX	X
Cyphomyrus discorhynchus	X		X	X	X	XX	X
Mormyrus longirostris	X		XXX		XXX	X	XXX
Hydrocynus vittatus	XX	XXX	X	XXX	XX	XX	X
Alestes imberi	X	X		XX	X	X	
Distichodus mossambicus		X					
Labeo altivelis	XX	X	X	XXX	XXX	XX	XX
Labeo congoro	X	X		X	X		
Labeo cylindricus					X		
Heterobranchus longifilis	X						
Clarias gariepinus	XX	X		X	X	XX	X
Eutropius depressirostris	X	X	X	X	XX	XX	X
Synodontis zambezensis	X		XXX	X	XX	X	X
Tilapia rendalli rendalli				X			
Tilapia mortimeri	X	X		X	XX		
Haplochromis codringtoni	X						

X : Present at station XX : Either numerous at station or more commonly found there
XXX: Either abundant at station or most commonly found there

Two main physical factors must have played a considerable role on seasonal and spatial density variation of fish species at the river mouth. The first and foremost was the effect of the river flowing; the second was the decreased temperature and nutrient release in winter following overturn. (Begg, pers. comm., found this to have occurred in late May 1967, in the associated lake basin). Associated with these two factors are the behavioural patterns of the different fish species in relation to them. The patterns of distribution along the netting transect during the different seasons (Fig. 9.6) give some indication as to the migrational behaviour of some of the species. Low netting returns indicate, for example, movement away from the river mouth, as does a progressive increase of fish towards the outer station, and vice versa. Consideration at this stage of the potamodromous behaviour of some of the species, coupled with seasonal distributional data offers an opportunity to suggest seasonal migrational patterns of some of the fishes.

Available data suggest, therefore, the following seasonal movement of different species.

Mormyrus and Cyphomyrus:

October and November : movement into and accumulation of fish in the "estuarine" area.

December to March : fish move up the river to breed and then return to the lake.

April to September : fish into lake.

Clarias:

September to November : accumulation at highest point of the "estuary" (causing decrease in netted portion of "estuary").

December	: movement of fish up river to breed.
December to March	: movement back into lake via the "estuary".
April and May	: dispersed into lake.
June to August	: movement into estuary associated with plankton bloom following overturn, resulting in food abundance.

Hydrocynus, Labeo altivelis and Synodontis:

October	: start of an immigration of fish into the "estuary" reaching a peak in
December to March	: fish move up the river to breed and then return to the lake.
April to September	: emigration from estuary into lake where dispersed until the following October.

The suggested migrational pattern of the last group of fish is therefore similar to the two mormyrids mentioned in the first group, except that densest concentrations of these occur in October and November and not during the rains. A similarity also exists between Mormyrops and Hydrocynus in that both remain in denser concentrations more consistently within the study area than the other species which disperse after the rains. This is perhaps explicable by their food requirements as both are piscivorous (Mormyrops to a degree) predators and food was more easily available in shallower marginal waters.

The information made available by unseasonal flooding is of value in indicating the various species' reaction to flow when there is no breeding predisposition to move up it. Fish were all in early stages of activity. In summary, Mormyrops and Cyphomyrus, present before the flood, disappeared after it. Mormyrus seemed unaffected, apart from an atypical occurrence at the water surface. The Hydrocynus population showed a movement towards the surface. Alestes appeared in greater numbers, particularly at the water surface. Labeo altivelis and Synodontis increased greatly following the flood, particularly at the bottom. During this flood the temperature at the bottom dropped 7°C in a matter of minutes and a sharp temperature gradient existed a few metres off the bottom at this time. The increase of Labeo and Synodontis following the flood suggests that these fish were already acclimatised to the lower temperature and were therefore of riverine origin, having moved downstream with the flood. On this basis, it is suggested that fish at the water surface were of lacustine origin (increase in Hydrocynus at surface; atypical appearance of Mormyrus at surface) and those fish on the bottom were of lotic origin. If this was the case, a very large number of fish moved out of the river in this ultimate flood of the season; fish which alternatively would have had to have survived in the pools during the dry season. The increased numbers of Eutropius on the bottom, in the light of its sparsity in the river, indicates that the basic premise here is incorrect. Perhaps this fish was more capable of withstanding a sharp temperature drop than the other species and accumulated in response to a sudden influx of allochtonous food, which would also apply to the increased number of Clarias in surface waters.

One of the aims of this study was to ascertain the effects of Salvinia on the biotic components of the area. It is therefore pertinent to summarise findings in this respect with regard to those gillnetting data. Firstly, overall fisheries production underneath the Salvinia mat was as high as found at Station 2, and higher than at Station 1. Secondly, on the basis of a shift of the population density point between 1967 and 1968, following the movement of the mat edge inwards, there would seem to be a degree of inhibition to the free movement of fishes upstream during the rains. Because, however, a shift in density of some of the species, from surface outside the mat, to bottom under the mat, was monitored, it is suggested that the inhibition of movement was temporary and resulted from a necessity for individual fish to reorientate themselves to the bottom rather than the surface. Thirdly, Salvinia had the effect of encouraging a movement of essentially bottom dwelling fish to the surface. Fourthly, a wide range of fish species was found underneath the Salvinia mat, without real domination by any single species, although this could have been a function of shallowness of the water. Fifthly, the mat appeared to embody a habitat suitable for Mormyrops, for this fish was more consistently taken within the mat than elsewhere. Cyphomyrus was also found to prefer Salvinia as a habitat, particularly in the hot season and denser concentrations were found in the Salvinia than at any of the other netting stations. These findings suggest that in the Mwenda River estuary at least, Salvinia does not have a deleterious effect on the fish population and is, in fact, extensively used as a habitat.

4. RESULTS OF THE FORTNIGHTLY GILLNET PROGRAMME (1968/69)

The utilization of quarterly results to illustrate population fluctuations had limitations common to all the sampling carried out. As it was possible to instigate a fortnightly gillnetting programme in the following year under the direction of the station manager, it was considered in this aspect of the study at least, evidence from more frequent sampling could be collected.

During the period of this programme, surface temperatures of the water were taken and rainfall and flow data have already been given. (Chapter 5). The pattern of rainfall in the 1968/69 season (Chapter 5, Fig. 5.1) will be remembered as having been exceptionally high and was somewhat atypical in having a dry period from the latter half of January until the end of February, followed by exceptional rains in March, when more rain fell than during the entire 1967/68 season. Surface temperatures and lake level data for the period of the programme are figured (Fig. 9.7).

Rainfall throughout the Zambezi catchment was also high during the season and this was reflected in a rapid increase in water level during March and April, the water being nearly 4 m higher in mid-April than at the beginning of March. This violent increase caused considerable flooding in some areas, which was not as apparent at Mwenda due to the steepness of the shoreline. The most marked effect here, however, was the backflooding of the river, which had the effect of moving Station 3 approximately 500 m further away from the point of entry of the river into the lake, and which could have affected the results.

The river started flowing on the 14th December 1968, when Clarias gariepinus, Labeo altivelis and Mormyrus longirostris were seen to move upstream to the first barrier, the rapids above Deep Pool. This was a light transitory flow, however, and flooding only started in earnest at the end of December, continuing through January, with heavy floods over the 10th to 12th of January (S.A. Mitchell, pers. comm.). Thereafter a light flow was maintained and individual Hydrocynus vittatus, Synodontis zambezensis, Mormyrus longirostris, Labeo altivelis, Clarias gariepinus and Mormyrops deliciosus were seen moving sporadically, mainly downstream. The river ceased to flow on the 17th February. In early March the river again flooded to an unprecedented degree, 4.0 metres above normal flow level. The volume of water at this height had been roughly calculated as being ca. 350m^3/s (12,500 cusecs) and a surface flow was observed for the first time at Station 3. The area of discoloured water, usually never extending beyond Station 2, extended as far as the mouth of the bay. It is perhaps unfortunate that this programme was carried out over an exceptionally rainy season.

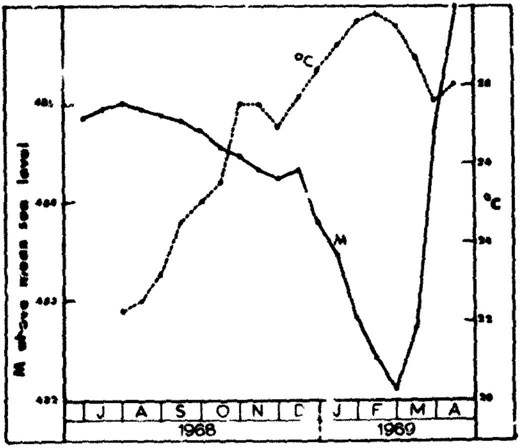


Fig. 9.7. Lake level and surface water temperatures of Sinamwenda Bay. July 1968 to April 1969.

The population constituents of the catch in this programme (Table 9.6) differed quite markedly from those in the quarterly survey. The Mormyridae constituted 40% of the catch by weight, the Cyprinidae 28%, and Characidae 11%.

<u>TABLE 9.6</u> <u>POPULATION COMPOSITION AT 10 m AS REFLECTED BY GILLNETS</u>

SPECIES	TOTAL CAUGHT (Kg)	PERCENTAGE CONSTITUENT OF POPULATION BY WEIGHT
<u>Labeo altivelis</u>	228.8	23.27*
<u>Labeo lunatus</u>	27.5	2.80
<u>Labeo cylindricus</u>	0.5	0.05
<u>Labeo congoro</u>	15.1	1.54
<u>Distichodus mossambicus</u>	0.6	0.06
<u>Mormyrus longirostris</u>	333.8	33.95*
<u>Mormyrops deliciosus</u>	41.0	4.17
<u>Cyphomyrus discorhynchus</u>	14.8	1.51
<u>Gnathonemus macrolepidotus</u>	0.1	0.01
<u>Clarias gariepinus</u>	55.2	5.61
<u>Eutropius depressirostris</u>	14.9	1.52
<u>Synodontis zambezensis</u>	143.2	14.56*
<u>Tilapia mortimeri</u>	0.9	0.09
<u>Hydrocynus vittatus</u>	107.4	10.92*
<u>Alestes imberi</u>	0.3	0.03

*Important species

The mean catch/91.5m/12 hours over the whole period was high at 10.8 Kg (23.7 lbs). This is, however, a reflection of the catching efficiency of the multimesh gillnet and a breakdown of mesh catches shows some considerable variation between meshes (Table 9.7). The smaller meshes show catches much lower than the mean; the catches gradually increase with mesh size with a mode between 88 and 100 mm, above which there is a slight decline to 125 mm. Thereafter, the mean catch for the 137 and 150 mm meshes increase very rapidly to a good catch rate of 18.6 Kg (40.7 lbs) for the 150 mm mesh. The reason for this was thought to be due to variations in the specific make-up

TABLE 9.7 CATCH BY MESHES

MESH	1½"	2"	2½"	3"	3½"	4"	4½"	5"	5½"	6"	MEAN
TOTAL CATCH (g) for 89 settings	29730	44801	65784	78488	115942	114880	103612	86052	155374	165434	959097
MEAN CATCH/ 91.5m/12 hours (g)	3340	5030	7390	8820	13030	12910	11640	9670	17460	18590	10770
MEAN CATCH/ 100%/12 hours (lbs)	7.4	11.1	16.3	19.4	28.7	28.4	25.6	21.3	38.4	40.9	23.7

of catches dependent on the selectivity of the different meshes. With this in mind analysis of results of the different meshes to ascertain their specific selectivity was undertaken, and has been considered (Chapter 9, Section 1.1).

The design of the project included an attempt to ascertain effects of the moon on catches; it has been said that catches by gillnets, predominantly surface set, fall off during new moon periods, presumably because fish are able to see nets and avoid them. Whether this effect extends to a depth of 10 m or not is not known, but results are inconsistent in this respect, as follows.

An attempt has been made to analyse results in order to clarify this problem. Firstly, successive new moon to full moon differences were calculated and expressed as percentage rise (+) or fall (-) in catch. An accumulated increase of 79% was found. Full Moon to New Moon catches differences treated in the same way also showed an accumulated increase, but of only 11%. Both periods showed considerable but inconsistent gains and losses. There would appear to be, perhaps, slightly more success over the new moon period but this must be regarded with suspicion. Secondly, the mean total catches/[illegible]m/12 hrs of the two periods were calculated and a difference of only [illegible]% in favour of new moon nettings was found, which in this [illegible]t is considered insignificant.

It would appear, therefore, that lunar effects may not need consideration in the interpretation of results, as they appear to be overwhelmed by the comparatively violent population fluctuations associated with potamodromesis. The use of running means of three, as illustrated in Figures 9.8 and 9.9 would tend to cancel out any slight effects of lunar fluctuations should these in fact occur, at the same time rendering the general trends more readily apparent. Hence the curves illus-

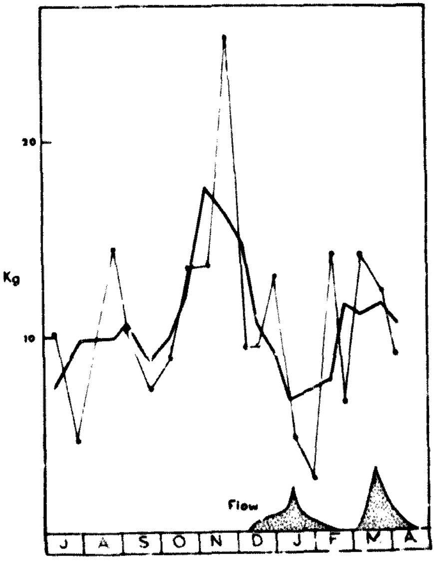
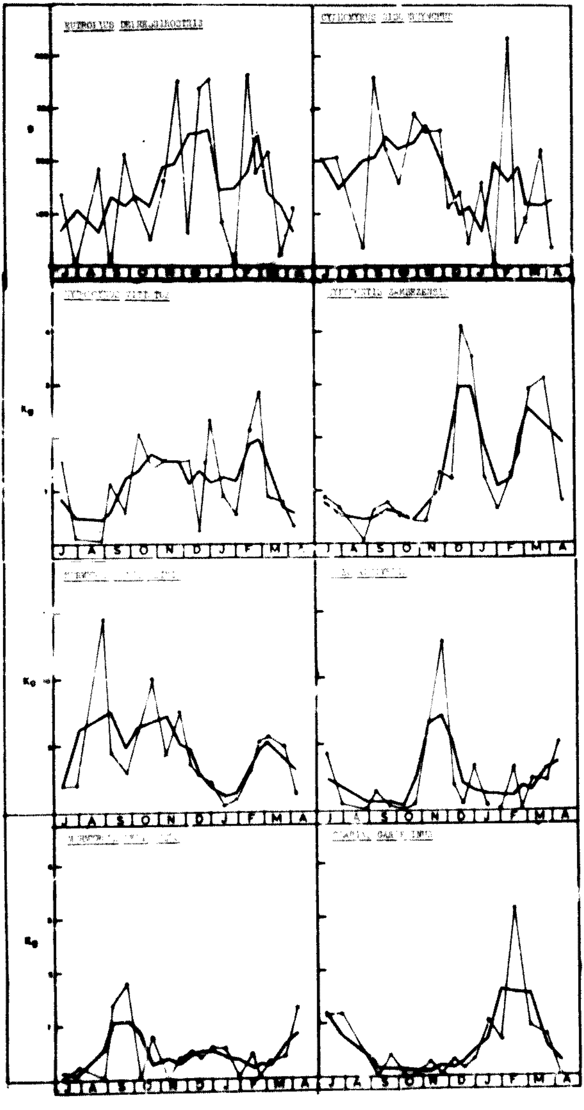


Fig. 9.8. Fluctuations of the mean total catch in Kg/91.5m 2 hrs showing flooding and flow periods.

Fig. 3.9. Temporal fluctuations in density of the more important species as reflected by gillnets (in weight/91.2m/12 hrs).



trated below have been treated in this way, but actual results obtained have also been shown, and are considered.

The data for the eight more important species relating to population fluctuations at Parrot Bend (Station 3) on the Mwenda River between July 1968 and April 1969 are given graphically (Fig. 9.9). The overall data (Fig. 9.8) indicate a sudden build-up in the population in November with a sudden decrease during December to a low, followed by an increase in February and March to levels much the same as found during the previous July to September. Heaviest catches were made in late November, followed by a decrease just prior to the river starting to flow. Variations in individual species (Fig. 9.9) occurred as follows: Mormyrops showed an increase in September 1968, but thereafter the catches remained at a low level throughout the rains. Cyphomyrus showed a decrease in December which tended to persist through the rains, apart from an increase which could have occurred during the non-flow period in February. These fluctuations in catch could indicate a movement upstream having occurred during the rains (as observed, see Chapter 10) and an accumulation of pre-migratory fish explaining the February accumulation, but are too inconsistent for definite conclusions.

Mormyrus catches were high during the hot pre-rainy season months and showed a gradual persistent decrease after the river had started to flow. There was some indication, although obscured by somewhat violent fluctuation in the netting results, that a population decrease at Parrot Bend started before the river flowed for the first time. Following low netting returns in January, there was a consistent increase during the non-flow period during February to a lesser peak during the March floods, followed by a decrease to low April catches. As Mormyrus is a potamodromous species, the data indicate the possibility of a pre-flow accumulation, initially at Parrot Bend and then upstream of it, followed by a movement of the population upstream as soon as the river flowed. The increase which occurred during February suggests a movement of this fish upstream throughout the rains whenever flow conditions permitted, as this was in all likelihood an accumulation of pre-breeding fish. The March peak could have been composed of post-breeding fish which had moved downstream with the persistent floods and which had dispersed into the lake by April.

Hydrocynus showed an accumulative increase from a winter low to an October and November peak. Decreases in catches in December coincided with the first floods, and the increase in January with a low flow phase, followed by a drop in mid-January again coinciding with the flooding of the river. The non-flow period in February saw a further increase in catches followed again by a decrease in March when the river flooded.

Labeo altivelis. A sudden considerable increase in catches of this species occurred in late November following low catches throughout the previous winter and hot dry season. Just prior to the first flood catches again dropped sharply, suggesting that like Mormyrus, the Labeo moved from Parrot Bend to a point higher up the "estuary". Minor peaks occurred characteristically in both low- and non-flow periods, followed by a decrease in the subsequent flow period. The increase during March could have resulted, as in Mormyrus, in an accumulation of post-breeding fishes which had moved downstream with the ultimate floods. Unlike Mormyrus and Hydrocynus, however, catches increased during April.

Eutropius. Catch figures of this species showed a correlation with flow in that although the population appeared to increase in nettings during the hot period, a drop in catch was coincident with the river flowing. This pattern was repeated in pre-flow and flow periods through the rains. Catches of this species were too low, however, to draw decisive conclusions. With this reservation in mind, Eutropius showed similar fluctuations to Cyphomyrus. Eutropius has never been found in the river or its pools, however, and in this instance fluctuations indicate rheophobia rather than upstream migration.

Clarias remained at a low level following a post-winter decrease, until January where an increase in catches coincided with the flood which occurred then. In February a major peak occurred during the non-flow period followed by a decrease during the March floods. By themselves, the catch data are essentially valueless as they are hardly explicable. They become more relevant in the light of other observations made on this species, as follows: During the 1966/67 and 1967/68 rains, no Clarias were either observed or caught running upstream. In both instances, however, signs left by predators suggested that a migration had occurred; Clarias skulls were commonly found along the river bank and the age of these suggested that the migration of this fish coincided with the first floods. In December 1968, a visit to the Mwenda River was made before the first flood and, judging by the frequency of aerial respiratory movements of Clarias in the Weir Pool at the highest point of backflooding of the lake, an extremely dense concentration of Clarias was present here at the time. During the hours of darkness on the morning of 15th December the river flooded for the first time that season and a visit paid to the river at first light was rewarded by the sight of a large number of Clarias making their way up the first rapid at the head of Weir Pool. In anthropomorphic terms the migratory technique used in passing up the rapid can best be described as gay abandon. Little concern appeared to be given to the damage received while passing up the rapid, which was traversed in a series of haphazard leaps. Fish were as likely to return to the water after contact with one of the boulders forming the rapid as to re-enter the water directly. This movement upstream had ceased by 10 a.m. The migration was observed, again on the very first flood, in December 1971 (Loveridge, pers. comm.). There would seem to be little doubt therefore that a Clarias migration occurs only as a single run with the first flood of the season. With this knowledge the catch data are more easily explicable. The low catches from September to December would indicate that the pre-migrational accumulation at the head of the estuary occurs before September. The February accumulation could possibly be associated with food availability in the estuarine area following flooding, for the Clarias run seems only to take place with the first suitable flood.

Synodontis was sparse in catches until November, when a slight increase occurred. In December catches rapidly rose to a peak which decreased following the January flood, indicating a movement into the "estuary" only when the river flooded. An increase again occurred at a lower level during the March floods. Although pre-breeding Synodontis were captured while moving upstream, so also were fish not in breeding condition. Catches in nets set across the river bear little relationship to the concentration of fish which occurred in the estuary. Coupled with observations on fish in full breeding condition being trapped well away from the river in the research station harbour, it would seem that Synodontis is not an obligatory river breeder. On this basis the estuarine accumulation of this species when the river flooded indicates a feeding, rather than pre-breeding accumulation.

5. DISCUSSION OF GILLNETTING RESULTS

Although the mean catch figures of the two programmes at Parrot Bend were much the same (Quarterly: 12.7 Kg; Fortnightly: 10.8 Kg) the importance of catch components, as percentage of total catch by weight, varied. The Mormyridae were nearly twice as important in the second programme in comparison with the first (20%, 40%), due mainly to an increased catch of _Mormyrus longirostris_; the Cyprinidae were more or less the same (36%, 28%) and the importance of _Hydrocynus_ was nearly halved (20%, 11%). The importance of _Synodontis_ as a biomass component of the population remained much the same (15%, 13%). A trend of change which undoubtedly occurred over 1968 was the increasing numbers of _Labeo lunatus_ taken in catches. Jackson (1961) did not find this fish in the middle Zambezi system and prior to the formation of Lake Kariba _L. lunatus_ was confined, as a population, to the upper Zambezi above the Victoria Falls (Jubb, 1967). Their occurrence in catches in these nettings was the first record of the species' presence in Lake Kariba. As they occurred as a breeding population, however, their entry into the lake must have taken place some years earlier. The 1967/68 programme does not list the species as being present, although _Labeo cylindricus_ is recorded to have occurred occasionally. Due to the morphological similarity of these two _Labeo_, these may well have been mistakenly identified and could have been _L. lunatus_. Nevertheless, by the 1968/69 programme, the fish had become significant in the gillnet catches (2.8%) and by the second programme were being separated from the _L. cylindricus_ which were far less significant (0.05%).

Data from the first programme suggested an outline of the movements associated with potamodromesis at the Mwenda River mouth. The second programme was specifically aimed at the clarification of these earlier findings. The question therefore arises: Were there any marked differences in the conclusions drawn from the separate data? Essentially, the answer is no. With regards to _Mormyrops_, data from both programmes are too sparse to draw any conclusions. _Cyphomyrus_ and _Mormyrus_ showed essentially similar migratory behaviour. The findings regarding *Clarias* were also the same in the 1967/68 and 1968/69 seasons. *Hydrocynus* were more consistently present in the 1967/68 season than implied by the April decrease in 1969. Instead of showing an anticipatory accumulation at the river mouth in October, as implied by 1967 findings, *Labeo altivelis* only showed a build-up in November in 1968, after the rains had started. More detailed examination of the 1967 netting results show that this was in actual fact the case then as well: the catch of *L. altivelis* increased within the estuary during the course of the netting programme started in October and finished in November. Surface nettings at Station 3 on the nights of the 31st October and 1st November yielded 3275 g and 1575 g *Labeo altivelis* respectively. On 13th November the catch rose to 29 946 g. On this evidence it would appear that the accumulation of *L. altivelis* took place in November of both years sampled.

Data from the first programme grouped the behaviour of *Synodontis* with *Hydrocynus* and *L. altivelis*. On the basis of the second programme and other observations, however, it would seem that the concentrations of *Synodontis* were not necessarily for breeding purposes, although some individuals are certainly potamodromous. Whether the accumulation is the result of the presence of allochtonous food, or whether the species is for various reasons rheophyllic, is still somewhat conjectual but the widespread occurrence of this species in rivers supports the former. Clearly, however, *Synodontis* showed a different pattern of behaviour from *Hydrocynus* and *Labeo* and cannot be classed with them.

Although *Eutropius*, on the basis of data collected during the second programme, showed some accumulation in the open waters of the estuary prior to the rains, the species would appear to have been rheophobic.

Population fluctuations at the Mwenda River mouth prior to and during the raine of 1967 and 1968 may be summarised as follows:

Prior to the first flood.

Cyphomyrus, Mormyrus and Hydrocynus showed a gradual accumulation at the river mouth between winter and the onset of flow of the river after the rains had started. The accumulation of Labeo altivelis was far more abrupt, a mass movement into the estuary having occurred during November, after the first rains had fallen and perhaps as a result of them. There were some indications that Hydrocynus remained throughout the estuarine area during the pre-breeding accumulation, whereas Cyphomyrus, Mormyrus and Labeo moved higher up the estuary than the netting station, in anticipation of suitable flow levels in the river. Clarias would have started accumulating at the very head of the estuary soon after temperatures started to rise in August and observations on these fish made in December indicated them to be lying quiescent on the bottom in anticipation of the first flood, but it is not known for how long prior to this observation these fish had behaved in this manner. An accumulation of Eutropius seemed to occur in the estuary up to the first flood. Mormyrops were also present and showed a peak of concentration in September which cannot be related to any known factor.

The first and subsequent floods prior to March.

Apart from the single massive run of Clarias which took place with the very first flood of the river, the pre-flood accumulation and post-flood decrease of Cyphomyrus, Mormyrus, Hydrocynus and Labeo altivelis suggests that these species move into the area of the river mouth through the rains and run upstream when flow conditions allow. Allowance for post-breeding fish need not be made, as higher catches were always taken before a flood. Synodontis only appeared in any numbers when the river flooded and it is considered for the reasons given earlier that only part of this population ran up into the river proper.

The March flood.

In March 1969, surface temperatures could have been sufficiently high (28°C) to stimulate a breeding condition. A drop of 2°C had occurred during February however. As it is still not clear, on consideration of temperature alone, whether it is actual temperature or a rise in temperature which, amongst other factors, bring on breeding condition in this population (4°C between July and October 1968, and 8°C between July and January); and as no information was collected, in the second programme, on gonad activity, insufficient evidence exists to suggest reliable reasons for the accumulation of some of the potamodromous species in March. This accumulation could have two sources: post-breeding river spawners and fish in late pre-breeding accumulation. It is probable that the increase in Clarias catches in March, because of the clear-cut single migration and because of the pre-flood February increase, was the result of a feeding accumulation as well as post-breeders returning to the lake. The March accumulation of Synodontis is probably more attributable to a feeding accumulation in the estuary than to an accumulation of post-breeding fish coming from the river Obviously post-breeding Hydrocynus, Cyphomyrus, Mormyrus and Labeo altivelis must have contributed to the March catch increase, but some unknown portion could have been composed of pre-breeding fish. Consideration of breeding condition in the previous year, to be presented in a later chapter, could clarify this problem.

6. RESULTS AND DISCUSSION OF RIVER CATCHES

6.1 The Trammel Net and Trap

Sampling of the river with the trammel net was only carried out on nine different days during the survey and resulted in a catch of 170 fish weighing, in all, 140 Kg. (Table 9.8 gives details). On consideration of the period of flow these nine days covered, sampling

TABLE [illegible] CATCH DATA FROM THE FLOWING RIVER

SAMPLING DATES		WATER LEVEL	STATION	CATCH RATE (kg/1km/hr)	[illegible]	[illegible]	[illegible]	Alestes	L. [illegible]	L. [illegible]	Clarias	[illegible]	Total up	Total down	Total numbers	Total weight (kg)
					CATCH (Nos.)											
[illegible]/2/67	[illegible]	-	Above Elbow Rapid	190		3	4						Numbers not		9	
[illegible]/2/67	[illegible]	-	Below Elbow Rapid	132	1		2						recorded.		3	
[illegible]/2/67	[illegible]	-	Net drifted in Long Pool	245		2	19		10				Majority		[illegible]	
2-4/2/67	Overnight	-	Trap above Elbow Pool	-			6	5	1			1	going up.		10	
TOTAL FEBRUARY 1967				$\bar{x}$: 189	1	[illegible]	[illegible]	5	11			2			[illegible]	47
24/1/68	PM	70	Elbow Pool	56			1		12			1	11	3	14	
26/1/68	AM	70	Below Elbow Rapid	67			8		2			1	6	3	9	
[illegible]/1/68	PM	80	Below Elbow Rapid	[illegible]	1				11		1	1	9	5	14	
[illegible]/1/68	AM	65	Below Elbow Rapid	94	4	1	10		9			4	[illegible]	[illegible]	[illegible]	
[illegible]/1/68	Overnight	60	Elbow Pool	2					2				2		2	
TOTAL JANUARY 1968				$\bar{x}$(day): 61	5	1	17		[illegible]		1	7	[illegible]	19	67	[illegible]
12/12/68	[illegible]	60	Weir Site	61	2	1	[illegible]		10				[illegible]		14	
13/12/68	PM	70	Weir Site	13		1			4	1			6		6	
14/12/68	AM	66	Weir Site	102	1	[illegible]			3	1			10		10	
TOTAL DECEMBER 1968				$\bar{x}$: [illegible]	3	7	1		17	2			[illegible]	0	[illegible]	42
12/2/69	AM	[illegible]	Weir Site	24		1			1		1	1	1	3	4	
13/2/69	[illegible]	[illegible]	Weir Site	17	3		6							6	[illegible]	
13/2/69	Night	[illegible]	Weir Site	12	6								6	3	[illegible]	
14/2/69	AM	[illegible]	Weir Site	7	1		1							2	2	
TOTAL FEBRUARY 1969				$\bar{x}$(day): 16	10	1	6		1		1	1	4	16	[illegible]	16
TOTAL					19	17	[illegible]	5	[illegible]	2	2	11			170	154
MEAN				[illegible]												

was too sparse to allow more than somewhat indefinite conclusions and must be regarded as preliminary to further work currently being carried out on the river migrants. Limitations on the use of the net were imposed by other sampling commitments and the unfishability of the river, when using these methods, as soon as the height of water on the temporary gauge rose above 1 metre.

Eight species, listed in Table 9.9 were caught in the river in varying concentrations on the different sampling days. The catch rate in the river was very high compared to catches in static water, an overall mean of 81 Kg/100m/hr being taken. As in static waters, the fish population in the river was dominated by <u>Labeo altivelis</u> (38%) and <u>Hydrocynus</u> (30%), with <u>Mormyrops</u> (11%) a far more important constituent than in lake catches and <u>Mormyrus</u> (10%) and <u>Synodontis</u> (7%) significant components. <u>Mormyrus</u> was much more important when considered by weight.

<u>TABLE 9.9</u> PERCENTAGE COMPOSITION OF TRAMMEL NET CATCHES BY NUMBERS ON DIFFERENT SAMPLING PERIODS

	1*	2	3	4	Overall
<u>Mormyrops deliciosus</u>	2	6	12	53	11
<u>Mormyrus longirostris</u>	15	2	25	5	10
<u>Hydrocynus vittatus</u>	52	21	3	27	30
<u>Alestes imberi</u>	5	-	-	-	2
<u>Labeo altivelis</u>	23	61	55	5	38
<u>Labeo lunatus</u>	-	-	7	-	1
<u>Clarias gariepinus</u>	-	2	-	5	1
<u>Synodontis zambezensis</u>	4	8	-	5	7

*1 : 3-4/2/67
2 : 24-26/1/68
3 : 15-16/12/68
4 : 13-14/2/69

Sampling in February 1967 was carried out shortly after a slight increase in flow, as this subsided, late on in the middle third of the flow season. The catch was predominantly of Hydrocynus, but Labeo altivelis and Mormyrus were also running in some numbers. All Hydrocynus were in breeding condition and some half spent female fish were taken, indicating that this species was actually breeding somewhere in the vicinity of Elbow Pool. Some of the Labeo caught were not in breeding condition, but the majority were. Both these species were not feeding. Alestes imberi in breeding condition, and also not feeding, were also taken at the time. Most of the Mormyrus were caught in the morning of 3rd February and one of the females could have spawned already. The two Synodontis caught were both in breeding condition and were not feeding. Although numbers of fish moving up/downstream were not recorded, a clear impression of a majority upstream movement was noted. Water levels were not recorded, for the gauge had not been fitted at the time of sampling. The weight of fish caught per hour was considerably higher ($\bar{x}$: 189Kg/100m/hr) than at any other time sampled.

It will be remembered that the 1967/68 rains were lower than had previously been recorded and that, after starting to flow in mid-December, flow ceased for ten days during January. On 14th January, flow started once more and sampling was undertaken from ten to twelve days after this, before and after the only flood, a minor one, which was recorded during that season. Catches were at a lower level than the previous year ($\bar{x}$: 63Kg/100m/hr), and nearly a third of the fish caught which were mainly Labeo altivelis (61%) and Hydrocynus (21%) were moving downstream. On the evening of 24/1/68 the river rose from 0.7 m to 1.7 m in 35 minutes. Catches prior to the flood were moderate (23Kg/100m/hr upstream; 12Kg/100m/hr down) and composed mainly of

L. altivelis. Catches ceased as soon as the river started to rise, even when the net was still fishing properly. The following day the water level had returned to 0.7 m when fishing started in the morning. Migrating fish, now mainly *Hydrocynus*, had increased (61Kg/100m/hr). During the middle of the day the water level rose to 0.8 m and by the end of sampling at 1700 hours had dropped to 0.8m. Catches in the afternoon remained more or less at the same level (52Kg/100m/hr) but composition changed again to simulate the *Labeo* run of the previous afternoon. The flow diminished overnight so that when sampling on 26/1/68 was started the gauge height was 0.67 m and during the 2½ hours of sampling, fell to 0.6m. Catches on this day were high (65Kg/100m/hr up; 29Kg/100m/hr down). The morning run of *Hydrocynus* which was expected after the previous days' experience, took place, but several other species were also involved, including the only migratory *Mormyrus* to be taken and a moderate run of *Labeo*. Breeding, and non-feeding *Synodontis* were caught, moving in both directions. Several feeding Mormyrops with inactive gonads were caught.

In December 1968, the first flood was sampled, following the mass movement of *Clarias* which had taken place on the night of 14/12/68, the tail end of which was observed in the morning of 15/12/68. Catches the same morning were good (61Kg/100m/hr) and were dominated by the number of *L. altivelis* (55%). *Mormyrus* was also moving in quite appreciable numbers (23%). Other fish taken were *Mormyrops* (12%), *Labeo lunatus* (7%), caught for the first time migrating in the river, and a single *Hydrocynus*. By the same afternoon movement of fish decreased to 13Kg/100m/hr. During the middle of the afternoon a few *L. altivelis* were running, but as dusk approached *Mormyrus* started appearing. The following morning, when water level had dropped about 0.1 m overnight, a heavy run (102Kg/100m/hr) was experienced. Initially, this was largely *Mormyrus*, but by 1000 hours, large numbers of *Labeo altivelis* appeared in the catches. Catches of *Mormyrus* over the two days were interesting in that only female fishes were caught on the first and only males on the second day. Although it is unrealistic to draw any conclusions from a sample of seven fish, the supposed unisexual migratory behaviour of two other Central African Mormyridae, *Gnathonemus macrolepidotus* (Pike, 1965) and *G. monteiri* (Bowmaker, 1968) suggests that unisexual movement patterns may occur in *Mormyrus longirostris*, but this would require confirmation on more convincing evidence. All the species caught in December 1968, were either R or RR, except *Mormyrops* which were both feeding and sexually inactive. There is some indication in these results that the sequence of reaction to the first flood went from *Clarias* to *Labeo altivelis* to *Mormyrus* (see Table 9.8) but this could equally be the result of changing flow rate.

The final sampling with trammel net took place over the 13th and 14th February 1969, just before the river ceased to flow on the 17th February. Sampling therefore took place at very low flow levels, the residue of floods of a month before. Fishing was carried out from 1000 hours of 13/2/69 and continued into the night, ceasing at 2230 hours. Nettings were resumed the following morning at 0815 hours. Catches were low and decreased through the period sampled (24Kg/100m/hr on AM 13/2/69 to 7Kg/100m/hr on AM 14/2/69). Single *Synodontis*, *Mormyrus*, *L. altivelis* and *Clarias*, all in breeding condition, were taken on the first morning. In the afternoon catches were confined to *Mormyrops* and *Hydrocynus* before dark and while fishing continued at night, only *Mormyrops*, which occurred regularly, was caught. At first light the following morning, *Mormyrops* occurred again, followed in later nettings by *Hydrocynus*. The *Hydrocynus* were also in breeding condition, but all the Mormyrops were sexually inactive and feeding, although a single female could have been a post-breeder. The regular occurrence of Mormyrops through the night, containing food in their stomachs, suggests that the movement in the river was purely for feeding purposes. This subject will be returned to in a later chapter (Chapter 12).

During the sampling at Elbow Rapid in January 1968, spent and ripe running female Hydrocynus were taken and several observations were made of fish behaving atypically in water 10-15 cm deep at the head of the rapid. These fish could have been spawning. The turbidity of water was such as only to allow observation of fish, or parts of them, protruding from the water. The backs and dorsal and caudal fins of several Hydrocynus were glimpsed momentarily above the water surface. Fish gently and almost lethargically held position against the current, with head upstream, and occurred in more or less the same position for up to ten minutes. The single spent female fish caught was bruised and had lost some lateral scales, suggesting that the damage occurred during spawning, and that spawning had therefore taken place in fast moving water. Coupled with, for Hydrocynus, the marked peculiarity of behaviour, this damage to a spent female fish suggests quite strongly that the observed fish were actually spawning. Ova were artifically and successfully fertilised at this time, supporting this suggestion.

The upstream and downstream data in Table 9.8 are suggestive if viewed sequentially with respect to the time of the rainy season sampling was carried out. December sampling (1968) showed a complete upstream movement. Late January (1969) and early February sampling showed the majority of fish to be moving upstream (72% in January 1968). Sampling in mid-February (1969) showed the majority of fish to be moving downstream (80%). This apparent trend towards downstream movement is, however, suspect in the light of the different flow regime and specific composition of fish sampled in February 1969.

The results obtained by use of the trammel net, because of its various drawbacks as used in this study, are essentially unsatisfactory. Some useful information was gathered however, and some characteristics of migrational behaviour were suggested by the data. The only really reliable information concerns which species do migrate in the river in breeding condition and these are listed in Table 9.9. Mormyrops was the only non-breeding migrant.

Apart from the infrequent occurrence of an individual which was sexually inactive, all fish caught were either ripe, ripe running or spent, irrespective of their migrational direction. Mormyrops were all actively feeding in the river as were significant proportions of Synodontis and Mormyrus. The netting results give some idea of the extreme density of fish in the river during the rains, as compared to the catch in static waters, although these cannot be regarded as being directly comparable ($\bar{x}$ trammel netting; 61Kg/100m/12 hrs; $\bar{x}$ Str. 5 gillnet fleets: 12.5Kg/91.5m/12hrs). The data also indicate the comparative density of the different migrational species which are liable to capture by gillnet. Although in the case of the trammel netting results, number rather than weight of fish were thought to be a more realistic parameter, the percentage composition was essentially similar to gillnet returns from static waters (Tables 9.1, 9.6, 9.9). There was also a suggestion in the results that during the course of a fishing period, either an entire morning or afternoon, the predominant species Hydrocynus and Labeo altivelis tended to move in single species shoals which must have been widely dispersed along a section of river on consideration of the length of time each sampling period lasted: on four occasions Hydrocynus were either overwhelmingly dominant or were the only species of the two taken during a sampling period. On three occasions this was true of L. altivelis. Yet on one occasion both species were running heavily together (am 26/1/68). Mormyrus and the less numerous species occurred in conjunction with both Labeo and Hydrocynus. A further drawback of the trammel net was that it did not capture smaller migratory species which, on the basis of the literature, the list should include: Micralestes, Barbus species, Chiloglanis, Gnathonemus, Cyphomyrus and Labeo cylindricus.

6.2 Handlines

On the 25th January 1968, it was possible to capture fish by handline below Elbow Rapid. Eight Clarias gariepinus, one Malapterurus electricus and a Synodontis were taken, totalling 17 Kg. Both the Malapterurus and the Synodontis were ripe females, and the former contained food items in the stomach. The breeding condition of the Clarias at what was well past the first flood was disconcerting. Three fish were ripe males, three were ripe females and two other females were ripe running. These fish forcibly indicated a second breeding of Clarias to be underway at the time. No fish were taken in the trammel net which was operating just below Elbow Rapid at the same time, so the indications were that these fish were breeding, but were not migrating upstream to do so. The fact that they took bait freely would indicate they were feeding at the same time.

Despite the reservation imposed by the methods used therefore, river catches were not essentially at variance with conclusions regarding migration drawn from the distribution and abundance of fish in static waters as reflected by gillnet catches. The question of potamodromesis will be discussed further after presentation of data on the pools fishes and breeding activity, at the end of Chapter 11.

7. TELEMETRIC TRACKING

The irritating uncertainty which resulted from the use of nets in the river led to the necessity for more definite information. If an individual fish could be followed on its migration, more reliable information pertaining to factors such as how far upstream the individual migrates, how long it stays in the river, how quickly the movement takes place and at what stage the fish returns to the lake. An approach was therefore made to Dr. A.E. Rogers of the Physics Department of the University of Rhodesia who designed a transmitter suitable for introduction into larger fish. The results of this approach have been published as an internal report of the University of Rhodesia (Bowmaker and Rogers, 1968). A particular problem which separates radio telemetry of fish from other types of biotelemetry is the choice of a frequency that allows propagation through both water and air. Most radio tracking systems operate in the V.H.F. range of frequencies, due to the difficulty of power radiation at lower frequencies, owing to the very small efficiencies of antennae with dimensions much less than one-tenth of a wavelength. It is desirable that as high a frequency as possible be chosen, without undue attrition by the aquatic medium and the encircling flesh of the fish. On this basis Rogers chose a frequency of 3.5 MHz as being optimum.

7.1 The Transmitter

The transmitter is of a simple design (Fig. 9.10), composed of three resistors (20, 330K and 3.3KΩ), three capacitors (16µf, .002µf and 330µµf), a single transistor (BC129B), a 4 cm ferrite rod antenna and batteries. The circuit oscillates for about 140 milliseconds during which time the 16µf capacitor discharges and cuts off the transistor. The 330KΩ resistor then recharges the capacitor and oscillation starts again. The cycle lasts about two seconds and the result is a series of "beeps" on the receiver. Two sizes of battery were is a series of "beeps" on the receiver. Two sizes of battery were used, Mallory 1000 Mah and 500 Mah. The first had an expected life of about 40 days and the second 20 days and measured, when encapsulated, 100 mm x 40 mm x 25 mm and 75 mm x 40 mm x 25 mm.

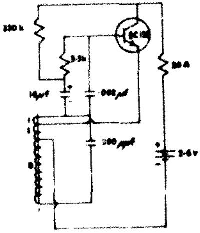


Fig. 9.10. The transmitter circuit of Dr. A.E. Rogers.

7.2 The Receiver

A simple sideband receiver, suitable for receiving the transmitters, was designed by Rogers, who considered single sideband as the most suitable demodulation technique, as a good clear note is produced during oscillation. A loop antenna was found to be satisfactory as it could be operated under water if necessary. The receiver was carried in a shoulder bag and an ear plug type loudspeaker was used (Fig. 9.11). The receiver was designed to receive signals from 12 different channels so that 12 pretuned transmitters, of slightly varying frequency, could be used simultaneously.

7.3 Encapsulation of Transmitter

The density of the encapsulated transmitter had to be slightly less than 1 so that the hydrodynamic balance of the fish was not interfered with and the transmitter would float if disgorged, thus being recover-

Fig. 9.11 The aerial and receiver.

able. The overall size was governed by the swallowing capacity and stomach size of the fish species to be tracked and the transmitter had to be protected from the digestive secretions of the stomach. To fulfil these requirements, the transmitter was embedded in balsa wood (Fig. 9.12) and then dipped in polyester resin. The encapsulation was smoothed and made as fusiform as possible.

7.4 Trials

Trials undertaken up to the end of 1968 yielded the following information:

1. The transmitter, when embedded in a 4 Kg *Hydrocynus*, was audible through a water column of 55 m. The range was further than 100 m when the fish was suspended 1 m below the water surface and the receiver was operated 1.5 m above the water surface.
2. The encapsulated transmitter was readily and easily engorged by *Clarias* (Fig. 9.13, 9.14) and *Hydrocynus*.
3. There appeared to be no change in frequency or "wowing" when placed in a live fish subsequently released.
4. Frequencies did change, however, when tracked fish moved close to large boulders. Similarly signals could be blanketed off if boulders occurred between transmitter and receiver.
5. Fish with transmitters in their stomachs appeared to behave no differently from controls when kept in tanks. Fish which were radio tagged were all in breeding condition and when offered live food neither controls nor tagged fish would eat. *Hydrocynus* used in the feeding experiment (Chapter 12) were either immature or not breeding and fed readily. The implication here is that *Hydrocynus* in breeding condition do not feed readily and that transmitters in the stomach do not upset their behaviour conspicuously.

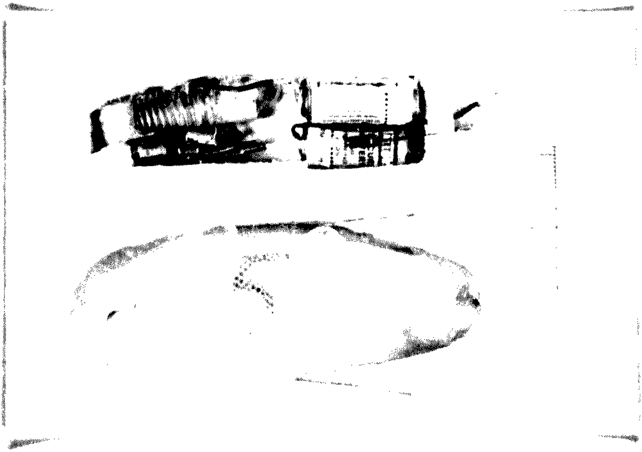


Fig. 9.12 The encapsulated transmitter.

The second type developed, with retention barbs, is illustrated. Scale in mm.

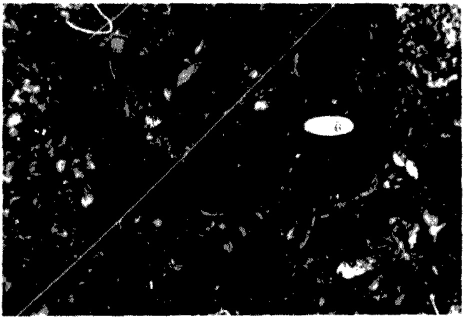


Fig. 3.13 Clarias and first type of transmitter.

Fig. 9.14 Transmitter in dissected stomach.

8. The first type of transmitter (Fig. 9.13) was easily and frequently disgorged by both _Clarias_ and _Hydrocynus_. Emplacement of transmitters in river fish was undertaken in December 1968, when eight _Clarias_ from the pre-breeding accumulation at the head of back-flooding were tagged. Shortly after this, and before the river flooded, three large crocodiles moved into the area and five of the tagged fish, possibly for this reason, were lost. Two of the remaining transmitters continued signalling from the same position for several days, suggesting that they had been disgorged. The remaining transmitter functioned properly and was lost only after the river flooded. Although extensive patrols were undertaken to find this fish upstream these were unsuccessful. One of the main problems apparent in this first attempt to track fish stemmed, it seemed, from the disgorgement of transmitters. For this reason a second type of padding was undertaken in the new series of transmitters constructed in 1969, and given a trial in February, when a visit was paid to the river specifically to give these a trial in the hope that they would be functional. Unfortunately the flow characteristics of the river did not allow a movement of _Hydrocynus_ and tank trials only were possible. Two approaches were used. The first involved the placement of spring barbs on the outside of the transmitter (Fig. 9.12) to prevent disgorgement. These were constructed of 6 mm wide clock spring. The ends were sharpened, but 2 mm from the point were broadly shouldered so as not to pierce the stomach wall. The barbs were strapped to the capsule with a netting strip impregnated with a poor quality resin. A transmitter was placed in a _Hydrocynus_ which was kept in a tank for one week. At the end of this period the transmitter was still functional and in the fish's stomach. It caused a degree of con-

tusion to the stomach wall. The poor quality resin had by this time been partly digested and the barbs would have fallen off after a few more days. This would have allowed eventual disgorgement by the fish (Fig. 9.15). The second approach involved coating the transmitter in resin without the balsa and placing it operatively into the body cavity. A total of seven large Hydrocynus were treated in this way but all died within 48 hours, apparently from operative shock, although great care was taken to minimise this. Fish were caught on barbless hooks and introduced directly into a solution of MS222. Once anaesthetised the head was left in the water and tail lifted out. An incision was made laterally several centimetres behind the pelvic fins and the transmitter, coated with antibiotic grease, was introduced through this into the body cavity. The incision was then tightly stitched. Post-mortem examination showed no damage to internal organs in all fish.

The transmitters are still, therefore, in a developmental phase. At present the main drawback seems to stem from the somewhat excessive size of the transmitters, dictated by batteries and aerial. For this reason a different approach is presently being investigated. If instead of a transmitter, a transponder was used, current would only be drawn off when the transmitting circuit was activated from an external transmitter, hence allowing reduction in battery size, and general reduction in size of the encapsulated transmitter. If a reduction to a cylinder 7 cm by 7 mm diameter size could be achieved this would mean that the transmitter could be introduced directly into the body cavity via a chiselled tube and plunger. The operation would be quick and cause minimal shock or damage to the fish. Professor F.E.J. Parvus of the Department of Electrical Engineering of the

Fig. 9.15 The effects of the second type of transmitter on the stomach of *Hydrocynus* after one week. Note the digestion of the poor quality rosin used to fit the barbs.

University of Edinburgh is currently looking into the problem. A transponder of this type would have wide application in both terrestrial and aquatic fields.

CHAPTER 10

THE FISH : POPULATION OF THE DRY SEASON POOLS

1. INTRODUCTION

An assessment of the fauna of the pools left by the river in the dry season, described in Chapter 3, was necessary for a better understanding of findings in lake and river. Furthermore, the amount of research that has been carried out on rivers which are subject to drying out and which abound in Africa, is minimal. Although the survey included an assessment of benthic components and fish, the former have been excluded from present consideration due to space limitations. It is necessary to point out however, that the pools maintained a rich and diverse benthic fauna, apparently, on both subjective assessment and the good condition of insectivorous species, sufficiently abundant to supply the needs of the insectivorous fishes found here.

2. METHODS

The methods used to collect fish from the pools have already been described. The 13 mm mesh seine net used (Figs. 10.1, 10.2) was effective, particularly in the rock-free pools or in conjunction with rotenone. Fig. 10.3 shows a typical catch sequence of fish above 12 cm from Surprise Pool in October 1966. After the application of rotenone catches decreased to zero after three hauls of the seine net, implying that the total fish fauna had been removed. Juvenile fishes were particularly susceptible to rotenone and reacted sharply to its introduction (Figs. 10.4, 10.5), some 50 to 60 minutes before adult fishes succumbed. The likelihood therefore that any fishes escaped capture from poisoned pools would appear to be minimal.

Fig. 10.1 The 13 mm seine operating in Surprise Pool, November 1968. *Hydrocynus* may be seen evading the net. Note the lack of snags which allowed efficient operating of the net in this pool.

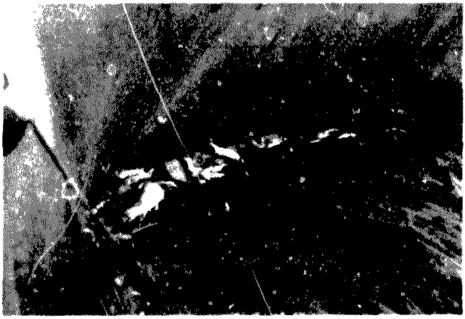


Fig. 10.2 A typical catch of the 13 mm seine net, predominantly in this instance *Labeo altivelis* and *Hydrocynus vittatus*. The terrapin, *Pelusios sinuatus*, were frequently found in the pools.

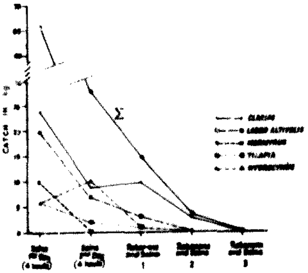


Fig. 10.3 The sequential catch of the 13 mm seine net before and after application of rotenone. The first two days are the composite of 4 hauls each. After application of rotenone, three single hauls are recorded.

Fig. 10.4 The collection of juvenile and small adult fishes after the application of rotenone. Small pool at the head of Surprise Pool, called "Rocky" Pool. November 1966.

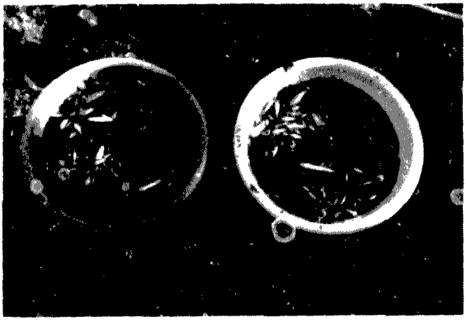


Fig. 10.5 Part of a typical collection of juvenile and small adult fish following rotenone application. Hammerkop Pool. July 1967.

A total of over 14,000 fish were collected in the river pools and examined. Dates and places of collection are given in Table 10.1.

TABLE 10.1 POOLS AND DATES THESE WERE SAMPLED

	1966	1967	1968
Whirlpool		28/10	
Surprise Pool	4/11	27/10	8/11
Hammerkop Pool		2/8	5/11
Champs Pool		30/10	25/7(½) 30/10(½)
Deep Pool		*2/8 *27/10	

*Tagging experiment

In July 1967, Champs Pool was separated into two with a mosquito gauze fence and fish from half the pool carefully collected by repeated seining; the other half was poisoned the following October and all the remaining fish collected. Fish from Deep Pool were tagged in August 1967, and collected again in October 1967. The tags used were red plastic, numbered individually and measured 11 x 5 x 1 mm. These were introduced through a narrow incision into the body cavity following anaesthetisation with Sandoz MS 222 (ethyl m-aminobenzoate, the methanesulphonate of meta-aminobenzoic acid ethylester. An isomer of benzocaine).

Procedure with individual fish as described for gillnetted specimens was followed. At times, however, the number of fish collected was so great that juvenile and small fishes were placed into formalin for later examination of length, gut contents and sexual activity. Before being placed in formalin the entire collection of each species was weighed separately for biomass estimations.

It is not considered necessary to give a detailed listing of all collections made. Relevant data will be presented where necessary in the following sections. Only results at variance with those presented will be extracted for consideration.

5. THE SPECIES

The following 19 species were found to occur in the pool collections:

Mormyrops deliciosus
Cyphomyrus discorhynchus
Gnathonemus macrolepidotus
Mormyrus longirostris
Hydrocynus vittatus
Alestes imberi
Micralestes acutidens
*Barbus lineomaculatus
*Barbus unitaeniatus
Labeo congoro
Labeo altivelis
Labeo cylindricus
Labeo lunatus ?
*Leptoglanis rotundiceps
Clarias gariepinus
Heterobranchus longifilis
Synodontis zambezensis
Tilapia mortimeri
Haplochromis darlingi

Those species which were only found in the pools are marked. Labeo lunatus has been included as it is probable, due to the difficulties of juvenile differentiation, that this species could have been confused with L. cylindricus. Apart from the mormyrids, pools fish were usually insipidly coloured. Clarias, for example, were all light grey with no mottling, Hydrocynus largely lost their horizontal stripes and Labeo altivelis were a pale rosey pink, rather than the green, grey and pink found in the lake.

4. ANNUAL DIFFERENCES IN COMPOSITION

Surprise Pool was the only pool to be collected at the initiation of the survey in October 1966. The pool was also sampled in 1967 and 1968 at the same time of year. The data from these collections should give an indication of the consistency of the fish fauna between one dry season and another (Table 10.2).

4.1 Faunal Density

The concentration of the fish fauna in 1966 elicited the name of this pool. It was estimated that the volume of water in the pool at this time was 385 m^3 so that the fish occurred in a density of approximately 0.4 Kg/m^3. In 1967, the volume estimate was considerably less (150 m^3) as the water level was lower when the pool was sampled. The fish density was estimated to be approximately 0.2 Kg/m^3. In 1968 the water level was slightly lower than in 1966 and the volume of the pool was estimated to be 290 m^3 (Fig. 10.4). At this volume the approximate density of fish was an intermediate 0.3 Kg/m^3. Two major factors, to explain the discrepancies between the different biomass of fish, need consideration. The first pertains to the amount and pattern of rainfall in the previous year and the second to the degree of attenuation of the water which took place in the different years sampled.

The 1965/66 rainfall records at the Research Station were improperly kept so that it is not possible to draw any correlation between density of fish in the pools and the pattern of previous years' rain. Attenuation effects will be considered in a further section. The most that can be drawn from the available data is that a wide variation of the ichthyomass of a single pool could occur from one year to the next.

TABLE 10.2 ANNUAL DIFFERENCES IN COMPOSITION OF THE FISH FAUNA OF SURIRIRE'S POOL

	NOVEMBER 1966		OCTOBER 1967		NOVEMBER [illegible]		TOTAL	
	Kg	%	Kg	%	Kg	%	Kg	%
Mormyrus longirostris	10.6	9.4	1.3	4.5	2.9	3.3	14.8	5.7
Hydrocynus vittatus	18.8	13.1	2.2	7.5	17.6	20.1	38.6	14.8
Alestes imberi	15.5	9.4	2.7	9.1	3.5	4.0	19.7	7.6
Micralestes acutidens	0	0	P	0	0.3	0.4	0.3	0.1
Barbus lineomaculatus					P	0		
Barbus unitaeniatus	0.8	0.6	0.5	1.5	0.5	0.6	1.8	0.7
Labeo altivelis	39.3	27.4	4.9	16.8	37.8	43.3	82.0	31.5
Labeo cylindricus	0.6	0.4	P	0	0.1	0.1	0.7	0.3
Clarias gariepinus	45.5	31.7	13.8	47.0	13.1	15.0	72.4	27.8
Synodontis zambezensis	2.1	1.5	P	0.3	0.6	0.1	2.7	1.0
Tilapia mortimeri	12.2	8.6	4.0	13.6	11.5	13.1	27.7	10.6
TOTAL	143.4		29.4		87.9		260.7	
BIOMASS Kg/m^3	0.4		0.2		0.3			

4.2 Faunal Composition

2.1% by weight of the population in 1966 was composed of juvenile fishes. If considered by numbers the population was overwhelmingly juvenile or immature. The large numbers of juvenile fishes were always present.

The faunal composition was typical of a pool with little cover and moderate attenuation characteristics, being dominated by Labeo altivelis (31.5%) and Clarias gariepinus (27.8%). Hydrocynus (14.8%) and Tilapia (10.6%) were important constituents. When considered by numbers, Alestes imberi and the Barbus spp. were most important, but only Alestes contributed appreciably to biomass (7.6%). Mormyrus was relatively insignificant.

The percentage mean occurrence of different species from the quarterly gillnet programme indicate a similar importance of L. altivelis in both lake and pools. Hydrocynus and Mormyrus apparently occurred with greater frequency in the lake. Alestes imberi was of far greater importance in the pools, as were the essentially riverine Micralestes, Barbus spp., and L. cylindricus. Both Clarias and Tilapia were of greater importance to the biomass of the pools than of the lake. Both however, could, more obviously than most species, be the result of sampling. In the first instance Clarias is clearly not easily susceptible to gillnets, but is to poison and a seine net. Tilapia has been shown to be far more frequent in areas away from the river mouth. The Tilapia biomass, as a percentage of total fish biomass in the pools, was in fact less than that reflected by Coke's (1969) gillnets in the Sanyati cleared area. Nevertheless it is probable that the pools were the most important habitat for Tilapia in the river and its near vicinity.

The variability between years of the total fish fauna is generally applicable also to its specific components (Table 10.2), although some of the species showed a remarkable similarity in biomass between 1966 and 1968 (Hydrocynus, L. altivelis and Tilapia). In all three cases, the 1967 biomass was found to be considerably lower. This could indicate that the unseasonal floods of 5th May 1967, gave these fish the opportunity to move downstream after the river had impressed itself, late on in the season, as being an unsuitable habitat for these species.

5. DISTRIBUTION IN RELATION TO POOL TYPE

It was clearly apparent when collections were made in the different pools that the fauna of a pool clear of stones, such as Surprise Pool, varied quite considerably from the fish found in the rocky pools. To illustrate this point, data from Surprise Pool, the small pool separated from Surprise Pool at its head (Rocky Pool, Fig. 10.4) and Hammerkop Pool are extracted from sampling carried out in November 1968 (Table 10.3). On the basis of these data certain species appear to favour the "protected" (rocky) pools. Gnathonemus macrolepidotus was only found in Hammerkop Pool. Mormyrus also occurred infrequently, but in both types of pool. Hydrocynus seemed to favour the pools clear of cover whereas Alestes and Micralestes appeared to show little preference between protected or clear pools. The two Barbus species show an interesting difference in their apparent preferences. B. unitaeniatus showed little preference for either, whereas B. lineomaculatus showed a clear preference for rocks. Labeo altivelis seemed equally distributed and showed little apparent preference. L. congoro was only found in association with rocks and L. cylindricus seemed to show a preference for this habitat. Clarias appeared in far greater biomass in the clear pool, as did Tilapia.

The most outstandingly lithophyllic species was Synodontis zambezensis, an insignificant constituent of Surprise Pool and an important

TABLE 10.3 THE PERCENTAGE COMPOSITION BY WEIGHT OF POOLS WITH FEW ROCKS (SUNRISE POOL) AND THOSE PREDOMINANTLY ROCKY (ROCKY, HAMMERKOP) NOVEMBER, 1968

	SUNRISE		ROCKY		HAMMERKOP	
	Kg	%	g	%	g	%
G. macrolepidotus	-	-	-	-	157	0.6
M. longirostris	2.9	3.3	110	6.2	3303	14.0
H. vittatus	17.6	20.1			1762	7.5
A. imberi	3.5	4.0	128	7.3	603	2.6
M. acutidens	0.3	0.4	30	1.7	57	0.2
B. lineomaculatus	P				188	0.8
B. unitaeniatus	0.5	0.6	20	1.7	140	0.6
L. altivelis	37.8	43.3	195	11.1	9837	41.6
L. congoro	-	-	-	-	510	2.2
L. cylindricus	0.1	0.1	435	24.8	598	2.5
C. gariepinus	13.1	15.0	105	6.0	588	2.5
S. zambezensis	0.6	0.1	280	15.9	4775	20.2
T. mortimeri	11.5	13.1	458	26.0	1135	4.8
TOTAL	87.9 Kg		1761 g		23.6 Kg	

constituent of Rocky and Hammerkop Pools. Indeed, when Surprise Pool was sampled in 1967, this species only appeared in the catches after a tree stump had been removed from the water. The information suggested by these data are summarised in Table 10.4. Two, perhaps three, species show a preference for rock-free pools. Five, perhaps six, show no apparent preferences. Three, perhaps six, show a preference for a rocky habitat. The matter will be reconsidered following the presentation of length frequency data.

6. SIZE COMPOSITION OF POOL FISH

Data on the size composition of the pools fish are valuable in throwing light on several different factors. Amongst these are:

1. The importance of the pools as a nursery.
2. The distance upstream migrating fishes run.
3. Potential predator take-off.
4. Juvenile habitat preference, or cover efficiency.
5. Juvenile growth data.

For this reason, length frequency data from Hammerkop, Surprise and Rocky Pools in November 1968, and from Champs and Hammerkop Pools separately in August 1967, have been illustrated (Figs. 10.6, 10.7). In these instances, numbers of fish and not biomass are emphasised.

The first obvious point apparent in these figures is the considerable portion of the population composed of juvenile fish and that all the larger potamodromous species are represented by juveniles. Bimodal frequencies (Fig. 10.6) can be seen in _Alestes_, _Synodontis_ and _Tilapia_. Perhaps a trimodal curve can be seen in the _Labeo altivelis_ frequencies, although the third is definitely questionable. These suggest that the first mode represents fish spawned the previous rainy season (1967/68) and subsequent modes, the rainy seasons previous to this. Tabulated, the data in Fig. 10.6 suggest the following approxi-

TABLE 10.4 HABITAT PREFERENCE OF ADULT POOLS FISH

SAND	BOTH/EITHER	ROCK
Hydrocynus vittatus ?	Hydrocynus vittatus ?	
Clarias gariepinus	Alestes imberi	Barbus lineomaculatus
Tilapia mortimeri	Micralestes acutidens	Labeo cylindricus
	Barbus unitaeniatus	Synodontis zambezensis
	Labeo altivelis	(Labeo congoro)
	Mormyrus longirostris	(Gnathonemus macrolepidotus)

The brackets denote that the only specimens of the species found were in association with rocks, but that too few specimens were taken for an assured conclusion.

mate growth rates for fish collected in November 1968:

Flow season spawning:		67/68	66/67	65/66
Alestes	:	4 - 8 cm	8 - 10 cm	
Synodontis	:	4 - 6 cm	15 cm	
L. altivelis	:	4 - 6 cm	14 - 18 cm	(30 cm)

Tilapia mortimeri has not been included in this tabulation as the size of juvenile fish indicate a continuation of breeding during the dry season, following cessation of flow.

Sizes of the larger potamodromous species do not show clear-cut modes, but the majority of juveniles of these species which could only have spawned during the previous rainy season are as follows:

Mormyrus	:	8 - 24 cm (?) (8 - 16 cm)
Hydrocynus	:	6 - 8 cm
L. cylindricus	:	6 - 8 cm
Clarias	:	6 - 24 cm

Data from Fig. 10.7 show a more easily discernable mode for *Mormyrus* (bracketed above) but the size range of seemingly first year *Clarias* is just as broad.

Two factors may be responsible for the wide differences in growth of apparently year-old fish. The first can result from widely based spawning. Fish presumably had the correct conditions to breed between December and April, perhaps May. There could have been, therefore, a difference of between three and four months in the ages of the first year group. The second involves the availability of suitable food to the individual fish. Greater food availability to an early spawning group would widen the gap resulting from age; greater or lesser food availability in the different pools would differentiate growth in a single spawning group (see Fig. 10.7; *Alestes* mode 2 - 4 cm in Champs Pool, 6 - 8 cm in Hammerkop Pool).

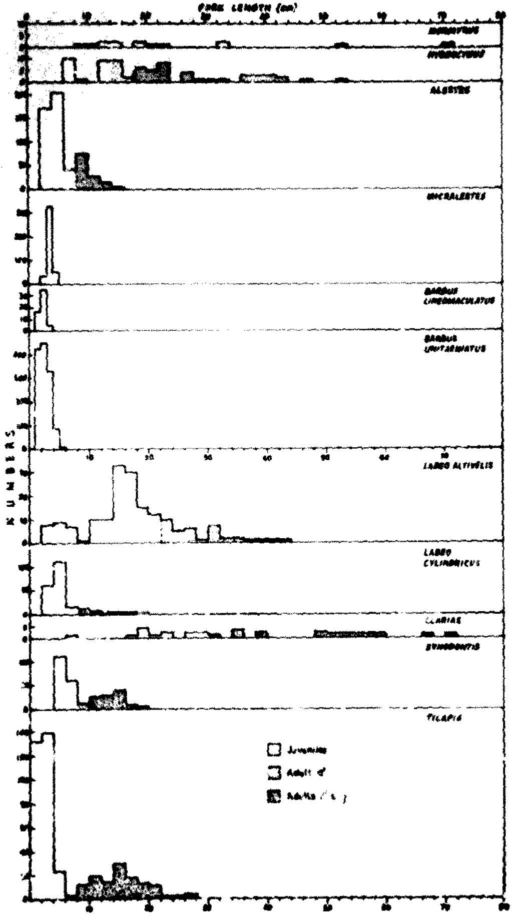


Fig. 10.6. The size composition of the entire fish population of Hammerkop and Surprise Pools. November, 1963.

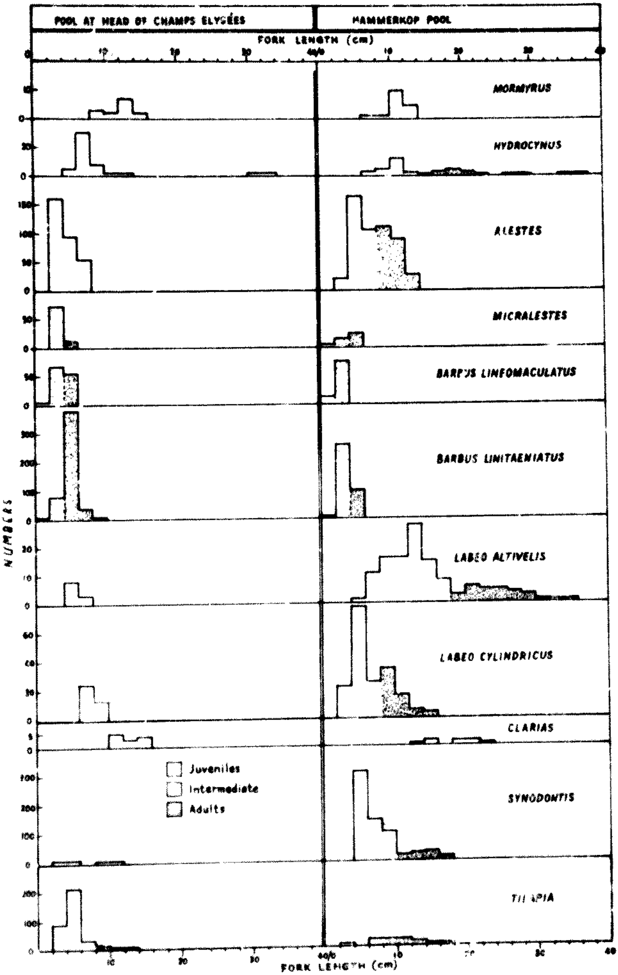


Fig. 10.7. Size composition of fish in Champs and Hammerkop Pools. November, 1967.

On this basis, by taking the middle of a non-modal size group and the middle of the breeding season, it is possible to gain a rough but perhaps more realistic impression of the growth of these species in the first nine months following spawning (Table 10.5). _Labeo altivelis_ poses a problem not readily soluble on available data. A 5 cm growth in nine months for a large tropical herbivore seems inordinately little. Yet a clear mode can be found in both figures (see also Fig. 10.3) at this length. Both figures are included until clarification is possible. A bimodal distribution could in fact occur where circumstances may have dictated two major spawnings far apart, but on the data available it would seem more likely that the 5 cm growth in the first nine months is in fact more realistic.

TABLE 10.5 ESTIMATE OF GROWTH OF POTAMODROMOUS SPECIES IN THE FIRST NINE MONTHS FOLLOWING SPAWNING. (Data in Figs. 10.6, 10.7)

Mormyrus longirostris	:	15 cm
Hydrocynus vittatus	:	14 cm
Alestes imberi	:	5 cm
Labeo altivelis	:	5 or 16 cm (?
Labeo cylindricus	:	7 cm
Clarias gariepinus	:	13 cm
Synodontis zambezensis	:	5 cm

Where sufficiently large numbers of individual species were collected, two characteristic length frequency curves are apparent; that illustrated by _Alestes_, _L. cylindricus_, _Synodontis_ and _Tilapia_ being the expected distribution of a breeding population, with greatest numbers at the shortest length, tailing off in a negatively hypernumbers at the shortest length, tailing off in a negatively hyperbolic way to few numbers at the longest length. Sufficiently large numbers of _Labeo altivelis_ were sampled to show a different type of curve, with the largest numbers in the middle size range of fish (Figs. 10.6 10.7), ind[illegible] either juvenile mortality or dispersion. The larvae behaviour of [illegible] sely related _Labeo victorianus_ (Fryer and Whitehead, 1959) suggest a mechanism encouraging downstream movement, so that it is quite likely that dispersion rather than mortality results in the paucity of juveniles in the pools. This argument could be extended to Mormyrus, Hydrocynus and Clarias to explain their paucity in the pools, which bore no relationship to the number of breeding adults which ran upstream. The suggestion is therefore that larval stages of these species also behave in a similar manner to L. victorianus and that this behaviour is as innate to these potamodromous species as is the upstream migration. Some support for this hypothesis is furnished by the larvae of Hydrocynus which have been observed to behave in this way. (A description of larval behaviour may be found in Chapter 11).

7. JUVENILE HABITAT PREFERENCE

Habitat preferences as indicated by the occurrence by weight of different species in different pool types have been considered in Section 4. Here however, the smaller or juvenile fish were obscured by the biomass of larger or adult fish and it is necessary to reconsider distribution from the numerical viewpoint, in the light of length frequency data.

MORMYRUS. Only juvenile fish were present in Champs and Hammerkop Pools in August 1967 (Fig. 10.7) and were apparently equally represented in both types of pool. There were, however, several large rocks at the head of Champs Pool and all Mormyrus were collected in their vicinity, indicating a utilization by the juvenile Mormyrus of the rocks. Nine juvenile and one adult Mormyrus occurred in Hammerkop Pool in November 1968, two juveniles occurred in Rocky Pool at the head of Surprise Pool and of the three fish present in Surprise Pool, two were juveniles. A single large fish present in Surprise Pool obscured this distribution as previously analysed. In 1968, therefore, a total of 11 juveniles of 15 caught occurred in association with rocks. When consideration is given to the relative sizes of Surprise and Rocky Pools (ca 800 m^2, 50 m^2) and realise that these two pools were, recently before sampling, connected, these meagre figures assume greater significance. On this basis it would appear that the juveniles of Mormyrus are either lithophyllic or are only able to survive predation when associated with rock cover.

HYDROCYNUS. The size distribution of this species in August 1967, in Champs and Hammerkop Pools showed no definite differences, although the juveniles in the latter pool were somewhat larger. Yet virtually all (266/300) the fish collected in November 1968, were from Surprise Pool, so here again data are inconclusive. It would seem that juvenile Hydrocynus were haphazardly dispersed irrespective of pool type.

ALESTES, MICRALESTES, BARBUS SPP. On the basis of biomass analysis Alestes, Micralestes and Barbus unitaeniatus appeared to be distributed irrespective of pool type, whilst B. lineomaculatus appeared to be lithophyllic. On the basis of numerical analysis, however, all four species were distributed irrespective of pool type.

LABEO ALTIVELIS. The juvenile population in Hammerkop Pool (Fig. 10.7) was far denser than in Champs Pool although it is not clear if these were first or second year fish. The population in Surprise and Rocky Pools (Fig. 10.8) does, however, give a clear picture of lithophyllic tendencies in juveniles.

LABEO CYLINDRICUS. Data illustrated in Fig. 10.7 clearly indicate lithophyllic tendencies in this species. Because the species remains small in pools, biomass data are in this instance acceptable. The conclusion drawn from Table 10.3 would appear to be valid and the indications are that this species exhibits strongly lithophyllic tendencies.

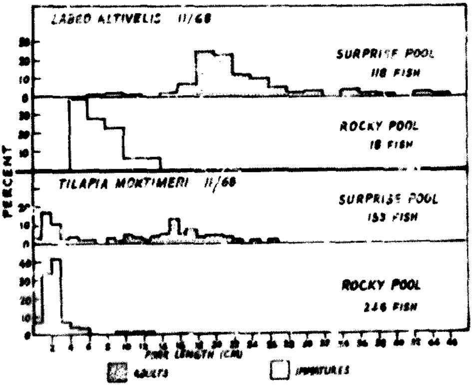


FIG. 10.8. The length frequencies of *Labeo* and *Tilapia* in Surprise and Rocky Pools. November, 1968

CLARIAS. Of the 28 specimens collected in November 1968, from Surprise, Rocky and Hammerkop Pools, 20 were from Surprise Pool. Surprise and Rocky Pools fish were essentially from the same population and it is interesting to note that of the nine fish under 24 cm which were collected, eight came from Hammerkop and Rocky Pools and constituted the entire population in these pools. On these data it seems likely therefore that Clarias are lithophyllic as juveniles and lithophobic as adults.

SYNODONTIS. Of the fish under 8 cm total length of this species collected in November 1968, 97 occurred in Hammerkop Pool, 72 in Rocky Pool and only 13 in Surprise Pool. On consideration of the relative sizes of Surprise and Rocky Pools these data indicate convincingly the lithophyllic tendencies of juvenile Synodontis, emphasized by juvenile distribution in Champs and Hammerkop Pools in August 1967 (Fig. 10.7).

TILAPIA. The August 1967 results (Fig. 10.7) for this species indicated a clear preference by juveniles for Champs rather than Hammerkop Pool, and the larger number of adults in the latter. A breakdown of distribution in Surprise and Rocky Pools indicate a different circumstance in 1968 (Fig. 10.8), for juveniles were found in greater numbers in the latter. This discrepancy is probably the result of predator pressure. 14 Hydrocynus over 30 cm length were present in Surprise Pool. In clear waters in the lake, juvenile Tilapia have frequently been observed utilising the very shallow marginal waters as a protective juveniles must have been subjected to the same sort of pressure and the result would have been, prior to a separation of Rocky from Surprise Pool by evaporation, a movement into the shallow headwaters of the pool where alternative cover from Hydrocynus predation was available in between the boulders found here. This is one explanation. The alternative is suggested by the August 1967 results (Fig. 10.7) in Champs and Hammerkop Pools where, in the latter where Tilapia adults predominated, a larger number of Hydrocynus adults also occurred. Hence the paucity of Tilapia juveniles in both Surprise Pool in 1968 relative to Rocky Pool and Hammerkop Pool in 1967 relative to Champs Pool would probably be related more to mortality as a result of predation by Hydrocynus than to any affinity with or against rocks. On this basis Tilapia juveniles are neither clearly lithophyllic nor the opposite.

A further factor which has not been considered is that both Champs and Surprise Pools offer suitable substrates for the construction of nests by Tilapia, whereas the acute slope of the sand bottom in Hammerkop Pool was unsuitable and could explain the paucity of juveniles in this pool.

The term "lithophyllic" has been freely used in this attempt to explain juvenile distribution in the pools. It is probably, however, that any form of cover if available in the pools would have been used by the juvenile fishes. Apart from Hydrocynus, Alestes, Micralestes, and the Barbus species, therefore, all the juvenile fishes in the pools either actively sought protection in the rocks or at least, particularly in the case of Tilapia, survived predation more effectively as a result of their presence.

8. <u>EFFECTS OF POOL ATTENUATION</u>

The experimental separation of Champs Pool and sampling of one half in 28/7/68 and the other on 30/10/68 offered the opportunity to assess the effects of pool attenuation through the dry season. A total of 2574 fish were sampled. The amounts of water in the pool when sampled were similar to those of 1967 illustrated in Figs. 3.8 and 3.9. The effect of the pools attenuation was startling. Approximately 9 Kg of fish were collected from half the pool in July (Fig. 10.9) and apart from *Clarias*, 0.6 Kg were collected in the other half in October. Two *Clarias*, weighing 58 g, occurred in July, and two large specimens, together weighing 4.4 Kg, were collected in October. The only other species present was *Tilapia mortimeri*, all others having disappeared. An extract from the field notebook reads "The spectacular collapse of the population in three months could only have resulted from predation from outside the pool. The presence of Marabou Stork, Hammerkop, Goliath Heron, Fish Eagles and a pair of Cape Fishing Owl in the near vicinity, the large number of scales scattered around the pool and the plethora of bird lime would indicate that bird predators were responsible. It is thought unlikely that mammalian predators take an active part as although ruminant spoor is everywhere around the pool margins, spoor of predatory mammals were not seen. Crocodiles have not been found in Champs Pool and no sign has been left of their previous presence." The conclusion reached, therefore, was that the predatory birds were responsible for the decimation of the fish fauna as the water level dropped, for it seems unlikely that the fauna of half of the pool would have been radically different from the other half in July. By itself this does not explain the complete absence of species other than *Clarias* and *Tilapia*, renowned for their ability to withstand adverse conditions. Chemical

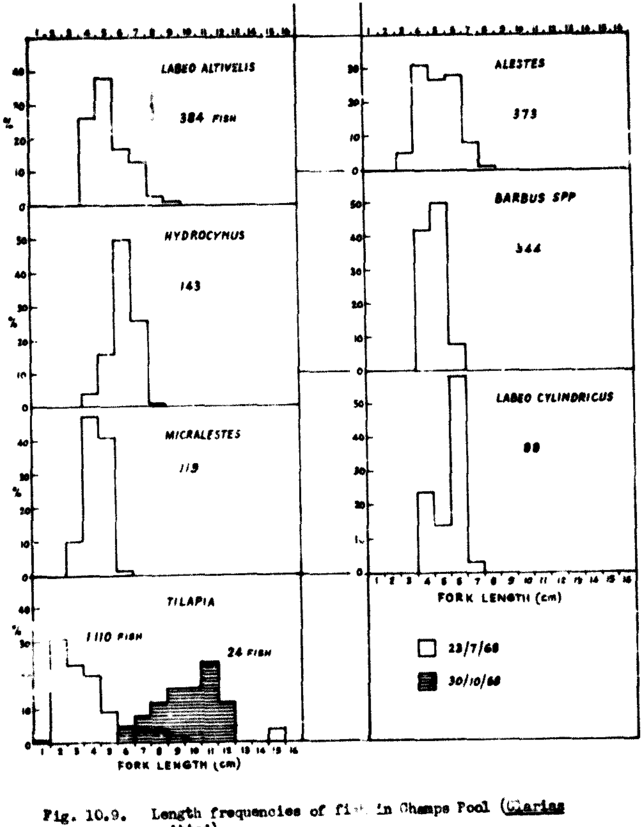


Fig. 10.9. Length frequencies of fish in Champs Pool (Clarias omitted).

analysis of Champs Pool the previous year showed this pool to have the highest conductivity (220 μmhos), lowest nitrate levels, lowest dissolved oxygen but apparently not at a limiting level (5.5 mg/l) and highest residual solids of all the pools. This was, however, after all fish had been removed the previous August. It would seem likely that the presence of a population of fish would have increased the concentration of most chemicals and decreased dissolved oxygen concentration. Under these circumstances the abiotic environmental factors could well have played a part in restricting the fish population to two "tough" species. The apparent bird predation (as intimated by the presence of Marabou Stork) may well have only taken place after mortality from environmental factors. Whatever the reason, the population of Champs Pool, typical of a large number of pools in the Mwenda River which, because of their ephemeral nature, have not been mapped, was subjected to a severe mortality, even when water remained.

9. <u>THE TAGGING EXPERIMENT</u>

Ninety-nine fish from Deep Pool were tagged on 8th August 1967, as listed in Table 10.6 and were returned to the pool. No initial mortality was noted in the following two days. The pool was re-sampled on 27th October and 10 <u>Hydrocynus</u> and 4 <u>Alestes</u> were recovered. Of the recovered <u>Alestes</u>, three were ripe females and one a nearly ripe male (AR). They were in apparently good condition but three had lost up to 3 mm length as follows: 138 to 135, 117 to 115, 136 to 134 mm. One fish of 112 mm retained its length. The tagged and recaptured <u>Hydrocynus</u> showed a wide variation in loss and gain in weight which were inconsistent with regard to sex and activity, but when percentage loss or gain in weight were plotted against original weight (Fig. 10.10) there was some indication that fish weighing 700 - 1000 g

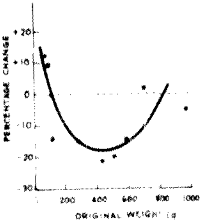


Fig. 10.10 Weight differences in individual tagged *Hydrocynus* in Deep Pool between August and November 1967.

Fig. 10.11 Photograph to illustrate condition of 100, 300 and 1000 g fish. Deep Pool. November 1967.

were only mildly affected by the conditions in the pool. Fish between 200 to 800 g lost up to 21% of their weight over the three months between tagging and recapture. In contrast, three of four fish below 200 g actually increased their weight. Condition of the middle size range of fish, whether tagged or not, was notably poor, yet the larger fish of about 1 Kg appeared to be in good condition and small (below 200 g) were in excellent condition, again irrespective of tagging (Fig. 10.11). If the reduction in condition in the 500 g size range of fish was attributable to the method of tagging, then it is reasonable to suppose that 100 g fish would be more greatly affected. As they were not, on the basis of weight gain/loss, the returns indicate that some natural factor must be at play, such as food availability. In order to find out whether or not this was the case, the condition factors of fish from the lake and another pool at the same time of year (November 1968, Station 3, Surprise Pool) have been calculated and are compared relative to size (Fig. 10.12). These results show clearly that up to a size of 300 to 400 g the condition of pools fish is as good, if not better, than fish of an equivalent size in the lake. Beyond that size, however, condition of pools fish is consistently poor. The tentative conclusion based on the meagre sample size of tagged fish over 700 g must therefore be regarded as suspect. Quite clearly, however, fish below 300 to 400 g weight are given excellent growth opportunity in the pools.

The data from the tagging experiment may be used to estimate total pool population, using the formula $N = \frac{F_1 F_2}{F_3}$, where N is the estimated population, F_1 the number of fish tagged, F_2 the total number of fish captured on the second occasion and F_3 the number of F_2 fish which were tagged. On this basis, the pool contained 22 Hydrocynus and

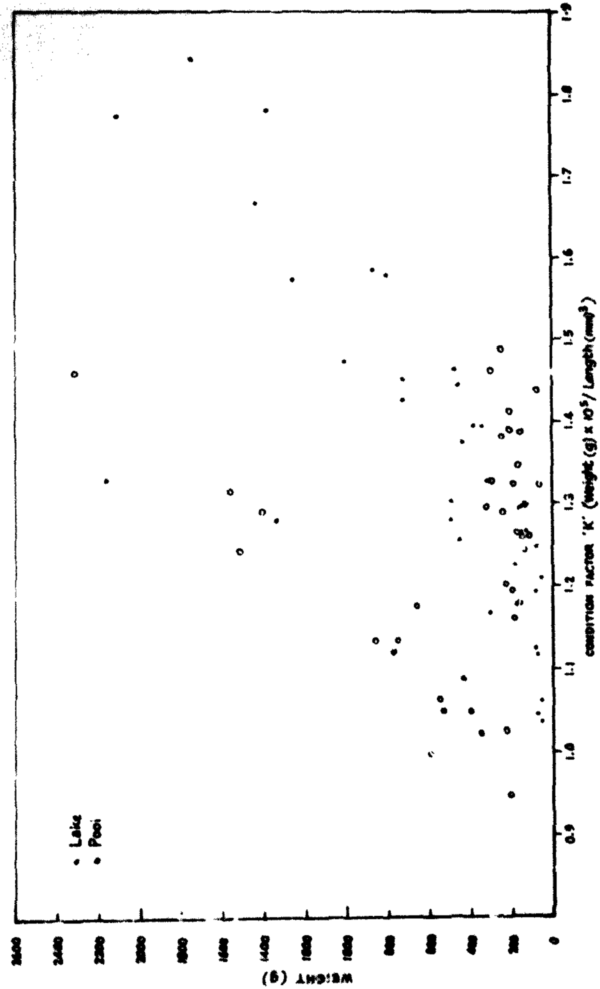


Fig. 10.12 A comparison of condition of Hydrocynus relative to size in the lake (Stn 5) and in Surprise Pool. November, 1968.

510 *Alestes*, a similar quantity to those found in pools where fish were completely collected. Data are given in Table 10.6.

TABLE 10.6 MARK RECAPTURE DATA, DEEP POOL, 1967

	F_1	F_2	F_3	N*
Hydrocynus vittatus	14	25	10	52
Alestes imberi	72	45	4	510
Labeo altivelis	9	15	0	-
Tilapia mortimeri	4	0	0	-

*See text for explanation of columns

10. DISCUSSION

Many Rhodesian rivers have the same characteristics as the Mwenda, namely being subjected to flash floods, high silt content and a gradual drying out into a series of pools in the dry season. Not many, however, discharge into a major lake and in this respect the Mwenda River is only typical of some of the smaller rivers flowing into Lake Kariba. It is perhaps because of this that the fish population maintained by the pools was so dense, in the region of 0.2 to 0.4 Kg/m^3 or in more usual terms, up to 0.6 Kg/m^2 (6000 Kg/hectare). At this concentration and on consideration of nutrient levels and apparently mediocre levels of primary productivity, this standing crop was obviously artificial; not only artificial but so concentrated that considerable stress was placed on the population as pool sizes decreased towards the end of the dry season. A population of riverine species is nevertheless maintained, some *Barbus* species, *Micralestes* and *Leptoglanis*, for example, were not found in the lake, yet were numerous in the pools; and this was not for lack of sampling with poison around the lakeshore, an aspect of the study which has not been reported on here.

Although a large proportion of the pools fish populations was juvenile, their numbers bore little relationship to the number (and potential fecundity) of adults which run upriver to breed. An hypothesis has been put forward that the juveniles in the pools are relicts of their year class, most of which could show behavioural adaptations to allow rapid downstream movement at an early larval stage. This is certainly true for the larvae of Hydrocynus and probably true for Labeo altivelis. It has been suggested that in due course similar behaviour patterns are likely to be found in Mormyrus and Clarias larvae. Quite considerable variations in faunal components were found between pools with and without cover; in this case conglomerations of boulders and stones. It is probable that this variation depended on a combination of two factors either, in some species, active lithophyllia or, in others, as a result of incidental usage and hence survival from predation. Juveniles of all species, apart from three characids, and two Barbus species were found to be more numerous in the rocky pools.

Conditions for the peak predator Hydrocynus, by the end of the dry season, were extremely severe for fish over about 300 g, and it is quite likely that terminal conditions would have been reached by a large proportion of the pools Hydrocynus had the rainy season started a month or two later. For fish below 300 g size, however, conditions within the pools were seemingly ideal as cond[illegible] f these small fish was extremely good. It has been suggested [illegible] the discrepancy due to size was probably in response to a change in feeding habits and food availability, a subject to be reconsidered in Chapter 12.

It would seem that the majority of the fishes occupying the pools were there because they had been trapped by the falling river and a large proportion of these fish die through a combination of external terrestrial and internal aquatic predation, severe physico-chemical conditions and desiccation. Intentional presence apart from a few small species was unlikely on the basis of collected data.

CHAPTER 11

THE FISH : BREEDING

The fish of Lake Kariba may be separated into three main breeding categories: the nesting species, species which breed in the lake and along its shoreline without nesting and species which migrate up the rivers to breed, defined by Myers (1949) as "potamodromous", a term which encompasses freshwater species which migrate up rivers to spawn. The location of the study area at a river mouth resulted in preoccupation with potamodromous fishes.

1. SEASONAL CHANGES IN SEXUAL ACTIVITY

Only ripe and ripe running stages of gonad development have been considered in the analyses of seasonal changes in sexual activity (Fig. 11.1). On the basis of this analysis most fish bred during the summer rains. _Hydrocynus_, _Alestes_, _Eutropius_ and _Clarias_ showed clear peaks of activity in both Januaries sampled, whereas _Mormyrus_, _Labeo congoro_ and _L. altivelis_ showed most activity from October to January and _Synodontis_ and _Cyphomyrus_ showed peaks somewhat later, from January to April. In both species the largest percentage R or RR fish occurred in April. _Mormyrops_ were clearly different from the other species, with predominance of activity occurring in April and October. It is not known where this species breeds, although in both there had been an increase in catch concurrent with full breeding condition in the female, indicating that breeding may have occurred in the estuarine area.

Little or no error could have resulted from the allocation of females to full breeding condition (R) but the method used must be considered suspect with regard to male _Mormyrops_, _Cyphomyrus_, _Clarias_

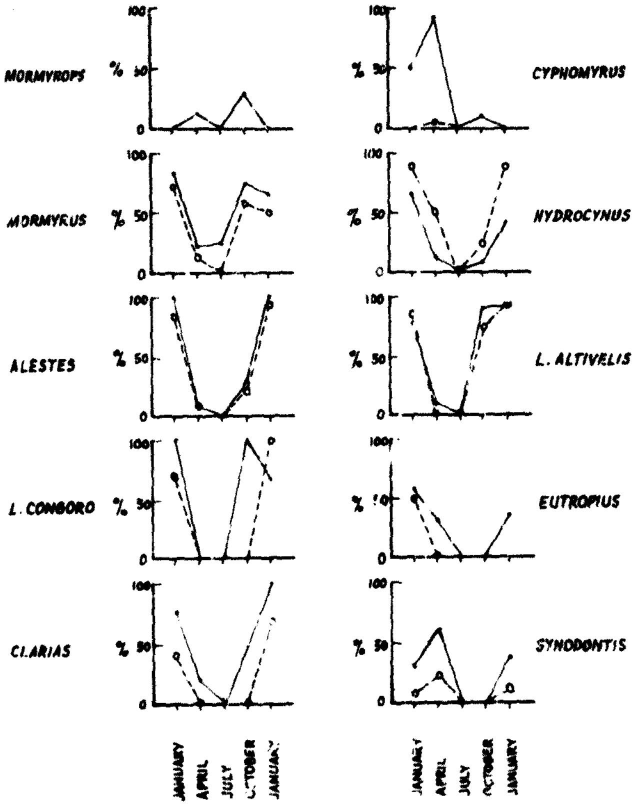


Fig. 11.1. Seasonal changes in sexual activity of male (o— —o) and female (o——o) fishes.

and perhaps, *Synodontis*, where R or RR males were comparatively infrequent when compared to concurrent females. Alternatively the males of these species only come into full breeding condition a short period before actual spawning. Nevertheless a more careful technique needs to be devised for the assessment of activity in the males of these species. Differences in activity between the sexes of other species were small, apart from *Hydrocynus*, where consistently, a larger proportion of males were ripe than females.

Apart from *Mormyrus* females, no fish were found to be R or RR in July. In fact most fish at this time were allocated an Inactive condition, with gonads thread or sac-like and gonadial blood vessels at their smallest in relation to the size of fish.

2. THE SEXUAL COMPOSITION OF SPECIES POPULATIONS

2.1 Maturation

The sizes of maturity of the different species and the largest specimens taken are given in Table 11.1. In most species, male fish mature either when smaller or at a similar size to females. The Mormyridae would appear to be different in this respect, although the sexual variation in maturation sizes are small. Data pertaining to *Clarias gariepinus* are suspect, as maturation is known from personal experience to occur at a much smaller size.

2.2 The Effect of Size on Sexual Composition of the Populations

Apart from *Mormyrops*, trends of change in sexual proportion with increasing size is noticeable in all species (Fig. 11.2). Whereas *Mormyrus*, *Cyphomyrus* and *Clarias* show male dominance with increasing size, females are dominant in larger *Hydrocynus*, *Alestes*, *Labeo altivelis*, *Synodontis* and *Eutropius*.

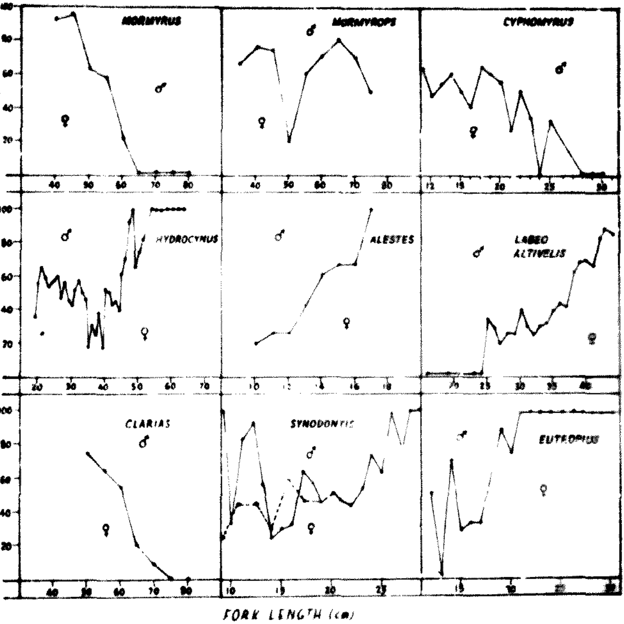


Fig. 1. .. The sexual composition of different species populations in relation to length.

TABLE 11.1 THE SIZE OF SEXUAL MATURITY OF SOME SPECIES AND THE MAXIMUM LENGTH OF THESE TAKEN BY GILLNETS

SPECIES	FORK LENGTH (cm)		
	A	B	C
Mormyrops deliciosus	38	35	98
Cyphomyrus discorhynchus	(11)	(10)	31
Mormyrus longirostris	43	41	83
Hydrocynus vittatus	14	17	67
Alestes imberi	(10)	(10)	17
Labeo altivelis	17	21	52
Eutropius depressirostris	12	12	36
Clarias gariepinus	44	53	66
Synodontis zambezensis	10	9	31

A : Smallest recognizable male fist

B : Smallest recognizable female fish

C : Largest fish takon

(Net selectivity excludes Alestes and Cyphomyrus smaller than 10 cm)

Mormyrus. Up to a fork length of 45 cm, 95% of sexually recognisable fish were female. This ratio changed consistently so that by the time fish were 65 cm long, all fishes were male.

Cyphomyrus. Until a length of 22 cm is reached, the sexual proportions were more or less equal. At this length, males began to predominate and all the larger fish, above 28 cm, were male.

Clarias. This species showed a consistently decreasing proportion of female fish from 75% at 50 cm length to zero at 75 cm.

Hydrocynus. The sexual ratio of Hydrocynus were similar until a length of 45 cm, thereafter being almost wholly composed of female fish. Kenmuir (1972) found that females dominated the population at all sizes above 17 cm, males decreasing from 40% at this length to zero at approximately 48 cm.

Alestes howed a more gradual assumption of female dominance with increased length, from 20% at 10 cm to a completely female population at 17 cm, not unlike the situation for *A. macrophthalmus* of Lake Bangweulu (Bowmaker, 1969).

Labeo altivelis. Below a length of 24 cm all sexually recognisable fish were male. Between 24 and 37 cm the ratio was roughly 2 male to 1 female and above 37 cm, females assumed dominance so that by 42 cm approximately 80% of the population was female.

Synodontis. First analysis of the *Synodontis* population suggested a preponderance of male fish in the middle size range, with females dominating the smaller and larger fish. At approximately 24 cm, female fish started to occur as a major proportion of the population and over 28 cm, no male fish were caught. Few males occurred prior to 14 cm length, due possibly to the difficulty of recognizing male fish at this size. On this assumption all immature fishes were grouped with male fish (solid points in Fig. 11.2) resulting in less fluctuation between length groups and a more equable proportionate sexual distribution than when only male fish were considered. It would seem likely therefore that in this instance a large part of immature fishes were presumptive males. On this basis the sexes were more or less evenly proportioned until a length of 24 cm when females assumed dominance; by 28 cm all fish taken were female.

Eutropius. Approximately 60% of the population under 17 cm were male and by 20 cm length all fish taken were female. It would seem clear in this instance that a large proportion of the smaller male population would have evaded the smaller meshes of the gillnet and it is for this reason that the sexual proportions based on gillnet data are questionable.

2.3 Seasonal Changes in Sexual Proportion

Kenmuir (1972) found that at the Sanyati River mouth the proportion of male *Hydrocynus* decreased during the winter months. Analysis of this aspect for all fish species was therefore undertaken for comparative purposes (Fig. 11.3). Most species retained a similar proportion throughout the year, showing little seasonal change. Exceptions, all showing a decrease in male fish in July, were *Mormyrus*, *Hydrocynus* and *Alestes*. Male fish of these species would therefore appear to have migrated away from the area of the river mouth when not breeding.

2.4 Sex Ratios

It would be unrealistic, considering firstly the seasonal changes in sexual proportions and secondly the selectivity of the gillnets towards one sex (e.g., *Eutropius* males), to attempt to ascertain the sexual ratios of the different fish species.

3. FECUNDITY

The term "fecundity" as used here refers to the number of eggs produced by the female adult fish. Egg counts were made as follows: gonads were carefully removed from a ripe fish in their entirety, weighed fresh and transferred to 10% formalin. In the laboratory, the entire gonad was reweighed, after removal of excess liquid, to the nearest 0.5 g. Subsamples were taken at random from this and weighed to the nearest milligram after being moved over filter paper to remove any excess liquid. The maternal tissue was then freed from the ova manually and also weighed to the nearest mg. Ova of the subsample were then counted and from these data the total number of eggs calculated. Initially, trials on the number of subsample counts necessary for each species were undertaken. This number was derived by repetition of counts until the standard error ($\bar{s}$) was less than [illegible]% of the mean and was thereafter used on all counts of that particular species. All subsequent counts which gave a $\bar{s}$ of greater than 5% were discarded.

Data are presented as a series of linear regressions most of which

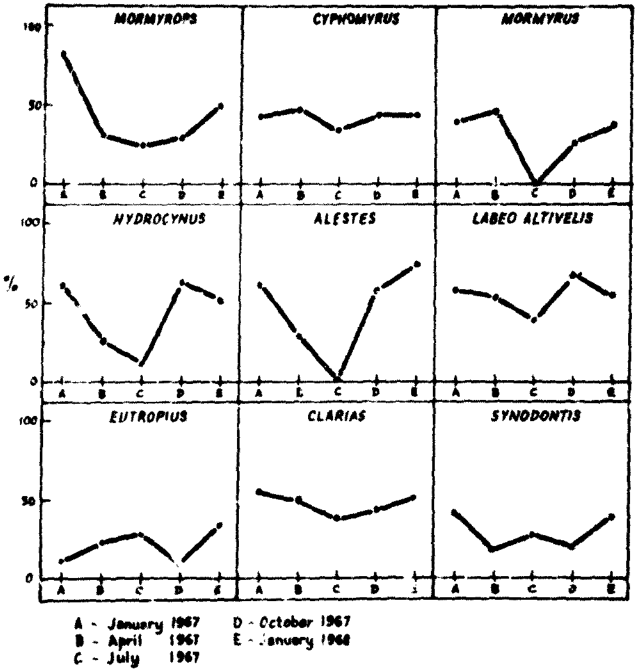


Fig. 11.3. Seasonal changes in the proportion of male fish.

were found to be significant at the 99.5% level (Fig. 11.4) and, in order to include fishes where only a few gonads were available, in Table 11.2.

Three species are outstandingly fecund, *Hydrocynus*, *Labeo altivelis* and *L. congoro* which produce, from a 40 cm fish, approximately 300,000 ova at one time. *Clarias* is next most fecund fish, an average specimen of 55 cm producing 80,000 ova at a time. In order of fecundity from average sized fish following these four, are *Mormyrus* (48,000), *Mormyrops* and *Malapterurus* (25,000), *Synodontis* (20,000), *Eutropius* (15,000), *Alestes* (10,000), *Tilapia* (4,000) and *Cyphomyrus* (2,500). It is of note that the five most fecund fish are potamodromous and that thereafter fecundity and breeding behaviour do not show any obvious correlation.

TABLE 11.2 THE MEAN EGG PRODUCTION PER CM AND REGRESSION COEFFICIENT 'b' OF SOME FISHES

SPECIES	MEAN OVA/ CM BODY	'b'
Cyphomyrus discorhynchus	195	298
Mormyrops deliciosus	333	c.450
Mormyrus longirostris	775	2,093
Hydrocynus vittatus	7,290	24,351
Alestes imberi	754	1,896
Labeo altivelis	7,260	26,921
Labeo congoro	8,940	c.12,000
Eutropius depressirostris	656	2,159
Clarias mossambicus	1,450	2,488
Synodontis zambezensis	854	1,373
Malapterurus electricus	494	-
Tilapia mortimeri	89	220

4. SIZE OF OVA

No attempt is known to have been made to measure the variation in size of ova of Central African fishes. As there could have been

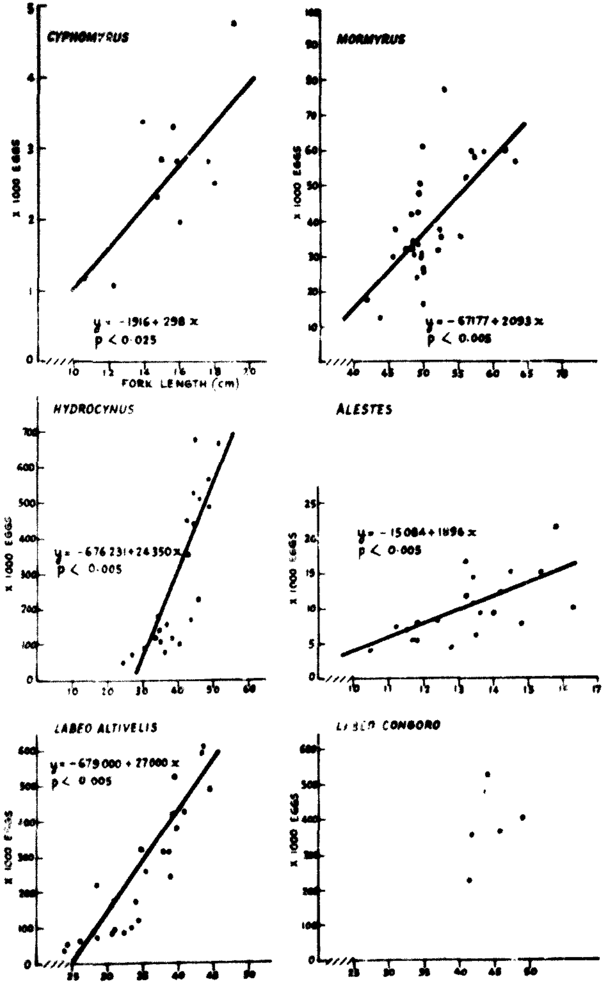


Fig. 11.4. Egg production of ten species in relation to length.

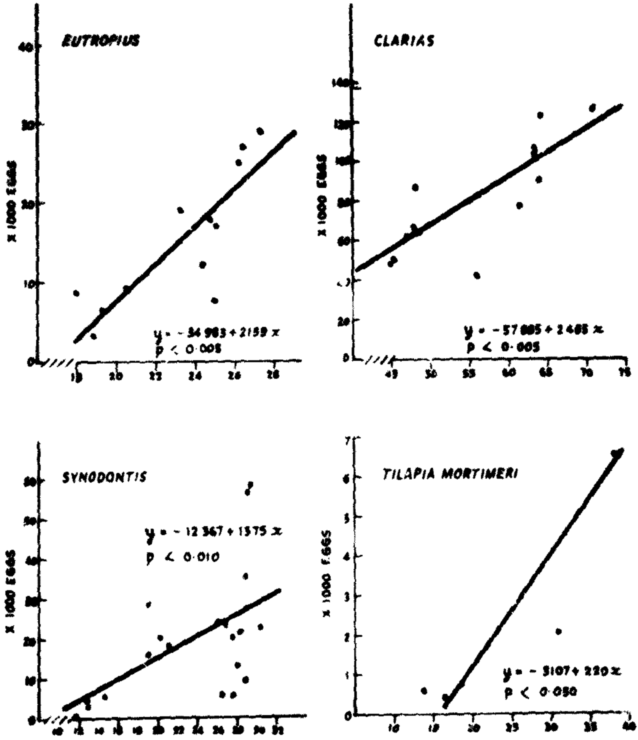


Fig. 11.4. (continued)

a correlation between the number of diameter frequency modes and breeding behaviour (in that two modes would suggest two or more spawnings in a single season) it was decided that ova diameters required measurement.

The same ovaries used for egg counts were used for measurement of ova. After varying times of storage, of between six and eighteen months, samples were taken randomly from gonads, teased to free maternal tissue and then shaken in a closed test tube. Four subsamples of between two and four hundred eggs were taken and processed individually. Each subsample was introduced into a perspex counting trough on a sliding rack, specifically constructed for the purpose, and measured by microscope graticule. Eggs were somewhat distorted and faceted after storage, so that accurate assessment from a small sample was not possible. With the size of sample taken it is probable that modal sizes found were true reflections of ovum diameters. Approximately 1000 eggs from each specimen were measured, samples being taken from 189 specimens of 13 species.

Little variation occurred between different specimens of the same species and typical diameter frequency distributions for each species are figured (Fig. 11.5) and modal diameters tabled (Table 11.3). The numbers of specimens sampled in each species and the proportion of those exhibiting uni- or bimodality are given in Table 11.4.

Because ovaries have been observed to have been free of ova in the non-breeding season, bimodality, which is so clear-cut in some of the species, implies one of two alternatives. Either fish breed twice or more in each season, or examined gonads were incompletely developed, the category "R" being allocated as a result of macroscopic examination, thus bimodality or the presence of a group of smaller ova was a function of incomplete ripeness. These alternatives

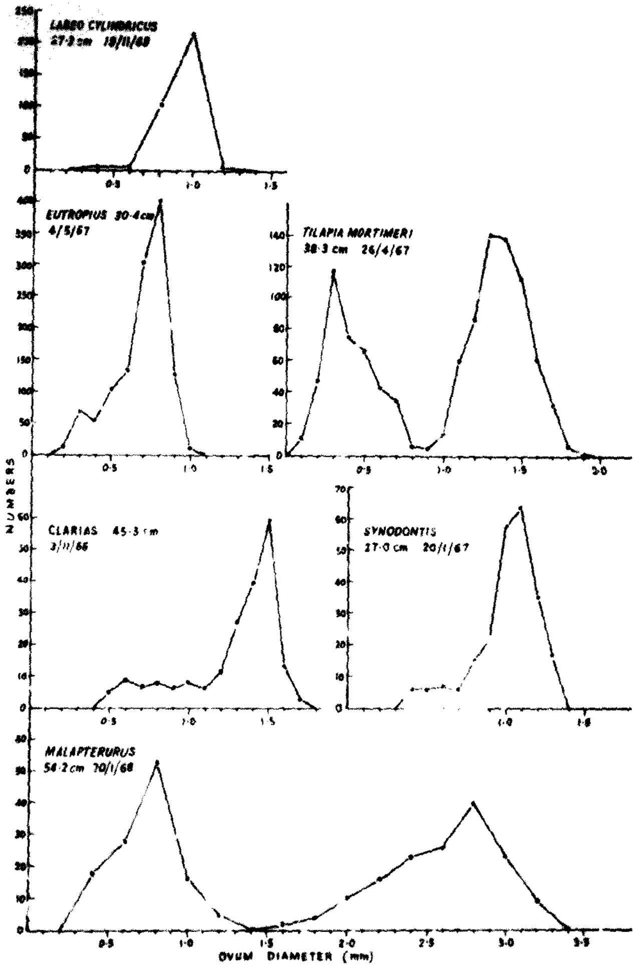


Fig. 11.5. Ova diameter frequency distributions of "ripe" specimens of 13 species.

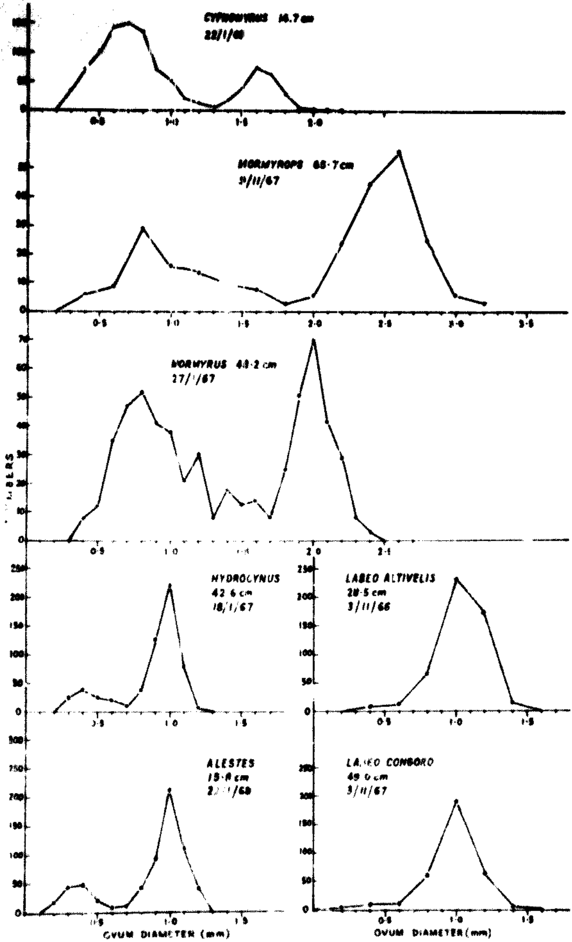


Fig. 11.5. (continued)

TABLE 11.3 THE MODAL DIAMETERS OF OVA

SPECIES	MODAL DIAMETERS OF OVA (cm) Underdeveloped	Developed
Cyphomyrus discorhynchus	0.7	1.8
Mormyrops deliciosus	0.8	2.5
Mormyrus longirostris	0.7	2.0
Hydrocynus vittatus	(0.4)	0.9
Alestes imberi	0.4	1.0
Labeo congoro	-	1.0
Labeo altivelis	-	1.1
Labeo cylindricus	-	0.9
Eutropius depressirostris	-	0.9
Clarias gariepinus	(0.8)	1.4
Malapterurus electricus	0.8	3.0
Synodontis nigromaculatus	-	1.0
Tilapia mortimeri	1.0	2.9

TABLE 11.4 THE NUMBERS AND PERCENTAGE OF SPECIMENS OF EACH SPECIES CONTAINING OVA WITH UNI- OR BIMODAL DIAMETER FREQUENCY DISTRIBUTIONS

	NUMBERS		PERCENTAGE	
Nos. of modes	1	2	1	2
SPECIES				
Cyphomyrus discorhynchus	1	13	7	93
Mormyrops deliciosus	0	3	0	100
Mormyrus longirostris	0	33	0	100
Hydrocynus vittatus	15	7	68	32
Alestes imberi	3	19	10	90
Labeo congoro	7	0	100	0
Labeo altivelis	28	0	100	0
Labeo cylindricus	2	0	100	0
Eutropius depressirostris	14	1	93	7
Clarias gariepinus	13	2	87	13
Malapterurus electricus	0	2	0	100
Synodontis zambesensis	19	3	85	15
Tilapia mortimeri	0	6	0	100

require discussion. Ignoring, for the present, individual variations which in the sizes of samples could result in misinterpretation; gonads collected in September should theoretically be in an earlier stage of development, hence be more definitely bimodal than gonads collected in the following February, towards the end of the breeding season. The gonads examined came from ripe fish collected over widely varying times of the year, so that seasonal error is to some extent overcome, and no trend from bimodality to unimodality is apparent in the results. If, under these circumstances, a high proportion of all gonads of a particular species collected throughout the breeding season was bimodal, the first alternative, that fish spawn at least twice each season, is more probable. Considering now the error which could result from individual variation (in that the ova of fish A, which will spawn in February, will be more markedly bimodal in September than fish B, which will spawn in November). If all, or even 90% of the sample showed bimodality, errors arising from individual variation are probably of little consequence. It is therefore probable that in these cases bimodal ova frequency distributions imply multiple spawning. The bimodal distribution of the ova of Tilapia mortimeri, a species known by culturists to be a multiple spawner, supports this conclusion.

The species which showed clear-cut bimodality were Cyphomyrus discorhynchus, Mormyrops deliciosus, Mormyrus longirostris, Malapterurus electricus and Tilapia mortimeri. At the other extreme, clearly single spawners were Labeo altivelis, L. congoro, L. cylindricus and Eutropius depressirostris. The ovaries of some individual Clarias gariepinus and Synodontis zambesensis, although clearly unimodal, contained a significant proportion of smaller eggs forming a shoulder to an essentially unimodal curve as illustrated in Fig. 11.5. 67% and 88% respectively did not have this "shoulder". Furthermore, the relatively minor proportion of smaller eggs, when these were present, and the lack of a clear-cut mode in these strongly suggests that these two species were single spawners. The curves of the characids Hydrocynus vittatus and Alestes imberi are less easy to interpret for although, as numbers, the smaller eggs are relatively insignificant in comparison with the fully formed eggs, the curve is more definitely separated than in Clarias and Synodontis. The relatively large proportion of Alestes sampled which exhibited bimodality (90%) suggests this fish to be a multiple spawner. In the case of Hydrocynus, 68% of sampled gonads were unimodal, implying a greater possibility of this species only spawning once; the seven fish with bimodal ova distribution being, possibly, incompletely developed.

Data up to this point are summarised in Table 11.5.

5. GONAD ATROPHICATION IN HYDROCYNUS

It was noticed that at times a quite high proportion of the ovaries showed signs of atrophication. The sequence in the atrophying process was as follows:

(1) Individual eggs in a ripe gonad, normally opaque and greenish yellow in colour, cleared, hardened and turned amber. This occurred randomly throughout the gonad.

(2) Groups of eggs then showed this reaction.

(3) The entire gonad, beginning posteriorly, hardened, turning an amber red and became brittle.

(4) The gonad decreased in size until pencil-like. This process took approximately a year and a new, comparatively small ovary with normal eggs would form ventrally to it.

(5) Presumably the atrophied gonad was then completely absorbed.

The percentage of female fish showing this phenomenon varied

TABLE 11.5 SUMMARIZATION OF FISH BREEDING DATA

	Breeding period	Female sexual maturity (mm)	Sex dominating larger fish	Males decreasing in winter	Egg production of average adult female	Ova diameter (mm) 1	2
Mormyrops	April, Oct (?)	35	Neither	No	25,000	0.8	2.5
Cyphomyrus	Jan-April	(10)	Male	No	2,500	0.7	1.6
Mormyrus	Rains	41	Male	Yes	48,000	0.7	2.0
Hydrocynus	Rains	17	Female	Yes	300,000	(0.4)	0.9
Alestes	Rains	(10)	Female	Yes	10,000	0.4	1.0
L. altivelis	Rains	21	Female	No	300,000	-	1.0
L. congoro	Rains	-	-	-	300,000	-	1.1
L. cylindricus	Rains	-	-	-	-	-	0.9
Eutropius	Jan-April	12	Female	No	15,000	-	0.9
Clarias	Rains	(53)	Male	No	80,000	(0.6)	1.4
Synodontis	Jan-April	9	Female	No	20,000	-	1.0
Malapterurus	Rains	-	-	-	25,000	0.8	3.0
Tilapia		-	-	-	4,000	1.0	2.9

seasonally: January 1967: 24%; April 1967: 8%; July 1967: 4%; January 1968: 18%. The implications of these findings are considered in Section 7.

6. EARLY DEVELOPMENT

Although attempts were made on several occasions to artificially fertilise ova of different species, the opportunity to do so occurred rarely and only in one instance was successful, when Hydrocynus ova were fertilised by stripping ova from a female fish into a river water filled bowl and then artificially ejecting milt from a ripe running male, caught shortly afterwards, into the same container. Ova and larvae were collected on two other occasions, once in amongst the roots of shoreline Salvinia and another time in invertebrate samples taken from Ceratophyllum. Nesting of Tilapia mortimeri was observed to occur in a shallow bay protected by grounded Salvinia at Chris' Beach.

The necessity to readily identify the youngest stages of development of fishes has been recognized for some time (Balinsky, 1948) but in Africa the opportunity to describe species not used in culture is obviously limited; only one publication, that of Fryer and Whitehead (1959) on the development of Labeo victorianus, is known to me, although early fingerlings of Hydrocynus have been described (Gaigher, 1967; Kenmuir, 1972) and later development of Haplochromis multicolor is figured by Welcomme (1969).

6.1 Hydrocynus vittatus

The successful fertilisation of Hydrocynus eggs took place at 10.00 hours on 25th January 1968, following a minor flood on the previous day (see Chapter 10, 6.1) during a moderate run of the species. Fertilised eggs were immediately taken to the research station laboratory and placed, well spread out, in shallow enamel dishes, covered with 3 cm of lake water and well aerated. Opaque eggs were removed at this stage to minimise the likelihood of fungal infection. Sample embryos were removed in duplicate series at varyingly spaced intervals and fixed and stored in 70% alcohol or 10% formalin. Apart from the removal of samples and dead ova and aeration, the dishes were disturbed as little as possible. Post-larvae were offered plankton collected by 60 mesh netting, and fed readily. When the remaining post-larvae had reached 22 days they were transported by open plastic bag aerated with compressed oxygen to the laboratory in Salisbury to an aquarium kept at 28°C and fed here on early instar cladocerans.

Water temperature in the research station laboratory varied little around 25°C, although for short periods the temperature dropped to 24°C and rose to 26°C. Eggs and larvae were never exposed to direct sunlight, so that little inhibition of growth could have occurred as a result (see Smith, 1957).

The ripe ovarian eggs of Hydrocynus vary in diameter between 0.8 and 1.2 mm, but the majority are between 0.9 and 1 mm and are a bright yellow. Swelling of the vitelline membrane occurs when the ovum is placed in water, irrespective of fertilisation, resulting in an egg of 1.1 to 1.2 mm in diameter containing a yolk of 0.75 mm. In the fertilised egg the membrane is perfectly spherical and although transparent, is somewhat adhesive so that the entire egg is covered by a thin layer of minute detritic particles, rendering the egg cryptic and observation of the embryo without removal of the vitelline membrane rather difficult. Eggs are very slightly denser than water, are therefore demersal, but easily go into suspension.

The main features of development are illustrated in Fig. 11.6 and described with regard to outstanding features in Table 11.7. It is

Fig. 11.6. The early development of *Hydrocynus vittatus*. See Table 11.7 for explanation (vitelline membrane has been omitted from 2 to 8). The scale is 1 mm.

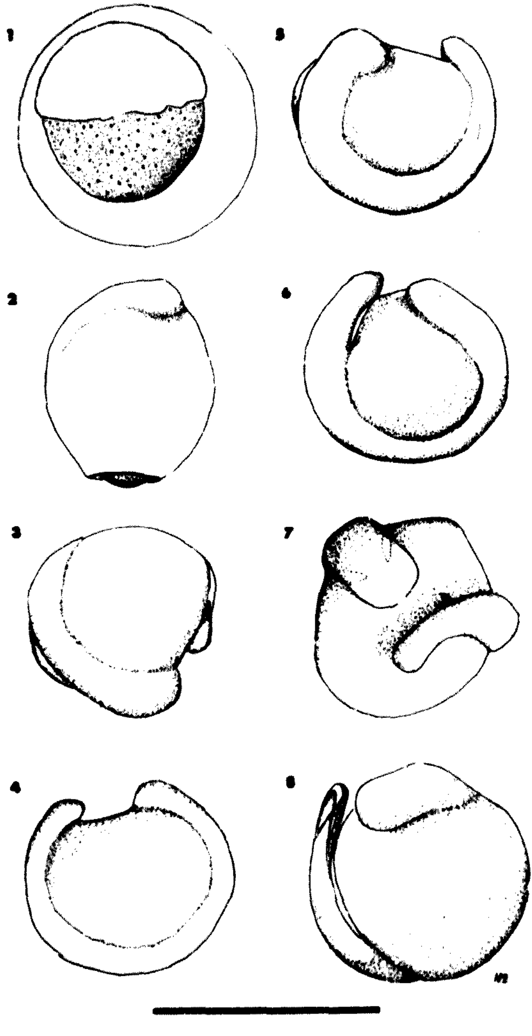


Fig. 11.6.

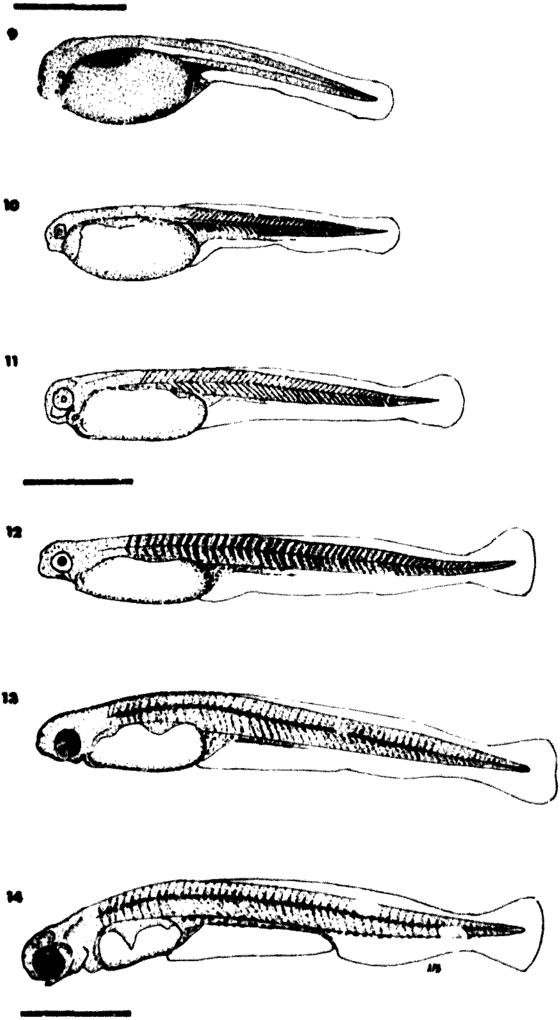


Fig. 11.6. (continued)

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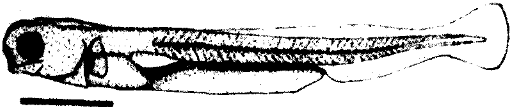

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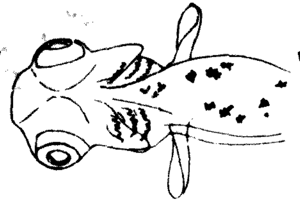

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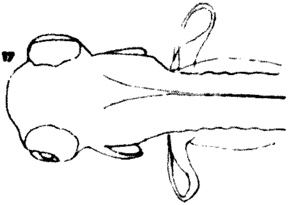

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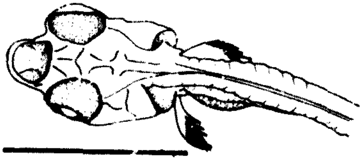

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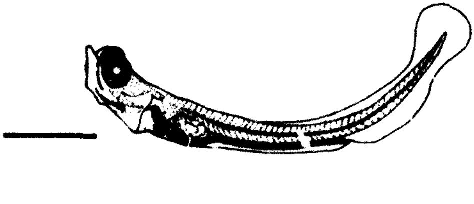

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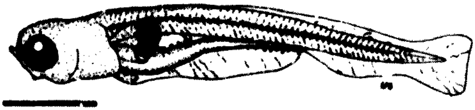

Fig. 11.6. (continued)

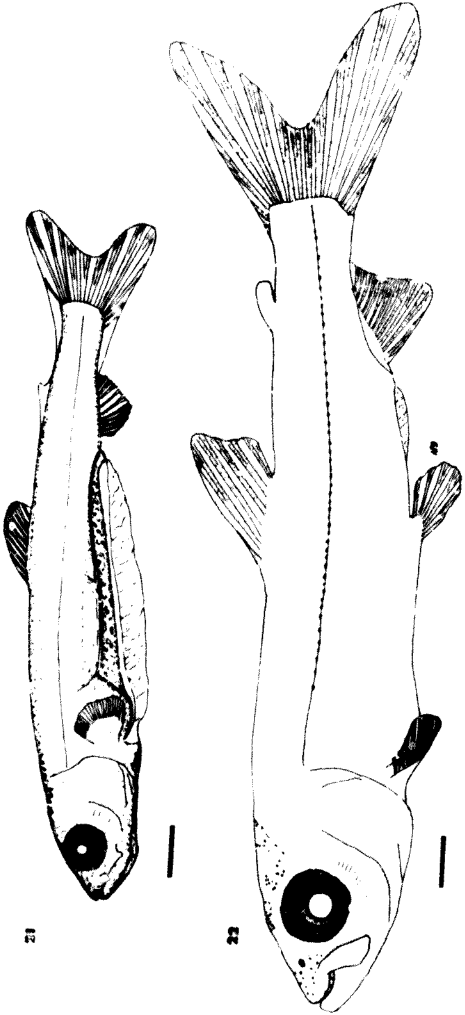

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Fig. 11.g. (continued)

TABLE 11.7 THE DEVELOPMENT OF THE EARLY STAGES OF *HYDROCYNUS VITTATUS* AT 24° - 26°C (Figure numbers as in Fig. 11.6)

Time	Fig. No.	Stage of development
00.00hrs	-	Ova fertilised.
(01.05 hrs)	-	(Ova placed in aerated aquarium).
01.20 hrs	-	4 cell stage.
08.30 hrs	1	Middle gastrula. Blastodermal cap has reached equatorial position.
12.00 hrs	2	Late gastrula. Blastoderm covers entire yolk except for yolk plug. Head region differentiated at the animal pole as rounded raised thickening.
22 hrs	3, 4	Embryo length (2 mm) 7/8 yolk circumference, encircling yolk eccentrically. 8% of embryo freed from the yolk sac at caudal end.
29 hrs	5	22 somites developed. Eye and ear rudiments visible in live material.
34 hrs	6, 7	27% of embryo freed from yolk sac at caudal end and growing in a curve away from the anterior end. Embryo now 2.2 mm long, encircling yolk sac eccentrically.
45 hrs	8	Embryo [illegible].5 mm long, head region becoming free of the yolk sac, fin fold forming on the end of the tail. 50% of the pro-larva now free of the yolk sac. Embryo active within the vitelline membrane, but still curved around yolk sac.
47 hrs	9	Larva 3.2 mm long, yolk sac 1.2 mm long by 0.6 mm deep, oval and elongate. Hatching occurs, fin fold developed along tail, somewhat deeper ventrally. Melanophores sparsely present on head surface and at each end of the yolk sac.
48 hrs	10	Larva 3.2 mm, yolk sac 1.1 mm x 0.5 mm, optic vesicle and heart rudiments apparent in preserved material. Caudal end of fin fold more greatly expanded than the remainder. Ventral fin fold clearly deeper than dorsal.
70 hrs	12	Larva 4.5 mm, yolk sac 1.1 mm x 0.4 mm, caudal fin fold clearly differentiated as expanded portion of fold. Lens apparent in optic vesicle in preserved material.
96 hrs	13	Larva 4.8 mm, yolk sac 1.0 mm x 0.4 mm, eye pigmented.

TABLE 11.7 Continued

Time	Fig. No.	Stage of development
120 hrs (5 days)	14	Larva 4.9 mm, yolk sac 0.7 x 0.5 mm. Mouth and visceral arches apparent. Gut fully formed, sparsely pigmented. Pigmented spots appear sparsely along the ventral edge of the mid lateral line.
8-10 days	15, 16, 17	Larva 5.4 mm. Yolk absorbed. Mouth, operculum and gills fully formed. Paddle-like pectoral fins present. Head broadened laterally so that eyes are widely spaced. Air bladder apparent. Relatively large but well separated melanophores occur on the belly. Melanophores persist along the gut.
16 days	18, 19	5.2 mm long. Eyes and mouth have increased disproportionately in size. Operculum more clearly defined. Pectoral fins distinctly rayed. Air bladder wall developed. Gut with melanophores.
22 days	20	5.1 mm long. Pectoral fins more greatly developed (10% of body length as opposed to 6% at 16 day stage). Body greatly increased in depth, eyes centrally as opposed to dorsally position in the laterally viewed head. Gut well developed with melanophores posteriorly. Melanophores positioned laterally along each side of the body mainly at the junction of the myomeres and dorsally in the pectoral region. Caudal fin fold truncate, having previously been rounded.
26 days	-	Caudal fin noticeably forked.
28 days	-	Anal fin obvious.
30 days	21	12.5 mm. All rayed fins apart from pelvic and adipose fin well developed, the latter represented by a membranous fold. Articulating bones of skull becoming obvious. Caudal fin forked and rayed, joined smoothly to dorsal and ventral surfaces of caudal peduncle by a membranous remnant of the fin fold. Melanophores present, dorsally above the operculum, anteriorly along the leading edge of both jaws and ventrally on the pectoral girdle. Fin fold remnant extends from pectoral girdle to vent.
35 days	22	17.5 mm. Clearly recognizable as a <u>Hydrocynus</u> fingerling. Unicuspid teeth have developed in both jaws. All rayed fins developed. Adipose fin fully developed. A short relict of the ventral fin fold occurs between vent and pelvic fin. Melanophores occur along the lateral line and on the dorsal surface of head and body. External nares visible for the first time.

pertinent here to discuss certain features in respect of the development of the cyprinid _Labeo victorianus_, described by Fryer and Whitehead (1959), as several distinct differences and some similarities are apparent.

6.1.1 _The perivitelline space_

Fryer and Whitehead (1959) point out that Horn (1930) believed the large perivitelline space to be advantageous to swift water spawners in that it offers a degree of protection to buffetting in turbulent waters. They also suggest that the extra buoyancy imparted by swelling is advantageous in ephemeral flood conditions, "enabling the eggs to pass out (from side pools and channels) into the main river as the water recedes". They found the perivitelline space to be considerably larger in _L. victorianus_ (overall egg diameter less yolk diameter approximately 2.6 mm) than found here in _Hydrocynus_ (0.4 mm), although the actual yolk size is similar. Ova of _Alestes imberi_, _Labeo altivelis_ and _L. cylindricus_ were found to be similar to _L. victorianus_. Fryer and Whitehead (1959) suggest that the large perivitelline space is a relic of a former fast-water spawning habit. If this is true, the smaller perivitelline space found in _Hydrocynus_ eggs suggests that there could be a gradation of this characteristic. Nevertheless the size of the perivitelline space of _Hydrocynus_ and the observed resilience of the vitelline membrane must be of great survival value in a river subject to violent flooding over rapids, such as the Mwenda; particularly if breeding does occur in rapids as suggested by the observed behaviour of this species (Chapter 9, 6.1).

6.1.2 _Preserved material_

Where time was available, free-hand drawings were made of developing embryos, using live material. It was possible to discern far greater detail in this material than was subsequently possible with regard to preserved material. Particularly in respect of somites, and the optic and otic vesicles. For this reason these embryological characteristics have intentionally not been emphasised and direct comparison with Fryer and Whitehead (1959) in respect of these characteristics has been avoided.

6.1.3 Yolk sac

A characteristic of *Labeo victorianus*, in common with *L. gonius* and other asiatic cyprinids, was the development of a posterior extension of the yolk tube beneath an essentially straight embryo. *Hydrocynus* is markedly different in this respect, the yolk sac remaining ovoid at all times, being spherical prior to hatching when encircled by the embryo and being, subsequent to hatching, elongately ovoid.

6.1.4 Hatching time

Although there was a degree of disparity in the rate of individual development and hatching occurred over two to three hours, this was not as great as found in *L. victorianus*, where hatching took place over 20 hours. The *Labeo* material was, however, collected in the field and could have been the result of different spawnings, although Fryer and Whitehead (1959) suggest that hatching disparity may also have survival value in an ephemeral environment.

6.1.5 Larval behaviour

As soon as the larvae of *Hydrocynus* hatched they were able to swim vigorously. Very like the behaviour of *L. victorianus* larvae, *Hydrocynus* larvae would swim rapidly upwards to the surface and on reaching it, become passive, sinking slowly to the bottom. When the bottom was touched the cycle would be repeated. Unlike *L. victorianus*, however, the only resting phase observed occurred during the sinking phase of the cycle and larvae were not seen resting on the bottom unless dying. In a flowing river this behaviour could only help in a downstream movement, and would also tend to lessen the opportunities of being damaged as a result of contact with obstructions along the river bottom.

Larvae start feeding at four to five days old when eyes and gut are fully developed and pectoral fin primordia have developed. Dense zooplankton concentrations were added to the rearing trays and the feeding behaviour was characteristic and not seen to vary. At this stage the bottom to surface movement had ceased and the larvae had started to show a degree of shoaling. On approaching a small plankter a larva would stop one to two millimetres away, deliberately coil its body into an S shape on the horizontal plane, at all times keeping the plankter directly in front of the head, and then lunge at the plankter in a single spasmodic movement. In many instances the lunge was unsuccessful, due either to its misdirection, rapid avoidance by the plankter or the plankter being too large for the mouth of the larva.

6.1.6 Pigmentation

Unlike Labeo victorianus and the European cyprinids (Balinsky, 1948) the only pigmentation of any permanence up to the last stage described here, occurred along the gut. Apart from the very obvious eyes, larvae were transparent until approximately 28 days and countershading was in its earliest stage of development in the largest fish (17.5 mm).

6.1.7 Growth rate

In accordance with Balinsky (1948) and Fryer and Whitehead (1959), extreme caution is necessary when comparing growth rates in the field with those obtained under laboratory conditions. In this instance the temperatures of rearing trays were much the same as environmental temperatures. Food was not, however, directly comparable. The most noticeable factor with regard to growth rate was the discrepancy exhibited between individuals. The two final individuals, for example, were markedly different in size when the smaller was removed at 30 days. Samples taken between 8 and 10 days also had quite a wide variation in development. The correlation of field data with these results must therefore be carried out with caution and can only be regarded as approximate. Kenmuir (1972) using a large fry net in the Sanyati River gorge towards the end of March 1970, found a preponderance of fry between 10 and 20 mm. On these data these fish would have been, roughly, about four to six weeks old and would have been spawned around the beginning of February. Approximate ageing criteria are given in Table 11.8.

6.1.8 Teeth

Teeth had not yet developed in the 12.5 mm. individual, but unicuspid teeth, irregularly spaced on both jaws, had developed by 17.5 mm. This is in agreement with Kenmuir's (1972) findings, where conical teeth were found to be present between 12 and 22 mm, tricuspid teeth between 24 and 33 mm and conical teeth again from 34 mm; data which support Roberts (1967) in his hypothesis that the unicuspid teeth of Hydrocynus were derived from the tricuspid type found in Alestes.

It can be seen, therefore, that considerable differences exist between the development of Labeo victorianus and Hydrocynus vittatus; particularly in the size of the perivitelline space, the straightness of the prehatching embryo of Labeo, the presence of the yolk tube extension in Labeo not seen in Hydrocynus and the possibility of delayed hatching in Labeo eggs not found in Hydrocynus. The major similarity between the two lies in the bottom to surface swimming behaviour which will be returned to below.

TABLE 11.8 APPROXIMATE AGEING CRITERIA FOR *HYDROCYNUS* KEPT BETWEEN 24° AND 26°C UP TO 30 DAYS, AND 28°C THEREAFTER (Figures refer to Fig. 11.6)

Days	Fig. No.	mm	Criteria
2	9	3.2	Hatching, no eye or mouth. Yolk sac present.
4	13	4.8	Pigmented eye, no mouth. Yolk sac present.
5	14	4.9	Mouth and gut develop. Yolk sac present.
8-10	15-17	5.4	Mouth and gills well developed, pectoral fins unrayed "paddles". No yolk sac.
16	18-19	5.2	Mouth large, air bladder present, pectoral fins lightly rayed, caudal fin rounded and membranous.
22	20	6.1	Caudal fin fold truncate.
26	-	-	Caudal fin noticeable forked, rays developing.
28	-	-	Anal fin develops.
30	21	12.5	Adipose fin develops, fin fold extends from pectoral girdle to vent. No pelvic fin.
35	22	17.5	Conical teeth present. All fins present. Fin fold remnant extends from halfway between pelvic fin and vent, to vent. Clearly recognisable as *Hydrocynus*.

6.2 The Clariid (*Heterobranchus longifilis*?)

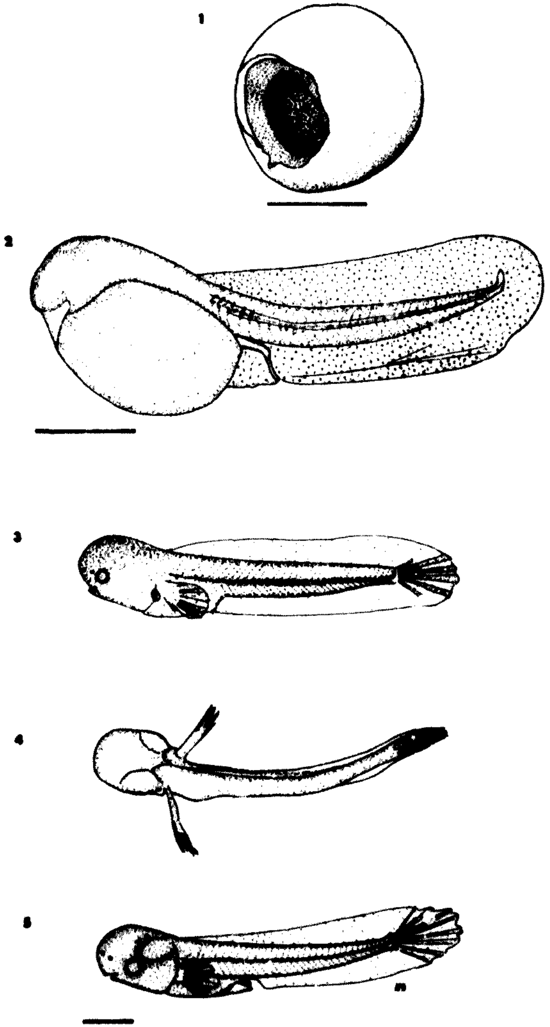
The development of the clariid was markedly different from that found in both *Labeo victorianus* and *Hydrocynus vittatus*.

Eggs were found along the shoreline of Chris' Beach in amongst *Salvinia* "roots" which were lying on the bottom on 3rd November 1967. At this point the shoreline is gently sloping, protected and sandy. The water level at this time had been more or less stable for two weeks, having dropped only 0.1 m in the previous fortnight. A concerted search resulted in the collection of nine larvae and eight eggs, which were found only in water between 5 and 15 cm depth. The marginal *Salvinia* at this point extended approximately 5 m out from the shoreline. Eggs and larvae were returned to the laboratory and placed in shallow glass aquaria under 15 cm of lake water, with several *Salvinia* plants. Very few samples were taken from the aquarium due to the paucity of material and growth could not be continued after 10 days due to the termination of the field trip. Details of the development may be found in Fig. 11.7 and Table 11.9.

When collected the development was in late gastrulation and the embryo was much larger than in *Hydrocynus*, being 1.7 mm in diameter. There was no perivitelline space, the embryo being tightly confined by the vitelline membrane. They were light green in colour and perfectly spherical and smooth externally. Embryos preserved for examination and figured were not necessarily at the same stage of development as those which hatched during the night of 3rd November, as larvae up to about 8 days old were collected at the same time as the eggs.

The larvae which hatched were dark green in colour and lacked melanophores. They were far more robust than the *Hydrocynus* larvae and within 30 hours of hatching had developed a mouth, absorbed the yolk sac and developed rayed pectoral fins. Forty hours after hatching the epibranchial chambers had developed as subcutaneous bubbles in the postero-dorsal region of the skull. By ten days the larvae were 8.[illegible] mm long, the eyes were fully functional and although a large part of the fin fold persisted, the rudiments of the dorsal and anal fins could be seen. The behaviour of larvae throughout was unremarkable. They would be almost continuously quiescent on the bottom of the aquarium in the *Salvinia* roots, but if disturbed would swim deeper into these. Presumably they fed at night on detritus which had been introduced into the aquarium with the *Salvinia*. Small melanophores

Fig. 11.7. The early development of a clariid, probably *Heterobranchus longifilis*. See Table 11.9 for explanation. Vitelline membrane removed in 1. The scale is 1 mm.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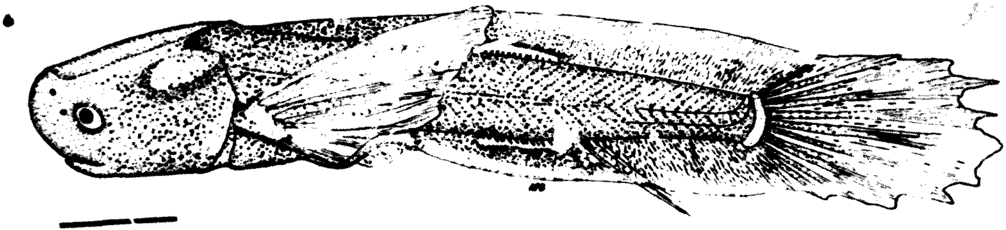

Fig. 11.7. (continued)

developed strongly by 10 days, widely scattered over the body and fin fold, but concentrated to some degree along the borders of the myomeres and lateral line.

TABLE 11.9 THE DEVELOPMENT OF THE EARLY STAGES OF A CLARIID AT 22° - 25°C. (Figure numbers as in Fig. 11.7)

Time after hatching	Fig. No.	Stage of development
-	1	Late gastrula, with yolk plug.
18 hrs	2	Larva 5.3 mm, yolk sac 1.8 mm x 1.3 mm. Notochord and approximately 29 myomeres apparent. Tail surrounded by deep membranous fin fold, smoothly rounded caudally.
30 hrs	3	Larva 7.6 mm. Yolk absorbed, 33 myomeres apparent. Mouth, two pairs of external nares and operculum developed. Eyes apparent as rounded elevations. Rayed pectoral fin present and caudal portion of fin fold with six developed rays.
40 hrs	4	Larva 7.2 mm. Caudal fin with eight rays, alimentary canal more obvious and probably functional. Epibrancheal chamber apparent as subcutaneous cavities on each side of the head in a postero-dorsal position.
10 days	5	Larva 8.[illegible] mm. Caudal fin extending posteriorly with eight rays. Eyes functional. Bones of dorsal and anal fins developing within the membranous larval fin.

It was unfortunate that it was not possible to allow the larvae to develop to a clearly recognizable stage, but the large size of the ova collected suggests that, of Heterobranchus longifilis and Clarias gariepinus (one of which they must have been, having an epibranchial chamber) the former is more likely. The fertilized eggs of Clarias have been described by Holl (1968) as having a flattened adhesive disc not apparent in these specimens. Other differences from Clarias based on Holl's (1968) description was that on hatching, Clarias were 3.5 - 4.0 mm long (of 5.3 mm at eight hours) and the yolk sac was absorbed in seven days (cf 30 hours). It is probable, therefore, that the development described is that of Heterobranchus longifilis.

7. POTAMODROMESIS IN THE MWENDA RIVER

It is necessary to consider breeding data in relation to seasonal changes in distribution and abundance of fish at the river mouth, in the dry season pools, and findings of other workers.

7.1 Previous Work on Potamodromesis in Africa

Compared to the considerable quantity of data which has been accumulated on the migratory behaviour of the fishes of the northern temperate zone, little information is available on the migratory behaviour of tropical fishes, particularly in Africa, although the subject has received a comparatively large amount of attention. In East Africa, Whitehead (1959) has studied fish migration in the rivers of north-eastern Lake Victoria. Fryer and Whitehead (1959) reported in greater detail on the breeding biology of one of the more important potamodromous species of this lake, Labeo victorianus Boulenger, which was the subject of further studies by Cadwalladr (1965a, b). van Someren (1962) used an inclined grid trap on a small easterly flowing river in Kenya, principally to sample catadromous species, in particular Anguilla nebulosa labiata Peters, but gained incidental information on potamodromous species. Subsequently Welcommo (1969) has clarified certain aspects of the biology of smaller fishes in a stream/swamp system which flows into Lake Victoria and gives evidence of complex migrational movements.

In Southern Tropical Africa, work on migration of freshwater fishes has been even more severely confined. Mortimer and Bell-Cross's (1960) data revealed a complicated bidirectional movement of fish in a ladder situated in the spillway of a small dam in Zambia.

Badenhuizen (1965) gave preliminary results on the potamodromous behaviour of fishes in the Lufubu River at the southern end of Lake Tanganyika which is an important weir fishery. Pott (1969) has studied the biology of fishes in the Pongolo River of South Africa in an attempt to assess the effects of the proposed J.G. Strijdom dam on the fish life and gained valuable information on fish movements. Finally, Bowmaker (in press) has described the climbing mechanisms of Leptoglanis rotundiceps (Hilgendorf) and Labeo cylindricus (Peters) up a damp concrete spillway of a Rhodesian dam.

Information on the breeding biology of African potamodromous species is therefore sparse. Apart from knowing the species which are potamodromous (see Lowe, 1952; Poll, 1956; Jackson, 1961; Jubb, 1967) this lack of knowledge has to be accommodated by generalisation. Thus, generally speaking, potamodromous species are thought to congregate at river mouths prior to the onset of the rains and, when a suitable flow is realised, move upstream varying unspecified distances to varying substrates. Present knowledge has hardly progressed beyond the statement made by Fryer and Whitehead (1959) more than ten years ago: "The most we can say is that this species (Labeo victorianus) exhibits a positive response to the influx of flood water, which leads mature individuals to sites . . . . where spawning activities can be successfully carried out".

Indian workers have perhaps greater experience of tropical potamodromesis and at a symposium in 1945 specifically to discuss the subject, concluded that no single factor could be held responsible for the inducement of spawning (Ganapati and Chako, 1952). The "triggering" mechanism for upstream migration, it is generally believed, also cannot be attributed to any single factor, but results from the combination of many physical and chemical factors associated with flooding, though subsequently, Lake (1967) working in Australia, believes that a single substance, "petrichor", may provide the final stimulus for spawning. This oil is released from dry ground when it is dampened and is a complex mixture of organic compounds containing acidic, basic and neutral fractions.

The pressing need to gain detailed knowledge of the variations in behaviour and requirements of different African potamodromous species need not, perhaps, be stressed, for the place of importance that the knowledge of breeding biology in relation to management of natural fish populations is sufficient in itself to do this. This is particularly true for a man-made lake where essentially lotic species are forced into a lentic environment and breeding still occurs to a large extent in the rivers. This behaviour offers an ideal opportunity for human manipulation, but is one which should be thoroughly understood prior to interference.

7.2 Fish Migration

Bearing in mind that this discussion involves the first two phases of a three phase study, the third being the utilization of a flume-type flow gauging weir incorporating two-way fish traps with constant recording of abiotic data; the data were largely inadequate for definite conclusions, due principally to the inaccuracy of gill and trammel nets as sampling tools, and must at this stage be regarded as tentative.

The species which have been found to migrate upstream for breeding purposes were *Mormyrus longirostris* Peters, *Hydrocynus vittatus* Castelnau, *Alestes imberi* Peters, *Labeo cylindricus* Peters, *Labeo [illegible]* Jubb, *Labeo congoro* Peters, *Labeo altivelis* Peters and *Clarias gariepinus* (Burchell). Species which were found to migrate upstream essentially for feeding purposes, but whose juveniles were found in small numbers in the pools were *Synodontis zambezensis* Peters and

Tilapia mossambica Peters. *Cyphomyrus discorhynchus* (Peters) and *Heterobranchus longifilis* C-V also moved upstream in small numbers, but no juveniles were found. Several species were found only in the rivers and pools and not in the lake. These were *Barbus lineomaculatus* Boulenger, *B. unitaeniatus* Gunther, *Chiloglanis neumanni* Boulenger and *Micralestes acutidens* (Peters). *Alestes lateralis* Boulenger was found in the pools, but was not caught while migrating. The main population of this species was, however, found throughout the year in weed beds along the lake margins.

Four of the truly potamodromous species, *Mormyrus longirostris*, *Hydrocynus vittatus*, *Labeo altivelis* and *Clarias gariepinus* constituted 83% of the population by weight as reflected by gillnets at Parrot Sand. With the reservations imposed by the methods used, the behaviour of these four species was, briefly, as follows:

Hydrocynus vittatus. This species accumulated at the netting station in September 1967, three months before moving upstream only during heavy floods and then in their residual flow in late December and mid-January 1968. On the basis of netting results it is considered that there was a constant immigration of pre-breeding fish into the river mouth area throughout the breeding season, for accumulation of *Hydrocynus* occurred if the river ceased to flow. Migrational runs occurred in waves of fish, as if shoals had been formed and were moving together. There was some indication of diurnal activity and heavy runs took place on overcast days if the river was flowing sufficiently, but these two conditions were normally concurrent. Spent female fish were taken moving downstream in January, at the same time as pre-breeding fish moved upstream. Male fish were sexually precocious, exuding milt while migrating in the company of pre-breeding females. There seemed to be a variation between individuals regarding the length of stay in the river dependent, probably, on the distance upstream they migrated. Spawning females were taken at the first point available in the river on the one hand, and on the other must have travelled considerable distance upstream, for year 0 juveniles were present in some quantity in the highest dry season pool sampled, some 4 km from the lake. The behavioural adaptation of the larvae which would seem to allow for passive downstream transport and which will be discussed below, indicates that spawning must take place considerably further than 4 km from the lake. Migration occurred only after flow had reached a level higher than seemed necessary for other species.

Mormyrus longirostris. Unlike Hydrocynus, the Mormyrus population started at a high dry season level at Parrot Bend, and gradually fell off prior to the river starting to flow. This could indicate a gradual movement from Parrot Bend towards the river mouth not sampled by the gillnets, as the species is strongly potamodromous. All migrating fish were adult and both females and males stayed in pre-breeding condition while migrating. Movement upstream seemed to occur sporadically throughout the rains, particularly during the lower post-flood periods. This is perhaps understandable in view of the weak swimming ability of this species. As Mormyrus is essentially found in deep water and as it is probably capable of electro-orientation (Lissman, 1963), it is anticipated that the third phase of this study will show predominantly nocturnal movement. There was, nevertheless, considerable movement during the day. Large numbers of juveniles were found in pools which were rocky; very few in pools free of cover. On the basis of lack of readiness to breed and ova diameter bimodality, the indications were that Mormyrus tended to spend a longer period in the river than the other species.

Labeo altivelis. The population of _Labeo altivelis_ increased explosively at Parrot Bend six weeks before the first floods and numbers decreased just as rapidly following the initial flood. Utilization was thus made of the initial flooding, but both up and down-stream migrations occurred throughout the rainy period, when flow permitted. A seeming preference for lower flow periods was shown and _Labeo_ was frequently running at the same time as _Mormyrus_. Both species were found in association with _Hydrocynus_ at higher flow rates, but _Labeo_ seemed more capable of migrating during these higher flows than _Mormyrus_ was. The indications were that spent fish returned downstream as soon as flow allowed. On the basis of breeding readiness shown by the fish which accumulated at the river mouth and the numbers which undertook an upstream migration, _Labeo_ appeared to be strongly potamodromous and males exuded milt while migrating. The presence of this species at the river mouth suggest that _Labeo_ was more transitory here than the other species were; once at the river mouth, they moved upstream at the first opportunity. Similarly, the floods were not anticipated for as long a period as by _Hydrocynus_, _Clarias_ and _Mormyrus_. Quite frequently migrating fish of this species could be seen moving upstream as the very tip of the high dorsal fin just protruded above the surface. As the water depth in the observed cases was sufficiently great not to impose surface movement in the species, it is considered that this behaviour would be of depth orientational value in turbid water and would explain a function of selective value for the inordinately deep dorsal fin of this species.

Clarias gariepinus. The nature of the _Clarias_ migration was found to be entirely different from the other species. A week before the first floods, an extraordinarily dense concentration of _Clarias_ was observed, lying quiescent on the bottom, underneath the _Salvinia_ ment in one to two metres of water, at the very highest point of back-flooding of the river by the lake. These fish migrated upstream immediately the first flood water reached them and were observed leaping up the first rapid. Many were damaged on the leading edge of the mouth from collisions with rocks in this rapid and crocodiles took toll of considerable numbers. The nature of the flood was such that this first and probably last wave of the migration in this particular instance could only have travelled 200 m upstream before meeting an impassable barrier, but male fish, which had been lying quiescent in pre-breeding condition only hours previously, were exuding milt within 12 hours. The only female fish caught in the rocky pool below the barrier was found to be spawning. Data collected in other years also indicate that this species moves upstream at the first opportunity only, as they were never found migrating upstream in the lower reaches of the river after the very first floods. However, some must have moved considerably further than the 200 m reported here, on the evidence of juveniles found 4 km upstream in the dry season pools. Downstream movement must, on the data available also, occur on the first opportunity following spawning. Yet on one occasion, a group of <u>Clarias</u> were found in full breeding condition at the river mouth but were not running upstream, a variation so radical that it gives some support to the idea that <u>Clarias</u> exist in Lake Kariba as two separate populations.

8.3 <u>Variations in Migrational Behaviour</u>

The reasons for upstream migration therefore varied and in the Mwenda River were associated either with breeding or feeding.

Similarly the timing and duration of the upstream migration for breeding purposes also seemed to vary, from a single massive early run by <u>Clarias</u>, on the one hand, to the more fragmentary migrations of

Hydrocynus, *Labeo* and *Mormyrus* which were apparently varyingly dependent on the flow volume, on the other.

There were also differences in pre-breeding behaviour. *Clarias*, *Mormyrus* and *Hydrocynus* seemed to "anticipate" flooding by several months in that they accumulated at the river mouth some time before the rains started. Whereas this was the only time breeding *Clarias* accumulated in association with a river migration, *Hydrocynus* and *Mormyrus* seemed to migrate from the lake to the river mouth continuously throughout the rains; particularly during the first few months of the season. On the other hand *Labeo* appeared to concentrate at the river mouth only after the rains had commenced and before the river started to flow and spent a considerably shorter period in the area. The breeding sequence of individual *Labeo* would therefore seem to have beem more rapid, in that they moved upstream at the earliest opportunity.

The question regarding the length of stay in the river is on present data unanswerable. There were indications, however, judging by the variation in gonad state and ova size between the different species during upstream migration and by the accumulation of post-breeding fish after flooding, that here also there was variation. *Mormyrus* would appear to have bred some time after moving upstream and could be multiple spawners, whereas *Clarias*, *Hydrocynus* and *Labeo* bred more quickly once the river had been entered. Spawning females of all three of these latter species were taken at the first possible point available in the river, though the frequency in which they were found and the number of juveniles occurring in the dry season pools suggest alternative main breeding areas further from the lake. Closely linked with this aspect of behaviour was the distance travelled upstream by the various species. The behaviour of *Hydrocynus vittatus* larvae shortly after hatching and its remarkable similarity to that of *Labeo victorianus* described by Fryer and Whitehead indicate adaptations which could result in a downstream movement of these species at an early developmental stage. Eight-month old juveniles of all four species have been taken in a dry season pool at the highest sampled point, 4 km from the lake. The distance travelled upstream by some individual *Hydrocynus*, at least, and probably *Labeo*, must therefore be considerably further, for the volume and power of larger floods would rule out the retention of larval fish which do not actively seek backwaters.

A further point to consider is the variation in substrate chosen by the different species. It was considered by Jackson (1961) that breeding of most species present in the middle Zambezi River, prior to formation of the lake, took place in shallowly flooded vegetation and that this behaviour was of considerable significance in the role it played in predator evasion. *Clarias gariepinus* has also been observed to spawn in newly flooded grassland on the Rhodesian pl[illegible] (Hall, 1968), essentially similar to the substrate used by *C. mossambicus* of Lake Victoria (Greenwood, 1955). Lowe (1952) reports that the *Labeo mesops* of Lake Nyasa spawns on this substrate, having moved up small muddy streams, whereas *Barilius microlepis* and, possibly, *Tilapia shiranus*, *Synodontis zambezensis* and *Barbus rhoadesii* migrated up large relatively clear rivers; not unlike the Lufubu River, Lake Tanganyika, discussed by Badenhuizen (1965), where *Hydrocynus vittatus*, *Alestes macrophthalmus*, *Citharinus gibbosus* and *Barbus tropidolepis* move up to spawn. The Kalungwishi River of Lake Mweru is also of this type and supports t[illegible]ation of *Alestes macrophthalmus* (Bowmaker, 1969a). Having [illegible] this type of river, Lowe (1952) reports that African fishermen [illegible] a deep rocky pool as being a spawning site for B. *microlepis*, as they had observed juveniles in this pool. The well-documented spawning run of *Labeo altivelis* up the Luapula River (Matagne, 1950) suggests the possibility of two types of spawning substrate, namely flooded swamp vegetation or soft muds in association with slowly flowing water.

Bowmaker (1969a) observed non-anadromous breeding in the *Alestes macrophthalmus* of Lake Bangweulu. This species is reported elsewhere as being anadromous but could well fall into Corbett's (1961) stage 3, namely a species which feeds and breeds in both lakes and rivers (as a stage in development from a purely lotic to purely lentic species); for breeding occurred on a wave-washed sandy shoreline. Thus at least one species, and probably some of the Mwenda species, do not have to spawn on exactly the same sort of substrate and Greenwood's (1965) suggestion may be correct: that a ruling factor in the choice of spawning sites for some species is the necessity for a cleansing action by rolling of ova, either in turbulent or in flowing water. This postulate is lent support by the nature of the Mwenda River, as nowhere is there the type of backflooded vegetation mentioned by Jackson (1961) as being so necessary for successful breeding. Substrates offered by the river are either rock, sand or mud, with vegetation offered only by the occasional trailing branches of the bush *Combretum obovatum* F.Hoffm. There is no backflooding of grassland along the river margins and this only occasionally occurs, in a very limited area, when the lake level rises to excessive heights.

A further problem arises from the "anticipatory" accumulation of fishes at the river mouth. The recognition of rivers and in some cases particular rivers by fish has long been considered to result from perception of their particular odours and Hasler (1954) showed that odour perception in fishes can be extremely acute. The fact that fish may perceive the mouth of a river which ceased to flow some seven months previously suggests either that orientation is not necessarily based only on odour perception or that the sense of smell in the fishes involved is remarkably well developed.

Are the species mentioned in this study necessarily exclusively potamodromous? This is a factor of considerable importance in the formulation of management policy and is a question that cannot be answered with any certainty. The only data remotely pertaining to this question arises from the atrophication of ripe ovaries of Hydrocynus, which has been found to occur with some frequency in the Mwenda area in January particularly, and which may result from too long a wait prior to the river flooding sufficiently, but could also result from disease or some breakdown in ethological breeding sequence. On the other hand, the observed presence of large shoals of adult Clarias gariepinus in Lake Kariba some distance away from the river mouth at the time the single breeding run of Clarias occurred, suggests that this species also breed elsewhere, probably on the flooded shoreline. The observed breeding readiness of some of these fish when not migrating supports this suggestion.

Although a wealth of evidence suggests that potamodromesis is innate and therefore obligatory, exceptions do occur, probably as a result of essentially lotic species either evolving into or having a predisposition for lentic breeding, provided that the essential conditions are fulfilled, as suggested by Corbett (1961). In Lake Victoria, for example, two non-endemics (Mormyrus kannume and Bagrus docmac) are apparently not obligately potamodromous (Whitehead, 1959). It would therefore be unwise at this stage to apply a general rule regarding the obligation of the potamodromous species of Lake Kariba to breed in the rivers.

The complexity and variability of behaviour between species indicated by the results of this preliminary study suggest ancient behavioural mechanisms of lotic stock which may not necessarily be advantageous under the lentic conditions imposed by damming. It would seem that, in the case of Kariba, some of the potamodromous species form a more important part of the lentic fish population, (Clarias, Mormyrus) than they had under lotic conditions, others remain more or less the same constituent (Hydrocynus) whilst others (Labeo altivelis, L. congoro) are showing a changing pattern of distribution and importance (Begg, 1969), dependent on the balance of lotic and lentic water quality content which characterise the series of basins which make up Kariba as described by Coche (1963).

Two further facts, relating to the return of juveniles to the lake, need discussion. The first involves the behaviour of Hydrocynus larvae which is remarkably similar to the behaviour of larvae of Labeo victorianus (Fryer and Whitehead, 1959). That two species with widely differing ancestry should have in common both this larval behaviour and be potamodromous suggests a possible link between the behaviour of adult and larvae. Namely, the larval behaviour encourages flow effect and rapid downstream movement away from the breeding ground, facilitating an early re-introduction into the lake or large river the breeding river joins. The rapidity of the downstream movement of larvae is dependent on the flow regime, and its actual occurrence in the Mwenda River is supported by the numbers of juvenile fishes remaining in the pools, which bear little relationship to the large numbers of breeding adults. The frequency of occurrence of approximately six-week old Hydrocynus fry found by Kenmuir (1972) in the Sanyati River gorge in static lake waters also supports the supposition of rapid downstream movement.

It has been proposed in Lake Kariba that the presence of _Salvinia auriculata_ mats at river mouths may hinder the movement of adult fish upstream and the return of juveniles downstream, in that a barrier of deoxygenated water is set up underneath the mat (Begg, 1969). It has been shown, however, that in the Mwenda River the flow levels required to initiate migration of adults are such as to break through this barrier as an oxygenated density current (Chapter 5). Though some of the larvae and young fishes must enter the lake at low flow levels and could be killed, the majority would probably do so during flooding and would thus be swept through the _Salvinia_ before coming to quiet waters, although this may not be the case in the long gorges whereby some of the larger rivers enter the lake. The main danger is considered to be the creation of an underflow on the drowned river bed which may actually penetrate the lake thermocline and carry larvae to the deoxygenated hypolimnion. In rivers of the same sort of size as the Mwenda this could only occur during exceptional floods, but all larvae in the river at such a time would almost undoubtedly be carried by this type of flow.

CHAPTER 12

THE FISH : FOOD AND FEEDING

1. INTRODUCTION

Few detailed investigations on the food and feeding habits of African fishes have been attempted and those which have been carried out are somewhat marred by an inability to recognize insect food items beyond major taxonomic groupings; with the marked exception of the works of Corbet (1961) on non-cichlid fishes of Lake Victoria, Fryer (1959) on the feeding relationships of a community of Lake Nyasa fishes and Munro (1967) on the food of the commercially important fishes of the Rhodesian highveld impoundment, Lake McIlwaine. Other works include those of Fish (1955) and MacDonald (1956) on, respectively, Tilapia species and Mormyrus kannume in Lake Victoria; de Kimpe (1964) and Matthes (1964) on the commercially important species of Lakes Mweru and Tumba, respectively, in the Congo River basin; Bowmaker (1969) on Alestes macrophthalmus of Lake Bangweulu; Groenewald (1964a and b) on Clarias gariepinus and Eutropius depressirostris in the Transvaal; Schoonbee (1969) on Cyprinus carpio, Barbus holubi, Clarias gariepinus, Labeo capensis and L. umbratus in Lake Barberspan, also in the Transvaal; and Hamblyn (1960) on food and feeding behaviour of Lates niloticus in East Africa. Hydrocynus vittatus has received a disproportionate amount of attention, feeding being described by Jackson (1961a, b, c) who drew attention to its predatory impact, mainly in the Bangweulu and Middle Zambesi areas; Matthes (1968) on this species in Lake Kariba, subsequently considered by Kenmuir (1972); and Gaigher (1970) in the Inkomati River, South Africa.

Authoritative works by Poll (1953), Greenwood (1956), Crass (1964), Jackson (1961d), Hulot (1950) and Jubb (1967) all generally summarise the diet of fishes found in the respective areas considered. Detailed assessments of diet for a large proportion of the species here are not available.

The stomach contents of several non-entomophagous species have been analysed by the frequency of occurrence method (the number of fish in which each food item occurred was listed and expressed as a percentage). Hynes (1950) discusses the methods of analysis of the food of fishes at some length and concludes that the occurrence method ". . . although apparently the least satisfactory is now shown to give substantially the same results as theoretically better methods". Analyses have been kept spatially and seasonally separated, but where no substantial differences were apparent, have been combined. It is considered more realistic, because of the frequent outstanding numerical predominance of a single small food item in entomophagous species, to use here a variation of the method described by Ball (1961), essentially a variation of the methods of Neill (1938) and Ricker (1937). The method used entailed identification and counting separately the numbers of each species found in each fish, a process greatly facilitated by use of the reference collection and camera lucida drawings of the code "species". Numbers have then been converted to "wet" weight biomass (as opposed to the volumetric measurement Ball (1961) used) using the conversion factors given in Table 7.3. This method allows a more realistic assessment of the relative importance of different food species than the purely numerical method, for it incorporates the size of food items.

2. RESULTS AND OBSERVATIONS

2.1 Mormyridae

2.1.1 Mormyrops deliciosus

60 fish ranging in size between 35.6 and 98.4 cm fork length were examined. Of these 45 (75%) contained food items in the stomach. 39 of these were taken by gillnet in the lake and 6 by trammel net in the river. Results from the lake are shown in Table 12.1. Food items occurring in the stomach show a clear preference by Mormyrops for larger organisms. The species is predatory, feeding predominantly on larger insect nymphs and larvae, particularly the Odonata (34%) and smaller fish species (32%). Most insect sub-imagines were taken late in their development when at their largest aquatic stage. The only small food items found to occur in adult Mormyrops were Chaoborus, the Salvinia mayfly Euthraulus sp., and the ceratopogonid sp. 19.

Apart from Dipseudopsis, all species taken occurred upon rather than within submerged substrates. All the food fish taken were small, ranging in length between 1.5 and 5.6 cm. There was some indication that individual Mormyrops specialise in the type of fish taken. Of the stomach contents of two fish, for example, taken in the same net setting, one contained six Tilapia mortimeri (15 - 53 mm), the other nine Alestes lateralis (30 - 56 mm). Large fish scales, probably picked off the bottom, occurred quite frequently (10%). Too few fishes were taken to indicate any spatial or seasonal differences in diet, or changes in diet with size, but results obtained were sufficiently consistent to indicate reasonable overall reliability. Fish taken in the flowing river (Table 12.2) suggest a limited availability of larger insects, small fish forming 96% of contents examined.

TABLE 12.1 FOOD ITEMS FOUND IN THE STOMACH OF *MORMYROPS DELICIOSUS* FROM THE LAKE. RESULTS ARE EXPRESSED AS PERCENTAGE OCCURRENCE % OF FISH CONTAINING PARTICULAR FOOD ITEMS

CRUSTACEA		15
Caridina nilotica	15	
ODONATA		34
Macromia [illegible] nymphs	8	
Ictinogomphus ferox nymphs	6	
Gomphid nymphs	2	
Libellulid nymphs	18	
EPHEMEROPTERA		6
Povilla adusta nymphs	2	
Euthraulus sp. nymphs	4	
TRICHOPTERA		2
Dipseudopsis capensis larvae	2	
CULICIDAE		11
Chaoborus spp. larvae	7	
Chaoborus spp. pupae	4	
CERATOPOGONIDAE		2
"*Culicoides*" sp. 19	2	
PISCES		32
Alestes lateralis	2	
Barbus fasciolatus	4	
Hemihaplochromis philander	4	
Tilapia mortimeri	2	
Digested fish remains	10	
Large fish scales	10	

N.B. All insect subimagines and *Caridina* were in either late or final developmental stages.

TABLE 12.2 FOOD ITEMS FOUND IN THE STOMACH OF *MORMYROPS DELICIOSUS* FROM THE FLOWING RIVER, BY PERCENTAGE FREQUENCY OF OCCURRENCE

ODONATA		4
Ictinogomphus ferox	4	
PISCES		96
Barbus spp.	18	
Micralestes acutidens	4	
Digested fish remains	57	
Fish scales	17	

The external appearance of Mormyrops deliciosus does not suggest a fish predator, with its small eyes and mouth, widely spaced, small peg-like teeth and lethargic movement. Yet it would seem to be successfully predatory in a limited field (only 17 independent items). An explanation for this species's success was suggested by an observation made by torchlight at night in water approximately 1.5 m deep. The posterior halves of nine large (ca 70 cm) Mormyrops were seen protruding from a small isolated bed of Ceratophyllum, some 2 m^2 in area and 1 m deep. The fish remained quiescent in this position for several minutes before one backed out of the weed, and being disturbed by the light, moved quietly off to deep water. As soon as this fish seemed to register the light and start to react to it, all the other individuals reacted simultaneously, some burying themselves in the Ceratophyllum, others moving into deeper water. The impression received was that some form of efficient communication existed in the shoal. Lissman (1963) has shown experimentally that Gymnarchus niloticus and an unnamed mormyrid can detect objects by an electrical mechanism involving, he suggests, a dipole field set up between head and tail. It is possible that the behaviour observed at Sinamwenda indicated a similar ability in Mormyrops and would explain the reasonable success of an apparently sluggish predator; the nocturnal feeding patterns suggested by trammel net catches (Chapter 10); and relative uniformity in size of prey items, whether late instar Odonata nymphs, small minnows, Caridina, or final instar Povilla nymphs. Should an electrical sense be used by this fish, it is unlikely to be the only sense used, for the small but significant proportion of species such as Chaoborus in the diet indicate utilization of normal sensing mechanisms. The behaviour of the shoal suggested further that the dipole field, if used, may be applied by a shoal of Mormyrops working in conjunction with each other. Certainly this fish deserves experimental study.

2.1.2 *Cyphomyrus discorhynchus*

370 fish ranging in size between 11.0 and 37.7 cm fork length were examined. Of these 358 (97%) contained food items in the stomach. All fish were captured in the lake by gillnet. Results are shown in Table 12.3. In this instance the "count and conversion to biomass" method was used; stomach contents totalled 12115.86 mg, representing approximately 10,000 individual food items. This species is clearly entomophagous, the total results indicating a predominance of Odonata (51.7% by biomass), mainly late instar Libellulidae, with *Dipseudopsis* (Trichoptera) and *Chaoborus* (Culicidae) each contributing approximately 21% and *Povilla* (Ephemeroptera) forming 16.2% of stomach contents. Chironomid larvae play a relatively minor role (8.6%) as food to *Cyphomyrus* and other groups occurred infrequently. The major source of food of this species was therefore derived from a limited number of species although a wide variation in food types was found.

Some spatial trends are suggested by the results. The Odonata were infrequent in fish from the open bay stations (2.6%), but along the margins within *Ceratophyllum* beds were of greater importance (19.1%), as they were with movement into the "estuary" (20.7%). Within the *Salvinia* mat the libellulids formed the single most important constituent (55.1%). The Trichoptera formed a valuable food component in most of the study area, particularly in deeper water (39%) but apart from a 0.2% occurrence of *Ecnomus thomasseti*, were absent in the stomach of fishes captured in the *Ceratophyllum* bed. The culicids showed a similar distribution, being absent in fishes from *Ceratophyllum*, but were most important as a food constituent at Station 3,

[illegible] THE STOMACH CONTENTS OF [illegible] FROM DIFFERENT SECTIONS OF THE STUDY AREA. RESULTS ARE PRESENTED AS [illegible] DERIVED BY CONVERSION FROM NUMBERS OF INDIVIDUAL FOOD ITEMS FOUND   P: less than 0.05%

n: nymphs   l: larvae   p: pupae

	OPEN BAY %	CERATOPHYLLUM BED %	SALVINIA FREE "[illegible]" %	SALVINIA %	OVERALL %	
CRUSTACEA						
[illegible] sp. 107			P		P	
[illegible] (?)		0.9			0.1	
[illegible]				1.1	0.4	
ODONATA						
[illegible] n.		2.6	0.1	0.1	0.4	
Early instar Libellulidae n.				0.2	0.1	
Mid instar Libellulidae n.	2.7	3.5	6.5	1.1	3.9	
Late instar Libellulidae n.		10.2		53.7	21.1	
[illegible] africanus n.		1.8	0.5		0.4	
[illegible] n.			3.9		1.7	
[illegible] n.			9.7		4.1	
HEMIPTERA						
[illegible]			0.1		P	
EPHEMEROPTERA						1
[illegible] n.		63.8	11.9	5.8	16.2	
Baetidae n.			0.1		0.1	
[illegible] sp. n.			P	0.4	0.2	
TRICHOPTERA						2
[illegible] l.	39.5		71.3	23.4	20.6	
[illegible] p.			0.8		0.5	
[illegible] l.		0.2	0.1	P	0.1	
LEPIDOPTERA						1
Pyralidae l.		10.0			1.2	
COLEOPTERA						
Dytiscidae l.				P	P	
CULICIDAE						21.
[illegible] africanus l.			P	0.1	P	
[illegible] spp. l.	27.3	0.3	32.0	11.1	20.0	
[illegible] spp. p.		0.1	3.0	0.6	1.6	
[illegible]						6.
[illegible] l.				1.4	0.6	
[illegible] l.	7.9	0.7	4.5	1.0	3.1	
[illegible] l.			1.3		0.6	
CHIRONOMIDAE						
[illegible] sp. 150 l.	1.8		0.1		0.2	
[illegible] sp. p.	0.3				P	
[illegible] sp. 7 l.	0.3		0.3		0.2	
[illegible] Chironomini l.	7.0	5.6	0.2	P	1.3	
[illegible] sp. 15 p.	0.5				P	
[illegible] sp. l. and p.	6.1				0.5	
[illegible] l.	0.9				0.1	
[illegible] l. and p.	5.7		P		0.5	
[illegible] sp. 5 p.			2.1		0.9	
[illegible] sp. 45 p.			P		P	
[illegible] l.		0.5	0.3		0.2	
[illegible] l.			P		P	
[illegible] sp. 107 l.			0.2		0.1	
[illegible] sp. (AJM 23) l.			0.3		0.1	
[illegible] sp. 110 p.			0.2		0.1	
[illegible] sp. 355 l.			0.1		P	
CERATOPOGONIDAE						0.1
[illegible] "[illegible]" sp. 61 l.				P	P	
[illegible] "[illegible]" sp. 39 l.			0.?		0.1	
[illegible] "[illegible]" sp. 210 l.			P		P	
MOLLUSCA						
[illegible]						

in "estuarine" waters free of Salvinia. Ephemeroptera nymphs, almost solely Povilla adusta, were an outstandingly important constituent of Cyphomyrus food in the Ceratophyllum beds (63.8%) and were absent from the gut contents of fish captured in open water. Povilla appeared as a minor food constituent within the estuary, but were more important than the baetids, unexpectedly, and Euthraulus. Chironomid larvae and pupae appeared in stomach contents throughout the study area, but were important only in deeper water (30.5%) where they were represented mainly by Clinotanypus maculatus and Chironomus (Nilodorum) fractilobus and to a lesser extent by the sub-genera Cryptochironomus and Dicrotendipes.

As is understandable, certain species were only taken by Cyphomyrus in the vicinity of substrates that, from benthic sampling, they were typical of. For example, Clinotanypus claripinnis and Euthraulus were only taken (in values greater than 0.04%) in the vicinity of the Salvinia mat; Cyclestheria and pyralid moth larvae were only taken within the Ceratophyllum beds. The low incidence of Zygoptera in Ceratophyllum in comparison with the somewhat higher incidence of Anisoptera, after benthic sampling had strongly indicated that Anisoptera were available in far greater numbers, suggests that in some way Zygoptera were able to avoid predation by Cyphomyrus. Conversely, as is also apparent from the high incidence of Libellulidae in the stomach contents of fish taken near Salvinia, that the Anisoptera were vulnerable to predation by Cyphomyrus.

On the other hand, examples such as the high incidence of Povilla, essentially utilising the drowned trees as a substrate, in the stomachs of fish taken within the Ceratophyllum bed indicates that the degree of movement of fish can be quite considerable. Further, individual fish taken at Station 5 had sometimes, by their gut contents, clearly been feeding in marginal weed beds. The results are not therefore clear cut, but the large numbers of fish examined allow some confidence in the spatial distribution of major food categories as reflected by gut contents.

The predominance of larger entire food items, such as Povilla, late instar libellulid nymphs, Dipseudopsis and pyralid larvae is surprising, for Cyphomyrus has a small mouth invested with few teeth. In appearance this species would seem well adapted to taking smaller items, such as Chaoborus and Chironomid larvae, in the bottom muds, as the "chin" is extended into a blunt fleshy lobe which would appear to have a sensory function. The very bright reflection of the eyes in torchlight at night not seen in other species, suggests that Cyphomyrus has well developed night vision. When Cyphomyrus are freshly opened, a major proportion of the gut contents are living and seemingly unharmed, indicating a slow rate of digestion in the stomach. The feeding of this species would be subject to an interesting and necessary study, particularly as its size is ideal for smaller aquaria.

Individuals taken at the same time and place were quite frequently found to have been feeding exclusively on one organism, the exclusive food organism differing between individuals. At the same time, however, other individuals contained a full spectrum of [illegible] le food items. There were indications therefore that some individual Cyphomyrus could have been "specialist" feeders, and that a learning process was involved in developing feeding technique.

2.1.3 Mormyrus longirostris

104 fish ranging in size between 29.3 and 83.6 cm fork length were examined in the lake. Of these 103 (99%) contained food in the stomach. In the pools, 18 adult fish (28.6 - 81.2 cm fork length) and 34 juveniles (10 - 16 cm) were examined, all of which contained

food. Examined stomachs contained 56.78 g of food, representing approximately 7,500 individual food items.

Although a broad spectrum of insect food types were taken by *Mormyrus* (Table 12.4), overall results show the outstanding importance of *Dipseudopsis capensis* larvae and pupae as a food to this species (80.9% as biomass) at all netting stations and in the river pools. The only other food of any importance in overall results were dragonfly nymphs (11.9%) and *Chaoborus* larvae and pupae (4.7%). The Ephemeroptera (0.5%), Ceratopogonidae (0.6%) and, most surprisingly, Chironomidae (1.2%) were relatively unimportant as food. Very few Crustacea were found in stomach contents and oligochaetes only occurred in a single stomach. Hemipterans occurred, also on a single occasion, only in the river. Only larvae of Coleoptera were taken, and these most infrequently. A surprising find was two juvenile *Barbus* sp. (30 mm long) in one stomach. The intake of fish scales occurred so infrequently that occasions in which they were found in gut contents were possibly accidental. An interesting case of fish predation was found. The eggs recorded in the table were almost certainly the same as those tentatively described as *Heterobranchus longifilis* eggs earlier (Chapter 11), as they conformed in size and shape and the fish which contained them was captured at the same time within the *Salvinia* mat.

93.4% of all food taken were relatively large in size: *Caridina*, libellulid nymphs, *Povilla* nymphs and *Dipseudopsis* larvae and pupae. Of the smaller food items, *Chaoborus* occurred in large numbers quite frequently. In lesser numbers, but nevertheless an important food constituent of some individual fish, were the ceratopogonid larvae. The relatively large larvae of *Clinotanypus maculatus*, *Cryptochironomus* sp. 7 and *Polypedilum* sp. 5 were the favoured chironomids. The only

TABLE 10.5 THE STOMACH CONTENTS OF [illegible] LONGIPALPIS FROM DIFFERENT SECTIONS OF THE STUDY AREA. RESULTS ARE EXPRESSED AS PERCENTAGES OF FIGURES DERIVED BY CONVERSION FROM NUMBERS OF INDIVIDUAL FOOD ITEMS FOUND P: less than 0.05%
Vertebrate [illegible] presence but as no conversion is available, are not included in percentages.

n: nymphs p: pupae l: larvae

	OPEN BAY?	SALVINIA FREE "NATURAL"	VIRGIN SALVINIA IN "NATURAL"	PONDS	TOTAL	
CRUSTACEA						0.1%
Caridina nilotica (early instars)	P	0.2			0.1	
OLIGOCHAETA						P
Unidentifiable remains	P				P	
ODONATA						11.9%
Zygoptera		0.2	0.1	0.[illegible]	0.1	
Early instar Libellulidae n.				P	P	
Mid instar Libellulidae n.		13.9	15.8	0.4	4.0	
Late instar Libellulidae n.			6.4		1.1	
[illegible] n.				1.4	0.2	
[illegible] n.		1.7	5.2	2.4	1.6	
Unidentified Gomphidae n.		0.2			0.1	
HEMIPTERA						P
Anisops [illegible]				0.1	P	
EPHEMEROPTERA						0.9%
[illegible] n.	0.1	0.2	0.2	2.5	0.4	
[illegible] sp. n.			0.3	0.1	0.1	
[illegible] sp. n.				0.1	P	
[illegible] sp. n.		P		P	P	
TRICHOPTERA						80.9%
[illegible] l.	79.1	51.5	49.[illegible]	88.1	65.3	
[illegible] p.	16.1	[illegible]	12.[illegible]	6.3	13.6	
[illegible] l.		P		0.1	P	
[illegible] p.				P	P	
COLEOPTERA						P
Hydraenidae? l.			P	0.1	P	
CULICIDAE						4.7%
[illegible] spp. l.	6.2	4.2	[illegible]	0.5	4.5	
[illegible] spp. p.	0.3	0.2	0.1		0.2	
CHIRONOMIDAE						1.8%
[illegible] l.	0.5	[illegible]	0.4	1.4	0.6	
[illegible] l.			0.1		P	
[illegible] ([illegible]) [illegible] l.	P			0.2	P	
[illegible] l.			P	0.3	P	
[illegible] (A.W sp. a) l.				0.2	P	
[illegible] (A.W sp. b) l.				0.1	P	
Unidentified Chironomidae l.			P		P	
[illegible] sp. l.				P	P	
[illegible] sp. ? l.		0.4		0.4	0.3	
[illegible] sp. ? p.		0.1		P	P	
[illegible] ([illegible]) spp. l.	P	P	0.1		P	
[illegible] ([illegible]) sp. l.	P				P	
[illegible] ([illegible]) sp. p.	P				P	
[illegible] [illegible] l.				0.3	P	
[illegible] sp. ? l.	0.4	0.2	0.[illegible]		0.2	
[illegible] sp. 4? p.	0.1	0.1			0.1	
[illegible] [illegible]		P			P	
CERATOPOGONIDAE						0.6%
[illegible] band "[illegible]" sp. 19 l.	0.4	0.5	0.7		0.4	
Narrow band "[illegible]" sp. 41 l.	0.2	0.1		1.1	0.2	
PISCES						P
[illegible] sp. (digested)		(2)			(2)	
Fish [illegible]			(1)		(1)	
Fish eggs			(10)		(10)	

specimens of the very large (20 mm) Chironomus (Chironomus) sp. listed in the table came from the stomach of Mormyrus.

Apart from the dominance of Dipseudopsis in stomach contents throughout the study area, a slight variation in importance of other constituents was found. Libellulid nymphs were most important in fish caught in the Salvinia mat (23.5%), indicating that Mormyrus actually feed within the Salvinia roots (a supposition lent support by the occasional occurrence of small root hairs in Mormyrus stomachs); became less important away from Salvinia in the "estuary" (16%) and were absent from fish taken in the open bay. Libellulid nymphs formed a small proportion of food in the pools (4.6%). Chaoborus occurred in stomach contents throughout the lake stations at approximately 5% of biomass, but was a very minor constituent in the pools, its place being taken by the increased proportion of Povilla and chironomid larvae here, particularly Clinotanypus maculatus.

Like Cyphomyrus, a significant portion of the stomach contents of Mormyrus were usually still living in freshly killed fish. The frequency with which this was observed, bearing in mind that fish could have been captured by gillnet and hence restrained from eating anything between one to 13 hours prior to examination, indicates a slow rate of digestion in the stomach. Apart from live contents and recognisable remains, the stomach usually contained a considerable volume of thick grey paste, presumably food material undergoing digestion.

It seemed obvious that the elongated snout of Mormyrus, terminating in a small mouth with a few tiny teeth, must have been associated with some sort of mud-burrowing function. Yet the actual mechanism involved was unknown until an explanation was offered by chance while poisoning Surprise Pool. The initial effect of rotenone is to disorient fish although other functions are not obviously impaired.

During this stage fish may appear at the water surface for some moments, sometimes upside down, before swimming below the surface once more. A large Mormyrus appeared at the pool's surface in this condition, with snout and belly at the water surface, but with the opercular openings submerged. As a move was made to capture the fish, a jet of water was shot from the mouth some considerable distance. The fish was captured and held in an identical position and this behaviour was repeated several times before it was further weakened by rotenone. The measured distance of the water ejection was 3.2 m.

Feeding behaviour as suggested by this observation is as follows: In suitable soft mud substrates as found in the drowned river bed, Mormyrus buries its snout into the mud, takes in water through its opercular opening and then, using a jet of water, "explodes" the mud, picking up any larvae disturbed. Dicrotendipes larvae, which feature so prominently in the food of this fish, are tube dwelling, the length of the tube being deeper than the 8 cm penetrated by grab. This method, if used by Mormyrus, would seem eminently suitable for the capture of Dicrotendipes larvae before they can escape down their tubes. Alternatively, the Mormyrus may dig down a tube, displacing mud with jets of water, until the occupant is reached. Whichever of these methods is used, this chance discovery lends credence to the anglers' tale that where small patches of bubbles rise to the surface, Mormyrus are feeding. The use of this feeding method would also seem suitable for displacing Oligochaetae which at times occurred in great concentrations in the study area (Chapter 7). Yet oligochaetes do not feature as a food of this fish, suggesting that they may be avoided by choice.

The food of juvenile fish captured in the pools was largely confined to smaller insect larvae, whether late instars of small species or early instars of larger species (Table 12.5). The most important single item was *Stictochironomus caffrarius* larvae.

TABLE 12.5 THE STOMACH CONTENTS OF JUVENILE *MORMYRUS LONGIROSTRIS* CAPTURED IN THE RIVER POOLS (% biomass derived from numbers)

	%
Stictochironomus caffrarius l.	54.5
Povilla adusta n. (early instars)	10.7
Chaoborus spp. l and p.	9.8
"*Culicoides*" sp. 19 l.	7.2
Conchapelopia thomasseti l.	5.5
Cloeon sp. n.	5.3
Caenis sp. n.	3.2
Clinotanypus maculatus l.	2.1
Early instar Libellulidae n.	1.4
Ostracoda	0.5

2.2 Characidae

2.2.1 *Hydrocynus vittatus*

1153 fish ranging in size between 13.6 and 63.7 cm fork length were examined in the lake. Of these 331 (29%) were feeding. In the pools, 139 adult fish (16 - 54 cm) and 43 juveniles (5 - 13 cm) were examined. Results are presented by frequency of occurrence of individual items, and lake and river data have been pooled (Table 12.6).

97.6% by frequency of occurrence of individual items were fish, the remainder being made up by occasional occurrences of late instar insect subimagines and the shrimp *Caridina nilotica*. Unrecognisable digested fish remains were the most prominent single item of food, and of recognisable contents, *Alestes lateralis* was by far the most important food item (37%), followed by the closely related and somewhat larger species *Alestes imberi* (7%). The three *Barbus* species, *B. fasciolatus*, *B. unitaeniatus* and *B. lineomaculatus* contributed to nearly 6% of stomach contents. Other species taken, but of very minor importance on these results, are listed in the table (12.6).

TABLE 12.6 THE STOMACH CONTENTS OF ADULT HYDROCYNUS VITTATUS CAUGHT THROUGHOUT THE STUDY AREA, AS NUMBERS OF INDIVIDUAL ITEMS FOUND AND PERCENTAGE FREQUENCY OF OCCURRENCE

l: larva p: pupa a: adult e: eggs n: nymph

FOOD ITEM	SIZE RANGE	n	%
CRUSTACEA			
Caridina nilotica	Final instar	1	0.3
ODONATA			
Ictinogomphus ferox n.	Final instar	1	0.3
EPHEMEROPTERA			
Povilla adusta n.	Final instar	1	0.3
Povilla adusta e.	-	1	0.3
CULICIDAE			
Chaoborus spp. p.	-	1	0.3
TRICHOPTERA			
Dipseudopsis l.	Late instar	2	0.6
LEPIDOPTERA			
Unidentified a.	Adult	1	0.3
PISCES			
Alestes lateralis	3.0 - 5.5 cm	124	37.0
Alestes imberi	2.0 - 7.0	23	6.9
Micralestes acutidens	3.6 - 5.0	4	1.2
Barbus fasciolatus	2.9 - 3.2	8	2.4
Barbus spp.	2.5 - 6.9	11	3.3
Labeo altivelis	6.7	1	0.3
Eutropius depressirostris	10.6	1	0.3
Synodontis zambesensis	9.1 - 18.0	3	0.9
Tilapia mortimeri	1.9 - 6.5	2	0.6
Digested fish remains	-	151	44.7

The only larger fish taken were a single Eutropius depressirostris and several Synodontis zambesensis. In the latter instance the very hard dorsal and pectoral spines were clearly being digested.

Tilapia mortimeri juveniles formed only 0.6% of the food of fish examined. It is considered, however, that this is not a true representation of this species in Hydrocynus gut as Tilapia juveniles actively used shallow marginal water as cover prior to the development of aquatic vegetation and were also, by observation, dependent to some unknown extent on the Salvinia. An observation made on Tilapia predation does, perhaps cloud my judgement somewhat: In January 1968, five pairs of _T. mortimeri_ adults constructed nests in water approximately 50 cm deep at Chris' Beach (see map). The beach was narrowly shelving at this point and, offshore, shallowed somewhat as a bar enclosing the basin in which the _Tilapia_ were nesting. _Salvinia_ was found resting on this bar, forming a protective barrier against the incursions of predators. At one point, near the shore-line, the bar deepened, allowing access to deeper water. At this point approximately 25 _Hydrocynus_, from 20 to 40 cm long, were patrolling. Three spinners were lost in quick succession to these fish, for as a spinner entered the water it was simultaneously attacked by up to a dozen fish. Scrutiny of the shoreline revealed, for approximately 15 paces from the nesting basin mouth, numerous skid marks made by turning _Hydrocynus_ in water down to 2 cm deep. These marks were recognized as a result of handling fish in experimental tanks. The conclusion drawn from this observation was that any _Tilapia_ finger-lings, present in large numbers in the nesting basin, which ventured out from the basin, even in very shallow water, were immediately taken by these _Hydrocynus_ which were patrolling this point in such numbers for this very reason. Yet simultaneous gillnettings at Station 5, in deep water only 100 m away, never revealed _Tilapia_ as an _Hydrocynus_ food. The sampling method was from this viewpoint in-adequate. Maar (pers. comm.) reported similar observations elsewhere in the lake, particularly in cleared areas.

The recognisable food of 10 - 13 cm _Hydrocynus_ in the river pools was wholly composed of _Barbus unitaeniatus_ and _Barbus lineomaculatus_, ranging in size between 2.5 and 4.8 cm. Digested fish remains were found in 21% of fish examined. Between 5 and 8 cm, _Hydrocynus_ juveniles were found not to be piscivorous. Sand occurred frequently in the stomach contents, indicating benthic feeding. 64% of the biomass of food was a large diaptomid copepod (*Tropodiaptomus* sp. ?). The remainder were composed of *Cloeon* sp. nymphs (19%), the pupae of *Stictochironomus caffrarius* (8%) and the hemipterans *Micronecta scutellaris* (7%) and *Nychia marshalli* (2%).

2.2.2 *Alestes imberi*

355 fish ranging in size between 10.5 and 17.5 cm fork length from the lake were examined, of those 39% were found to be feeding. Samples of 25 fish each in the size ranges of 11 to 13 cm, 7cm and 5 cm were examined from the pools. None of these fish was empty. Results are presented as percentage frequency of occurrence of fish containing the different food items (Table 12.7).

A wide range of food items were found in the *Alestes'* stomachs and the outstanding feature was the preponderance of fish containing allochtonous food of terrestrial origin (63%). Including these terrestrial arthropods, 73.5% of fish examined contained food obviously derived from the water surface. A large proportion of the allochtonous food was wood-boring beetles, probably as a result of the availability of dead wood in the form of drowned trees. Spiders found in the *Alestes* stomachs were very similar to those found in the *Salvinia* mat in large numbers. Of aquatic food, fish were a dominant portion, being found in one form or another in 9% of *Alestes*.

In the lake therefore, *Alestes imberi* would appear to have been essentially surface feeding and dependent to a significant extent on food of terrestrial origin.

The stomach contents of larger pools *A. imberi* (Table 12.8) indicate, surprisingly, that the pools fish were not as dependent on allochtonous food as those of the lake (9% as against 63%), nor did they seem to be surface feeders. The major source of food was the larvae and pupae of *Chaoborus* (49%), *Barbus unitaeniatus* (15%) and fish

TABLE 12.7 THE FOOD OF *ALESTES IMBERI* FROM THE LAKE. RESULTS ARE EXPRESSED AS PERCENTAGE OF OCCURRENCE OF FISH CONTAINING PARTICULAR FOOD ITEMS.

l: larva p: pupa a: adult n: nymphs

		%
PLANT MATERIAL		4.0
Dicotyledon seeds	1.3	
Chewed vegetable matter	2.7	
TERRESTRIAL ARTHROPODS		62.9
Unidentified insect remains	9.3	
Araneida a.	5.3	
Hemiptera a.	2.7	
Coleoptera a.	29.7	
Lepidoptera a.	4.0	
Orthoptera a.	7.9	
Alate Isoptera a.	2.7	
Alate Formicidae a.	1.3	
CRUSTACEA		1.3
Parasitic Argulidae (eaten) a.	1.3	
TRICHOPTERA		3.9
Dipseudopsis capensis l.	1.3	
Dipseudopsis capensis p.	1.3	
Dipseudopsis capensis a.	1.3	
EPHEMEROPTERA		6.7
Povilla adusta n.	2.7	
Povilla adusta a.	4.0	
ODONATA		4.0
Final instar Libellulidae n.	2.7	
Gomphidae a.	1.3	
CERATOPOGONIDAE		2.6
Narrow head "*Culicoides*" l. sp. 61	1.3	
Broad head "*Culicoides*" l. sp. 19	1.3	
CHIRONOMIDAE		2.7
Pupal casts	2.7	
MOLLUSCA		2.7
Gasteropoda less shell	2.7	
PISCES		9.2
Digested fish remains	1.3	
Cichlidae remains	1.3	
Barbus sp.	1.3	
Fish scales	5.3	

scales (23%), indicating a greater dependence on nekton and the bottom deposits as food sources.

The results from five and seven cm size groups were indistinguishable from each other, and suggest an almost entire dependence of this size range on bottom feeding. Sand grains were frequently encountered in stomach contents. Chironomid larvae (particularly those of Stictochironomus caffrarius and a species of Cryptochironomus) predominated. Early instar libellulid nymphs were frequently found as were Cloeon sp. nymphs, Ecnomus thomasseti larvae, Povilla adusta nymphs and, occasionally, Micronecta scutellaris.

TABLE 12.8 THE FOOD OF ALESTES IMBERI OF 11 TO 13.1 CM IN THE POOLS. RESULTS ARE EXPRESSED AS PERCENTAGE OCCURRENCE OF FISH CONTAINING PARTICULAR FOOD ITEMS

l: larvae p: pupae a: adults n: nymphs

		%
TERRESTRIAL INSECTS		9.5
Terrestrial insect remains	5.6	
Orthoptera a.	3.7	
HEMIPTERA		1.9
Nychia marshalli	1.9	
EPHEMEROPTERA		1.9
Povilla adusta n.	1.9	
CULICIDAE		40.8
Chaoborus spp. l.	33.9	
Chaoborus spp. p.	14.9	
PISCES		38.1
Barbus unitaeniatus	13.3	
Fish scales	22.0	

2.2.3 Micralestes acutidens

23 specimens of this small characin (ca 4 – 5 cm) were chosen at random from the various pool collections. All had been feeding and appeared to contain a full range of the commoner zooplankton species,

but particularly the large pools diaptomid (Tropodiaptomus?) which on subjective assessment contributed to approximately 50% of the gut contents.

2.3 Distichodontidae

2.3.1 Distichodus schenga

The two specimens of this species taken in the entire study (both 30.5 cm long) had their stomachs packed with, in one instance, two species of filamentous algae (both Mougeotia?) and, in the other, grazed Ceratophyllum.

2.4 Cyprinidae

Full analysis of cyprinid gut contents was not undertaken. It was thought better to supply samples of both algae from various substrates and entire intestines to an algologist for examination. This was done in 1966 but unfortunately the results are not yet available. Examination of a limited number of foregut contents has therefore been undertaken so that some idea may be gained of the types of food utilized by the cyprinids. Note was made in the field as to whether or not individual fish had been feeding.

2.4.1 The Barbus species

No clear difference in the gut contents of the three species found in the study area, B. unitaeniatus, B. lineomaculatus and B. fasciolatus was found in the 25 specimens of each which were examined. They appeared to utilise both benthos and plankton, Ceriodaphnia and Diaphanosoma being the most frequent individual items of food. Organic matter was present in most of the fish, as were sand grains. Chironomid larvae occurred frequently, and occasional mayfly nymphs (Cloeon sp.) were also found.

2.4.2. The *Labeo* species

Both *Labeo cylindricus*, in the pools, and *L. congoro* in the lake, have been observed scraping lithophytic algae off stones in shallow water. "Scrape" marks attributable by size and shape to both these species were seen occasionally after a drop in water level. The gut contents of 10 fish of each of these species reflected this type of feeding behaviour, being a conglomerate of organic matter and a wide variety of algae.

Labeo altivelis, on the other hand, seemed more dependent on organic matter. Few differentiatiable organisms could be found in the black "ooze" contained in the intestine. It is probable that this species is more dependent on the bottom muds both as a feeding substrate and directly as food.

2.5 Schilbeidae

2.5.1 *Eutropius depressirostris*

130 fish ranging in size between 10.2 and 36.2 cm fork length were examined. Of these 89 (68%) were found to be feeding. Apart from two fish from the river, all fish were taken in the lake. Results are presented as percentage frequency of occurrence (Table 12.9).

Eutropius contained a range of food mainly confined to larger invertebrate subimagines, particularly the Odonata (29%) and small fishes (24%). The only exceptions to the larger size of food were the occurrence of *Cyclestheria hislopi* (?) and *Chaoborus* larvae, both in single fishes. Allochtonous food of terrestrial origin occurred in a significant proportion (29%) of the fishes examined, some of the beetles being up to 5 cm long. The shrimp *Caridina* also occurred frequently (12%) as did emerging and adult *Povilla adusta* (10%). Large fish bones (particularly opercular bones of *Hydrocynus*) and fish scales were found in several individuals, indicating benthic

TABLE 12.9 THE FOOD OF EUTROPIUS DEPRESSIROSTRIS FROM THE LAKE. RESULTS ARE EXPRESSED AS PERCENTAGE OCCURRENCE OF FISH CONTAINING PARTICULAR FOOD ITEMS

l: larvae p: pupae a: adults n: nymphs

			%
TERRESTRIAL ARTHROPODS			18.8
Digested insect remains	13	9.0	
Orthoptera a.	6	4.2	
Formicidae a.	1	0.7	
Coleoptera a.	5	3.5	
Araneida a.	1	0.7	
Hemiptera a.	1	0.7	
CRUSTACEA			12.2
Caridina nilotica a.	17	11.5	
Cyclaestheria hisloni (?) a.	1	0.7	
EPHEMEROPTERA			10.4
Euthraulus sp. n.		0.7	
Povilla adusta a.	14	9.7	
ODONATA			29.3
Paragomphus hageni n.	2	1.4	
Ictinogomphus ferox n.	3	2.1	
Macromia sp. n.	2	1.4	
Libellulidae n.	25	17.4	
Coenagriidae n.	10	7.0	
CULICIDAE			0.7
Chaoborus spp. l.	1	0.7	
TRICHOPTERA			4.9
Dipseudopsis capensis l.	7	4.9	
PISCES			25.7
Digested fish remains	16	11.1	
Large fish scales and bones	9	6.3	
Alestes lateralis	4	2.8	
Hemihaplochromis philander	3	2.1	
Tilapia mortimeri	2	1.4	

feeding. Larvae of *Dipseudopsis capensis* in 5% of *Eutropius* also suggested this.

Analysis of food by origin infers the utilisation of a wide range of different feeding techniques and substrates, a point which will be returned to in the discussion of these findings.

2.6 *Clariidae*

2.6.1 *Clarias gariepinus*

48 fish from open waters of the lake, ranging in size between 21.6 and 86.5 cm fork length, were examined. Of these 34 (71%) were found to be feeding. These fish were all eating plankton and in this instance the results are presented (Table 12.10) as percentage frequency by numbers of individual food items, derived from counts taken in 1 ml samples of gut contents. Two fish caught in the *Ceratophyllum* beds were found to contain macroscopic food. The stomach contents of *Clarias* collected in the pools (90 fish), of which 52% were feeding, have been separated into two size ranges on the basis of gut contents, namely, 10 - 20 cm and 20 - 66 cm. In this instance results are presented as percentage frequency of occurrence in fish.

76% of food in the plankton-filtering lake *Clarias* was composed of organisms with a body length greater than 1 mm. Apart from 0.1% occurrence of organisms of less than 0.5 mm, the remainder of stomach contents was made up of organisms approximately 0.7 mm long. There would seem to have been, therefore, selection of larger planktonic organisms. As *Clarias* have been observed to continue feeding at night, when judging by *Chaoborus* spp. densities in benthic samples these would be abundant in the zooplankton, the feeding technique described below would appear to be inadequate to take these fast moving animals.

TABLE 12.10 THE FOOD OF CLARIAS GARIEPINUS SEPARATED BY STATION AND SEASON. RESULTS ARE PRESENTED AS PERCENTAGE FREQUENCY OF OCCURRENCE OF INDIVIDUAL FOOD ITEMS BASED ON COUNTS TAKEN FROM 1 ML SAMPLES OF STOMACH CONTENTS. ANACYSTIS IS NOT INCLUDED IN THE PERCENTAGE BASED ON NUMBERS, BUT AN ESTIMATE OF THE PROPORTION IS GIVEN, SUBJECTIVELY BASED ON ITS DENSITY IN SAMPLES P: less than 0.05%

SPECIES	"SEASON"	4/67	7/67	11/67		1/68		
	STATION	3	3	3	4	3	4a	$\bar{x}$
ALGAE								
Anacystis cyanea		(15%)	(40%)	P	(3%)	P	(50%)	
Volvox sp.		0.2	P	0.8	0.1	-	1.1	0.3
COPEPODA								
Diaptomid sp. I •		51.4	64.9	7.7	2.6	11.3	10.2	26.9
Diaptomid sp. II •		9.8	10.0	4.0	0.5	1.5	-	4.3
Mesocyclops sp.		5.2	8.0	4.5	2.6	1.9	25.2	8.4
Harpacticidae I		-	-	-	0.1	-	-	P
Nauplii ●		P	-	-	-	-	P	P
CLADOCERA								
Daphnia lumholtzi •		P	P	0.8	-	0.3	-	0.2
Diaphanosoma sp. •		28.6	P	28.6	91.0	80.9	63.5	48.8
Ceriodaphnia sp.		4.6	17.1	54.0	0.1	3.8	-	13.3
Bosmina longirostris ●		P	-	-	-	-	-	P
Chydorus sp. I ●		-	P	-	P	-	P	P
Moina sp. I ●		-	P	-	-	0.8	-	0.2
CULICIDAE								
Chaoborus spp. larvae •		P	-	-	-	-	-	P

• Organisms with dimensions 1 mm or over

● Organisms with dimension 0.5 mm or less

Clarias were, for most of the year, commonly seen feeding in shoals at the water surface as follows: The body was held at approximately 30° to the water surface with the tip of the upper jaw and nasal barbels protruding from the water. The mandibular and maxilliary barbels were usually spread and curved up to the water surface and along it. Up to four or five fish would swim quietly and slowly along in this position within a few metres of each other, gulping in water from the first few millimetres of the water surface and, apparently, filtering the zooplankton from it.

The only "season" when a marked decrease in this surface feeding activity was observed was in July, and the reason given for this was the effect of *Anacystis* on the fish: for fish opened at this time, containing *Anacystis*, had a greenish-yellow cast to the intestines which were also full of large air bubbles, not seen at other times of the year.

Of ten occurrences in the two fish taken in the *Ceratophyllum* bed, 7 items came from the water surface, including adult Libellulidae, an ant and a neuropteran adult; 3 items came from elsewhere including fish scales, digested fish remains and the nymph of *Ictinogomphus ferox*. Adult pool: fish appeared to subsist as opportunistic scavenger/predators, stomach contents including bones, charcoal, terrestrial insects and digested fish remains. Adult *Clarias* were resistant to rotenone and were always the last fish to succumb. The contents of fish captured by seine net some time after rotenone application illustrate their opportunistic nature. Sixteen fish, ranging in size between 29 and 75 cm contained 77 freshly ingested small fish of 1.1 to 16.5 cm length, including the full range of species available. Some individuals could seemingly not have taken a single item more, the belly being grotesquely distended (one fish of 54 cm contained

16 Tilapia, Barbus and Labeo cylindricus, mostly in the 5 cm range). Presumably the Clarias fed on these fish once they had been affected by the rotenone and were lying on the bottom of the pool.

Juvenile pools fish in the 10 - 20 cm range were, apart from a single case of fish predation (one T. mortimeri of 3.7 cm taken by a 16.5 cm Clarias) exclusively benthic feeders. Stomachs contained a range of benthic invertebrates including larvae and pupae of Stictochironomus, Cryptochironomus, Dicrotendipes, ceratopogonid larvae, Ostracoda, Dytiscidae and other insect remains.

It would seem therefore, that Clarias was essentially predatory. As adults in the lake they either fed on plankton (the main source of food) or against the margins on larger food items both on the water surface and on the bottom, but where conditions were more stringent, as in the pools, were far more catholic in their feeding habits. Juvenile fish were essentially benthic feeders.

These results are in close agreement with Munro (1967) who found juvenile fishes to be benthic invertebrate larvae feeders and that a gradual transition took place with increasing size to filter feeding. Schoonbee (1969) found a greater preponderance of fish in the diet of this species. Corbet (1961) reports of C. mossambicus (a synonym of C. gariepinus (Jubb, 1967)) that after a length of 3 cm this fish became progressively more piscivorous, and comments on the catholicity of diet. Jackson (1961d) describes C. mossambicus as "an omnivorous scavenger and predator on other fishes". It is of interest to note that the essentially filter feeding nature of adult Clarias found here and by Munro (1967), also in Rhodesia but in a eutrophic highveld dam, should be at variance with the other authors mentioned above.

2.7 Mochokidae

2.7.1 Synodontis zambezensis

414 fish ranging in size between 10.2 and 33.0 cm fork length were examined. Of these 61% were found to be feeding. Tabulated results (Table 12.11) concern only fish found in the lake, fish from the pools being considered below. Results are expressed as percentage biomass derived by conversion from numbers, which in this instance is not entirely satisfactory as plankton, present in some numbers in a very limited number of individuals, are not convertible to biomass. Similarly, vegetable debris, organic debris and periphytic algae, which when they occurred were almost invariably taken to the individual fish's capacity, could not be converted on a "presence" notation. The same applies to fish scales, eggs and digested fish remains, which would have been better presented as percentage occurrence. The method most reliable for the major proportion of food was chosen.

An extremely wide range of food occurred in Synodontis stomachs, ranging from organic debris, plankton, vegetation (obviously taken by grazing) periphytic algal "wads", through a full range of insects and molluscs from all substrates, to debris derived from fish (scales and teeth) and active fish predation. Nevertheless the major source of food was the insect subimagines. The pupae of Dipseudopsis capensis provided more than half the biomass of stomach contents, and with the larvae, this species constituted 65% of the biomass of food taken. Gasteropod molluscs were an important source of food (11%) as were the larvae and pupae of the Chironomidae (9%). Other significant constituents were Chaoborus (5%) and libellulid dragonfly nymphs (7%). Although not considered in the percentage composition by biomass, the 133 occurrences of fish scales in stomach contents indicate these to have been a significant food item.

TABLE [illegible] THE FOOD OF [illegible] ADULTS FROM VARIOUS PARTS OF THE STUDY AREA. [illegible] AS [illegible] OF CONVERSION FROM NUMBERS OF INDIVIDUAL FOOD ITEMS FOUND IN GUT CONTENTS. [illegible] results are numbers of organisms found and are not included in percentage estimations as no conversion values are available.

+ : large quantities a: adults n: nymphs l: larvae p: pupae or present

	OPEN BAY	[illegible]	[illegible]	[illegible]	OVERALL	
PLANT MATTER						
Vegetable debris			+	(1)	P	
Organic debris		P			P	
Periphyton algae	+	(1)			P	
[illegible] sp.		(5)			P	
CRUSTACEA						
[illegible] sp. 1 a.			(20)		P	
[illegible] sp. a.		(50)			P	
[illegible] sp. a.		(3)			P	
[illegible] a.		(1)			P	
[illegible] sp. [illegible] a.	(17)				P	
[illegible] sp. [illegible] a.				(8)	P	
[illegible] sp. 100 a.	(12)				P	
[illegible]						7.9%
[illegible] a.		27.5	4.6		6.2	
[illegible] a.	1.5	6.5	9.3		2.5	
[illegible] a.	0.3				0.3	
[illegible] sp. a.	0.9				0.6	
HEMIPTERA						P
[illegible] a.		0.1			P	
[illegible]						2.4%
[illegible] a.	1.1	6.6	10.[illegible]		2.0	
[illegible] a.	P				P	
[illegible] sp. [illegible]		P			P	
[illegible]						64.3%
[illegible] l.	3.8	37.0	64.7		18.1	
[illegible] p.	71.0	20.0			38.4	
CULICIDAE						5.1%
[illegible] spp. l.	0.9	0.4	1.3		0.8	
[illegible] spp. p.	5.8	0.5	5.0		4.5	
[illegible] l.	P		0.1		P	
CHIRONOMIDAE						9.1%
[illegible] l.	0.9	13.3	1.1	0.9	3.5	
[illegible] p.	0.1	0.1			0.1	
[illegible] l.	0.1		0.1		0.1	
[illegible] l.		0.3			P	
[illegible] l.	1.6				1.1	
[illegible] l.	0.2				0.1	
[illegible] sp. 45 p.	0.3	4.0			1.3	
[illegible] sp. 1	P				P	
[illegible] sp. p.	1.2	3.6			1.6	
[illegible] p.		0.2			P	
[illegible] sp. 7 l.	0.2				0.2	
[illegible] sp. 180 p.	P				P	
[illegible] sp. 397	P				P	
[illegible] sp. p.	0.1				0.1	
[illegible] sp. 350 l.	0.1				0.1	
Unidentified chironomid l.	1.5	0.1	0.5		1.0	
Unidentified chironomid p.	0.1	P	0.2		0.1	
CERATOPOGONIDAE						P
"[illegible]" sp. 46		0.1	0.1		P	
INSECTS						0.1%
Terrestrial insect remains	0.1	0.4			0.1	
MOLLUSCA						10.8%
[illegible] ([illegible]) sp. 30	[illegible]	1.1	5.0	34.1	7.0	
[illegible]	0.2			63.0	3.3	
PISCES						
Fish scales	(15)	(86)	(38)		(139)	
Fish eggs	(10)				(10)	
[illegible] teeth		(1)			(1)	
[illegible] fish remains		(1)			(1)	
[illegible]		(1)			(1)	

Some variation in proportional food intake was found in the study area. Anisopteran nymphs were relatively unimportant in the bay (3%) and increased as a proportion of food intake in the "estuary" (22% at Station 3, 14% in the Salvinia), similar to the nymphs of Povilla adusta (1%, 7%, 10% respectively). Dipseudopsis capensis subimagines were of similar importance in the open bay and in association with the Salvinia mat (73%, 65%); but were less important within the "estuary" in Salvinia free waters (47%), where chironomid subimagines formed a much more substantial proportion (22%) than elsewhere, particularly the relatively large larvae of Clinotanypus maculatus (13.5%). Here also, the intake of fish scales seemed to be higher.

Feeding within the Ceratophyllum bed was almost entirely confined to the two molluscs Physopsis globosus and Biomphalaria pfeifferi. These were ingested and passed through the entire intestine with shell intact, one fish containing up to 190 shells in the gut. On the other hand, fish found in association with the Salvinia mat seemed not to utilise this substrate, apart from an intake of libellulid nymphs, for typical "mat" fauna were either taken in small numbers or not at all.

Synodontis zambesensis kept in tanks behaved unlike any of the other species considered here. Their orientation depended to a large extent on a surface, whether the bottom or sides of the tank or the water surface; for fish would always swim with their bellies within a few centimetres of a surface, dorsal side uppermost on the bottom, one of the lateral sides uppermost against the tank sides, or ventral side uppermost at the water surface. Observations made by W.R. Thomson (pers. comm.) at night in the vicinity of Binga are of relevance here. Thomson was on crocodile control operations and on three occasions, all between 2000 and 2200 hours, saw shoals of

Synodontis "swimming on the surface of the water, upside down. Their pale bellies were very noticeable and their action was sluggish. They could be approached to within 5 feet and when disturbed disappeared in a flash". Thomson considered the fish to be feeding "although no such positive observation was made". A similar observation has been made by J.P. Loveridge (pers. comm.) in a small pool of the Rusiruhuru River, eight miles upstream from Lake Kariba. Loveridge also considered these fish to be feeding.

These observations, when taken with the high level of incidence of pupal as opposed to larval chironomids relative to the insectivorous mormyrids caught at the same time and place (Table 12.12) indicate that *Synodontis* is an active surface feeder, preying on pupae prior to adult emergence; a technique which would make full use of the sensory barbels at night. The intake of the very high proportion of *Dinagudopsis* pupae (Table 12.13), although partly explained by this technique, has a more likely explanation, due to the frequent occurrence of numerous tubes belonging to this species found in *Synodontis* stomachs. It is probable that the proportions of larvae to pupae found in *Mormyrus*, over the periods sampled, bearing in mind the likely efficiency of this fish's feeding technique in respect to *Dinagudopsis*, are nearer to actual population proportions as are likely to be achieved by any other sampling method. If anything, the pupal composition may be disproportionately high, for the active larvae are more likely to escape. Under these circumstances *Synodontis* are clearly more successful in capturing the inert pupae, taking at least four times the number of pupae to larvae than are available, and must carry out a limited degree of excavation to do this, whereas *Gnathonemus* is just as obviously incapable (seeing the small proportion of pupae present in their stomach contents) of any digging and probably rely more on speed of attack to capture larvae.

TABLE 12.12 THE PROPORTIONS OF LARVAL AND PUPAL CHIRONOMIDS IN THREE FISH SPECIES

	% Larvae	% Pupae
Mormyrus longirostris	92	8
Cyphomyrus discorhynchus	87	13
Synodontis zambezensis	69	31
*Synodontis zambezensis	40	60

*Less Clinotanypus maculatus, a favoured benthic food organism.

TABLE 12.13 THE PROPORTIONS OF LARVAL AND PUPAL DIPSEUDOPSIS CAPENSIS IN THREE FISH SPECIES

	% Larvae	% Pupae
Mormyrus longirostris	78.2	21.8
Cyphomyrus discorhynchus	98.6	1.4
Synodontis zambezensis	18.7	81.3

Stomach contents of adult pools Synodontis, which were only captured after rotenone application, showed these fish to be as opportunistic as Clarias, for all fish (ranging in size between 13.0 and 17.6 cm) contained only freshly taken, and presumably poisoned, fingerlings of Tilapia mortimeri and Alestes imberi, 15 - 25 mm long. Juvenile Synodontis in the 6 cm size range all contained a full range of bottom dwelling insect subimagines, excluding Odonata nymphs, and fish scales were frequently found in the gut contents.

2.8 Cichlidae

2.8.1 Tilapia mortimeri

Very few adult fish were captured in the routine lake gillnettings and 50 fish were examined from the pools. All these fish contained a mixture of periphytic algae and detritus. However, the proportion of these were remarkably different from that found in Labeo altivelis. In Tilapia, a very high proportion of the stomach contents were clearly algae, and a relatively minor portion was made up of organic matter. Gut contents are currently under examination by an algologist.

Gillnets set along the steeply shelving shoreline in the vicinity of the Research Station, yielded several large *Tilapia* which were packed with fully grown *Biomphalaria pfeifferi*. Investigation of the shoreline showed these to be numerous under stones. Presumably the snails emerged at night and were then available to the *Tilapia*. This instance has been cited to illustrate that the diet of *T. mortimeri* need not necessarily be confined to algae and detritic material.

2.9 *Feeding Activity*

The percentage of fish examined which contained food in the stomach, and in the case of the *Labeos*, the gut, is taken here to represent feeding activity. In fish like *Hydrocynus*, where the rate of digestion is obviously rapid, fish captured shortly after setting the net will probably have digested the stomach contents prior to examination the following morning and so the results are subject to a bias towards a lower level of activity than was actually the case. Matthes (1968) points out that *Hydrocynus* digest their food within "a few hours" and suggests that "about 20% of empty stomachs in gillnet samples are directly imputable to the method itself", although the means whereby he arrives at this proportion is questionable. (He subtracts percentage *Hydrocynus* found to be feeding from the mean value obtained for other fishes). Insectivorous species appeared, however, to have a relatively slow rate of digestion so that feeding activity considered in this way is more reliable.

Data are presented in Table 12.14.

Mormyrops deliciosus. The overall percentage feeding of this species was quite high (75%) but lower than found in the entomophagous mormyrids. Too few fish were examined to draw any definite conclusions regarding the effects of sexual readiness on feeding, but little or no effect was apparent in those fish examined. Feeding activity in the river

TABLE 12.14 FEEDING ACTIVITY OF ADULT FISH EXPRESSED AS PERCENTAGE OF FISH FEEDING

SPECIES	"SEASONS"						AREAS			PHYSICAL CONDITION							ADULT FISH EXAMINED	OVERALL % FEEDING
	1/67	4/67	7/67	10/67	1/68	10/68	Lake	Pools	River	I	IA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	60.0	41.7	100	92.3	50.0	-	65.1	-	81.0	70.2	65.5	76.7	100	100	-	0	60	75.0
[illegible]	93.*	96.6	95.5	100	-	97.1	96.2	-	-	95.5	95.8	99.5	96.0	96.3		100	770	96.8
[illegible]	100	100	100	100	93.8	100	100	100	60.6	100	100	100	100	97.9	100	-	506	99.0
[illegible]	12.1	41.7	35.0	35.0	20.0	10.6	28.7	26.6	10.3	31.7	32.6	15.4	20.0	13.7	4.0	25.0	1338	27.9
[illegible]	39.9	63.6	54.4	70.5	36.7	60.0	30.8	71.1	53.3	52.6	14.6	67.4	70.6	35.5	15.3	100	575	54.6
[illegible]	41.0	80.0	[illegible]	60.0	77.0	57.0	67.2	78.2	[illegible]	72.0	81.0	68.0	67.0	45.0	51.0	100	1088	69.8
[illegible]	35.3	32.5	-	55.1	60.0	-	70.8	32.3	60.0	64.5	66.0	54.5	50.0	46.7	0	100	147	47.9
[illegible]	33.8	55.0	91.7	62.8	70.0	68.8	63.4	-	100	91.3	64.4	56.0	56.5	78.4	-	50.0	130	64.3
[illegible]	65.4	71.6	65.0	85.1	72.8	58.0	60.9	60.5	50.8	63.0	72.3	69.2	66.2	70.1	50.0	77.8	434	60.6

was somewhat higher than in the lake. There was some indication that feeding activity may have been higher between July and October than during the rest of the year. Lowest activity was recorded in April (42%).

Cyphomyrus discorhynchus. Nearly all fish were found to be feeding (96.8%) and this species fed actively irrespective of state of gonad or "season".

Mormyrus longirostris. Virtually every fish examined contained food (99%) also irrespective of gonad activity or "season". The only fish found not to be feeding were migrating upstream, but other individuals (60%) were found feeding under the same circumstances.

Hydrocynus vittatus. Contents were found in relatively few Hydrocynus stomachs (23%) and there seemed to be a definite and consistent trend for the proportion of feeding fish to decrease with increasing gonad activity (from 32% at 1A to 4% at RR). This is reflected in feeding activity when related to area of capture. The proportion of feeding fish in the lake and pools were similar (at approximately 27 - 28%), whereas in the river this was much reduced (10%). Similarly, feeding activity appeared to decrease during the hot and rainy seasons, being highest in April and May, in marked contrast to Kenmuir's (19??) findings, which indicated "an increase with feeding activity with the onset of summer" in 1969. He relates this to falling lake level and subsequent increase in food availability as prey fish were forced from cover. "Seasonal" circumstances as such may therefore be of secondary importance in a developing and fluctuating system such as Lake Kariba.

Alestes imberi. Approximately half the fish examined contained food. Here also there could be a trend for decreased feeding with increased breeding activity, but not as marked nor as consistent as found in

Hydrocynus. A high proportion (70%) of pools Alestes were found to be feeding, whereas the level was similar in the lake and river at a much lower level (39% and 33% respectively). A fall in feeding activity in the lake was only noticed in January (the rainy season) of each year and not over the entire hot season as found for Hydrocynus.

Labeo altivelis. A high overall level of feeding was found (70%), which persisted throughout the development of activity of the gonads until fish reached a ripe condition, when a drop to 50%, persistent to a "ripe running" condition, was found. Approximately half the fish caught therefore ceased to feed when approaching full breeding condition and it was only when actually migrating in the river that feeding was found to cease throughout the sampled fish. Seasonal results are too inconsistent to allow any conclusions.

Clarias gariepinus. Overall results indicated a moderate level of feeding activity (43%) largely as a result, presumably, of limited food availability in the pools (32%), feeding activity in the lake and river being found to be at a much higher level (71%, 60% respectively). A decrease in feeding activity seems apparent in sexually "ripe" fishes and no food at all was found in the few "RR" fish examined. Seasonal changes are too patchy and inconsistent for comment.

Eutropius depressirostris. This fish showed quite a high overall level of feeding activity (65%), with no apparent correlation between breeding and feeding activity, nor any seasonal changes of note apart from the high level (92%) of July 1967. The few fish taken in the river were all feeding, but were caught on a baited hook.

Synodontis zambesensis. Again, a quite high overall level of feeding activity was found (61%), which only decreased when fish were fully ready to breed (RR), but 50% of these fish continued to feed. Levels of feeding activity in lake, pools or river were much the same and no seasonal trends are apparent on these data.

It is of interest to note that the species of fish which were found to have a lowered level of activity when in full breeding condition, which include Hydrocynus, Labeo, Alestes, Clarias and Synodontis all, immediately following breeding when in a spent condition, fed very actively.

3. DISCUSSION

3.1 A Feeding Categorisation of the Fish Fauna

The percentage frequencies of the occurrence of major food items in adult fishes are given in Table 12.15. As analysis by percentage frequency is not available for some species (Labeo, Barbus, Micralestes) and as in others (Clarias), results are spatially biased, major and significant food items of these species have been denoted by symbols. Adult fish fall into several groups.

3.1.1 Planktivorous species

Clarias gariepinus was essentially planktivorous, but at the same time was opportunistic in its feeding, sometimes feeding on allochthonous material at the surface or taking matter derived from dead or dying fish, or the fish themselves. No clear-cut instance of fish predation was recorded. The minnow-like Micralestes acutidens and three Barbus species found in the area (B. unitaeniatus, B. fasciolatus and B. lineomaculatus) also fed on zooplankton, although the former seemed selective towards larger diaptomid copepods, while the latter utilised a wider range of planktonic organisms supplemented by benthic feeding. The occurrence of phytoplankton in Clarias stomach contents appeared to be incidental.

TABLE 12.15 The percentage frequency of occurrence of major food categories in adults of the different fish species from the lake

• : most important food item   X : present in diet

	ZOOPLANKTON	PHYTOPLANKTON	PERIPHYTON	VEGETATION	ORGANIC MATTER	OLIGOCHAETA	CRUSTACEA	ODONATA	HEMIPTERA	EPHEMEROPTERA	LEPIDOPTERA	TRICHOPTERA	CULICIDAE	CHIRONOMIDAE	CERATOPOGONIDAE	TERRESTRIAL INSECTS	MOLLUSCA	FISH REMAINS	FISH
[illegible]	-	-	-	-	-	-	13	34	-	6	-	2	11	-	2	-	-	30	32
[illegible]	-	-	-	-	-	-	1	32	X	16	1	21	22	9	X	-	X	-	-
[illegible]	-	-	-	-	-	X	X	12	-	1	-	61	5	1	1	-	-	-	X
[illegible]	-	-	-	-	-	-	X	X	-	1	-	1	X	-	-	X	-	-	98
[illegible]	-	-	-	4	-	-	1	4	-	7	-	6	-	3	3	63	3	5	4
[illegible]	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	•	-	-	-	X	-	-	-	-	X	-	-	-	X	-	-	-	-	-
Labeo altivelis	-	-	X	-	•	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	-	-	-	-	-	-	-	29	-	10	-	5	1	-	-	19	-	6	16
[illegible]	•	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X
[illegible]	X	X	X	X	X	-	X	•	X	5	-	65	5	9	X	X	11	X	X
[illegible]	-	-	•	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-

5.1.2 Periphytic algae eaters

It is still uncerta[illegible] what source the algal contents of Tilapia mortimeri have. The nature of the stomach contents suggest quite strongly that the major source of these algae was the bottom deposits, which would tend to limit the depth of feeding success. Yet gillnets set through the canopy of a submerged tree would almost invariably capture Tilapia, whereas nets set a few metres away at the same time would not catch this species. The association with drowned trees was therefore quite marked and could have been as a result of their use as a feeding substrate. The other periphytic algal eaters not included in the table (12.15) were La[illegible] cylindricus and L. congoro. By its prevalence in the riverine pools, L. cylindricus would tend to have been a lithophyllic algal eater and feeding marks of L. congoro in the lake were seen on both rocks and trees. Synodontis zambesensis were on occasion found to be filled to capacity with wads of periphytic algae very similar to those seen to gather on submerged twigs. In this instance, however, periphytic algae were a relatively unimportant food source when all individuals are considered. The few specimens of Distichodus schenga taken indicated their partial utilisation of this food source.

5.1.3 Grazers

The only clear-cut grazing species taken was D. schenga, although the occurrence of chewed vegetation in Alestes imberi (4%) and Synodontis indicates a partial dependence by these two species on grazing as a source of food. No Tilapia rendalli, which occur with some frequency in Lake Kariba and which subsist almost entirely on grazing (Jackson, 1961d; de Kimpe, 1964; and Jubb, 1967), were caught, but the presence of this species in the study area cannot be discounted.

5.1.4 Detritus feeders

Organic matter appeared to be the major source of food of *Labeo altivelis*, one of the most numerous species in the study area. Possibly as a consequence of their feeding habits, organic matter also formed significant constituents of the diets of *S. zambezensis*, *T. mortimeri* and the *Barbus* species.

5.1.5 Invertebrate feeding

5.1.5.1 Oligochaeta

Although sometimes present at very high population levels, the Oligochaeta were not utilized and appeared to be actively shunned by benthic feeding fishes. Only one occurrence was recorded, when oligochaet remains were found in an adult *Mormyrus*. Avoidance of predators, particularly *Mormyrus*, cannot be regarded as a significant factor bearing in mind this fish's proposed digging ability. I have experienced only one indigenous African fish which feeds freely on Oligochaeta, the bagrid *Auchenoglanis occidentalis* of the Congo System. There would seem to be reason for consideration of this fish's introduction into the Zambezi River system.

5.1.5.2 Crustacea

Only one species of fish was found to utilise significantly non-planktonic crustaceans such as *Cyclestheria hislopi* (?) and *Caridina nilotica*, which were present in considerable numbers in the weed beds, and this was *Mormyrops deliciosus* (13%).

5.1.5.3 Odonata

The overwhelming preponderance of anisopteran nymphs as opposed to zygopteran nymphs in gut contents, particularly in fish taken in weed beds, suggests the former to be more easily taken. Libellulid nymphs formed important constituents of the food of *Mormyrops* (54%), Cyphomyrus (32%) and Eutropius (29%) and were significant in Mormyrus (12%), Synodontis (8%) and Alestes imberi (4%), being found also to occur in Hydrocynus.

3.1.5.4 Hemiptera

The water bugs were insignificant as food items, occurring only in very low numbers in Cyphomyrus and Synodontis.

3.1.5.5 Ephemeroptera

Povilla adusta nymphs were the only overall significant mayfly, but Euthraulus (particularly in Cyphomyrus) the baetids and caenids also occurred, especially in juvenile fishes. Fish which fed on Povilla included Mormyrops (6%), Cyphomyrus (16%), Mormyrus (1%), Hydrocynus (1%), Alestes imberi (7%), Eutropius (10%) and Synodontis (8%). Although seemingly a significant source of food to the fishes, Povilla is not nearly as important as found by Petr (1971) in Lake Volta, where fisheries productivity is apparently dependent to a large extent on this species.

3.1.5.6 Lepidoptera

The only fish found to prey on the pyralid larvae and nymphs which occurred in the terminal growth of, particularly, Ceratophyllum demersum, was Cyphomyrus, in which fish it formed 1% of the biomass of constituents.

3.1.5.7 Trichoptera

The larvae and pupae of Dipseudopsis capensis was the single most important food item of the entomophagous fishes, contributing 81% of the food of Mormyrus, 68% of the food of Synodontis and 21% of Cyphomyrus food. They also occurred in Mormyrops, Hydrocynus, Alestes and Eutropius.

3.1.5.8 Culicidae

Chaoborus spp. occurred in a quite wide variety of fishes, being notably absent from filter feeding Clarias and seemingly avoiding predation by these. Chaoborus was only significant in the diet of Mormyrops deliciosus (11%) and Cyphomyrus discorhynchus (22%) and were taken in particularly large numbers by the latter.

3.1.5.9 Chironomidae

Larval and pupal chironomids, apart from their frequent occurrence in a wide range of juvenile fishes, were found to be surprisingly unimportant as a source of food to the fishes, forming 9% of Cyphomyrus' and Synodontis' diet and a very low proportion of the stomach contents of Mormyrus, Alestes and the Barbus species. Although a wide range of species was freely taken, only one of these, by itself, formed a significant food item, the tanypod chironomid Clinotanypus maculatus.

3.1.5.10 Ceratopogonidae

The ceratopogonid larvae were found widely in the gut contents of entomophagous species, but were nowhere of any significance.

3.1.5.11 Terrestrial insects

These were found in all the surface feeding predatory fishes and were the single most important constituent of the diet of Alestes imberi (63%), forming also a significant part of the diet of Eutropius (19%) which tended to take larger insects than Alestes.

3.1.6 Molluscivorous fishes

Although the remains of Physopsis globosus and Biomphalaria pfeifferi occurred with some frequency in Cyphomyrus, Alestes and Tilapia, only Synodontis showed itself to be actively molluscivorous, gasteropods contributing to 11% of this fish's very catholic diet. Bowmaker (1968) in suggesting S. nigromaculatus as a potential biological method for the control of snail vectors of bilharsiasis, showed this species to take 15.2% snails and de Kimpe (1964) found a 14% occurrence, levels very similar to those found here. Jackson (1961d) mentions S. zambezensis as containing mollusc remains.

5.1.7 Fish predators

Three species fell clearly into a piscivorous category, Hydrocynus vittatus, which fed almost entirely (90%) on fish when adult; Mormyrops deliciosus and Eutropius depressirostris, both of which had an approximately 20% component of small fish in their diet. Alestes imberi, Mormyrus, and Synodontis were very occasionally found to have eaten small fish. Jackson (1961a, b) following research undertaken in the middle Zambesi River before flooding, and later on the infant lake, underlined the importance of Hydrocynus on the fish fauna of the area (App. 1.1 page 3). Being the only major fish predator, the effects of this fish on the dynamics of the fish population would be profound and it has therefore received a greater proportion of attention than other fish species. Jackson (1961e) found that in the Luapula River drainage basin and the Middle Zambesi River before flooding by Lake Kariba, that Hydrocynus prey was composed of 42% Cichlidae, 32% Characidae (Alestes spp.), 19% Cyprinidae and approximately 6% of other families. Munro (1967) found that in a Rhodesian highveld dam Hydrocynus food was again, but more markedly, predominantly composed of cichlids (70%), particularly Haplochromis darlingi. In contrast, Matthes (1968) reporting on results obtained in Lake Kariba, found only 34.2% occurrence of cichlids and a 47.4% occurrence of the Characidae, Micralestes acutidens and Alestes lateralis. These results were obtained during 1964/65, since when there would seem to have been a change in diet. Donnelly's (1971b) subsequent results show an 18% occurrence of cichlids in Hydrocynus' diet and a 54%

characid component. These results were synchronous with those obtained here (1967/68) but from the Sanyati Basin and are markedly different from my own, which indicate a cichlid component of 0.8%, a characid component of 45% and a cyprinid component of 6%. If these are recalculated on the frequency of occurrence of recognisable fish remains these values are changed to Cichlidae 1%, Characidae 85%, Cyprinidae 11% and others 2%. Subsequent work by Kenmuir (1972) gave the following results. In 1969/70: Cichlidae 34%, Characidae 21% and Clupeidae 1.5%. In 1970/71: Cichlidae 15%, Characidae 11% and Clupeidae 41%. The Lake Tanganyika clupeid Limnothrissa miodon was successfully introduced to Lake Kariba in 1967 and 1968. By the second half of 1969 "abundant shoals of the second generation" (Coche, pers. comm.) were found in the locality of introduction in Basin III, some distance away from the Sanyati Basin where Kenmuir's results were obtained. Bearing in mind the misgivings generated by the low level of the cichlid component of Mwenda Hydrocynus when related to my observations, the trends which become apparent in Lake Kariba as it develops are: an initial dependence on predominantly cichlid fry, with a change in 1964/65 to characids and again a change in 1970/71 to clupeids following their introduction. As Alestes lateralis is also a fish new to Lake Kariba (Balon, 1971) having previously been confined to the Upper Zambesi system and whose success in the lake has been attributed to the development of littoral hydrophytes (Bowmaker, 1970), predator pressure on the commercially important cichlids would appear to have been lessened due to the recruitment to the fish population of two non-endemic species which are admirably suited as prey fish to Hydrocynus. Should the Limnothrissa population behave as theoretically expected, and collapse following their initial population explosion, which may well have actually occurred in 1972 (Begg, pers. comm.), a reversion to original prey species could well occur, particularly on occasions when lake level fluctuations temporarily eradicate the cover provided by littoral hydrophytes.

Jackson (1961c) found that prey of *Hydrocynus* never exceeded 4% of predator length, though a considerable proportion of prey fish examined approached this value. A similar size relationship was found by Munro (1967), but he also found that although a trend of increasing prey size with predator length was apparent, beyond a predator length of 25 to 30 cm the prey stabilised at 5.5 to 6.0 mm length. Matthes (1968) found that generally the 4% rule held true but "on several occasions fish found in stomachs, especially *Hydrocynus* smaller than 30 cm exceeded 4% of predator length (up to 64% once)".

The outstanding factor in respect to size of predator and prey found here was the small size of fish prey taken irrespective of predator size (the few larger *Synodontis* and *Eutropius* taken were taken by larger *Hydrocynus* and predator/prey ratio never exceeded 37%). The size range of fish examined from the lake was 15.6 to 63.7 cm. most fish fell between 16 and 30 cm; yet the size range of prey of the very great majority of fishes was 2.5 to 5 cm. Whether the intake of small prey fish was by choice or was due to availability is not clear, but the latter is more likely as smaller *Hydrocynus* tended to take prey nearer the 4% mark.

5.1.8 Fish debris eaters

Eutropius depressirostris was the only species found with a marked predilection for fish bones. These were usually the larger opercular bones of *Hydrocynus*, possibly the result of crocodile predation, as crocodiles have been observed to vigorously shake *Clarias* until the head is flung from the body, which is then eaten.

Fish scales were surprisingly important in the diet of several fishes, and could have been the result of scales being dropped from fish entangled in the gillnets. They occurred in 10% of Mormyrops with food, 2% of Mormyrus (a single occasion), 5% of lake Alestes imberi and 25% of adult pools Alestes, 6% of Eutropius and 8% of Synodontis.

The feeding categorisation of fishes and their main food is summarised in Table 12.16.

3.2 Substrate Utilization

In order to gain some idea of the relative utilization of different substrates, the stomach analyses of ten species have been rearranged to indicate the probable proportions of food from various sources (Table 12.17). As there is no reliable quantitative information of absolute densities of each fish species it is not possible to calculate levels of utilisation of each substrate. Nevertheless it is clear that the bottom deposits supply the most food to the most species, the only species, in fact, which on these data does not utilise this substrate is Clarias gariepinus, and this only when away from the margins. The importance of allochtonous food is also of interest. Plankton and neuston supply a limited number of species. The nektonic component of food, mainly in the form of juvenile and small fishes, is important in four of the ten species considered, and was found in a further three. Very few species appear to utilise the trees as a feeding substrate, but the list does not consider Labeo congoro, L. cylindricus and T. mortimeri, which may well feed extensively on the trees to the depth of light penetration. The rooted macrophytes are also an important substrate to several species. In this analysis, however, the substrate is not as extensively utilized as expected. Salvinia supplies quite a considerable proportion of food to half the fishes considered.

TABLE 12.14 A SUMMARIZATION OF ADULT FISH FEEDING CATEGORIES

CATEGORY	SPECIES	MAIN FOOD ITEMS
Algae/organic matter	Labeo altivelis	Organic matter
	Labeo cylindricus	Periphyton
	Labeo [illegible]	Periphyton
	Tilapia [illegible]	Algae of indeterminate source
Vagrant	[illegible]	-
	Tilapia rendalli rendalli	-
Zooplankton	[illegible]	Zooplankton above 0.7 mm length excluding
		Chaoborus spp. larvae
	Micralestes acutidens (?)	Large [illegible] (?) sp.
	Barbus spp.	[illegible] and [illegible]
Aquatic insect sub-imagines	Order [illegible]	Late instar libellulid nymphs
		Povilla nymphs
		[illegible] larvae
		[illegible] larvae
		(All in the region of 80% by biomass)
	[illegible]	[illegible] larvae
	[illegible]	[illegible] pupae
Terrestrial insects	Alestes imberi (?)	Wood-boring Coleoptera
Mixed predators	[illegible]	Large anisopteran nymphs
		Fishes below 5 cm length
	Eutropius depressirostris (?)	Terrestrial arthropods
		Caridina nilotica
		Libellulid nymphs
		Fishes below 4 cm length
		Emerging Povilla
Fish predators	Hydrocynus vittatus (?)	Alestes lateralis

TABLE 12.17 THE PERCENTAGE FREQUENCY OF OCCURRENCE OF FISH FOOD SEPARATED ACCORDING TO SOURCE

SPECIES	Terrestrial	Neuston	Plankton	Nekton	Bottom deposits	Trees	Rooted macrophytes	Salvinia
Mormyrops deliciosus	-	-	-	55.0	45.0	-	18.0	4.0
Cyphomyrus discorhynchus	-	-	-	-	56.0	-	25.0	19.0
Mormyrus longirostris	-	-	-	0.1	90.4	0.4	0.1	-
Hydrocynus vittatus	0.3	-	-	97.9	1.8	-	-	-
Alestes imberi	62.5	1.0	-	5.2	13.2	-	8.1	-
Labeo altivelis	-	-	-	-	100	?	-	-
Eutropius depressirostris	18.8	9.2	-	29.2	16.7	-	12.5	13.2
Clarias gariepinus (open water)	-	-	100	-	-	-	-	-
C. gariepinus (margins)	70.0	-	-	10.0	20.0	-	-	-
Synodontis zambezensis	0.1	3.0	0.1	0.2	78.0	0.1	15.5	3.0

As could be expected in a system as recent as Lake Kariba, the feeding behaviour of the fishes, even when considered against these very broad substrate categorisations, suggests opportunism rather than specialisation, behaviour which would be of value in a fluctuating riverine environment. When considered against the large numbers of highly speciated cichlids of Lake Malawi (Fryer, 1959) it becomes apparent that there is a marked probability of inefficient utilisation of available energy, emphasised by the paucity of small littoral species when compared with a long established lake system.

5.5 Feeding and Food Availability

Insufficient evidence exists for much comment on fish at the primary consumer level. The periphytic/organic matter feeding fish were represented mainly by *Labeo altivelis*, a very important population constituent of the fishes in the study area (in itself indicative of adequate food supplies). The netting stations used largely ruled out capture of another commercially important species, Tilapia mortimeri. For reasons given earlier, it is probable that this species utilises epiphytic algae growing on the drowned trees within the photic zone. The effects of a very great increase in colonisable substrate as the result of the presence of drowned trees was not anticipated; but, bearing in mind the essentially riverine nature of the fish fauna, the presence of the drowned trees must have resulted in a considerably increased secondary production and is probably the main reason for the success of T. mortimeri, not apparent in these results, but reported elsewhere in Lake Kariba. Since the introduction of the Lake Tanganyika sardine, Limnothrissa miodon, the advantage of increased substrate area is not as demonstrable, as consideration must be given to the extraction of nutrients from the water which would have alternatively entered the planktonic food web.

It has been suggested that the size composition of the zooplankton population indicates only moderate predation by fishes. The selectivity by the feeding methods of Clarias gariepinus, at the time the only major zooplankton feeder, towards organisms over a size of 0.7 mm, emphasises this suggestion. It will be of interest to see how the zooplankton population size composition in the area has been affected by the establishment of Limnothrissa, as Begg (pers. comm.) has found a predominance of smaller zooplankton (particularly Bosmina) in the gut contents of these fish.

The outstandingly important food of the entomophagous species were the libellulid dragonflies, particularly later instars, Chaoborus spp., Povilla adusta and Dipseudopsis capensis, the latter being extremely important to benthic feeders. The libellulids were tertiary consumers which, in *Salvinia* at least, subsisted to some extent on their own earlier instars, and their utilisation indicates inefficiency in terms of fisheries productivity. *Chaoborus* is also predatory, but *Povilla* and *Dipseudopsis* are primary consumers.

Animals listed as "non-utilisable herbivores" (Table 8.17) when considered within the invertebrate food web, can now be seen to have been utilised to some extent by the fishes. Gastoropods are taken to some extent by *Synodontis zambezensis*, the pyralid moth subimagines by *Cyphomyrus discorhynchus* and *Caridina nilotica* by several species, but mainly by *Mormyrops deliciosus*.

The importance of *Dipseudopsis* subimagines as fish food bears little relationship to their frequency as suggested by benthic sampling (2% by numbers) indicating inefficiency in the sampling method used. Grab "blast" would be particularly effective in excluding a tube dweller such as *Dipseudopsis*.

On the other hand several groups of potenti food are only utilised to a limited extent in terms of their availability as reflected by sampling. In this context the oligochaetes are outstanding and, as has already been suggested, consideration of the introduction of a species which will utilise this group could well enhance fisheries productivity not only in Lake Kariba, but also in Rhodesian highveld dams (Munro, 1967) where their non-utilisation has already been pointed out. The chironomid larvae, apart from the errant predator *Clinotanypus maculatus*, would also appear to be more frequent than gut contents would suggest. Zygopteran nymphs, clearly dominant in the aquatic macrophytes, are unimportant in fish stomachs, suggesting an adeptness in evading predation.

The utilisation of zooplankton, seemingly only at a moderate level on consideration of fish stomach contents and the size composition of the zooplankton population, is likely to be at a very much higher level on consideration of the intermediary role played by Chaoborus. Being predatory, and planktonic at night, Chaoborus recycles energy from plankton into the bottom feeding fishes when, during the day, they are available to these fishes in the bottom muds.

CHAPTER 15

GENERAL DISCUSSION

The original aims of the project (Pg 4) have to some extent been achieved. However, even though every attempt was made to replicate sampling to an extent which allowed statistical verification, the inherent variability of the populations concerned and methods used proved, on eventual analysis, to be of too high an order. Too frequently any conclusions which have been drawn have been subject to a dissatisfying uncertainty. Any degree of certainty, should this indeed be attainable in a survey of the type carried out, could only have stemmed from a severe restriction on the field of study. As one of the main aims of the survey was to lay a foundation for future, more precise, projects (Pg 6) any tendency for restriction of effort had to be contained. Some idea then, has been gained of the seasonal abiotic changes and the spatial and seasonal changes in distribution and abundance of the biota which occurred, supplemented to some degree the fortunate circumstance arising from the development of rooted macrophytes in the area during the course of the study. The feeding relationships of the fauna below the level of the fishes has depended too much on estimations of diet based on mouthparts and requires a greater degree of in-depth study. Suggestions which have been made as to feeding relationships at those levels must therefore be regarded merely as an initial step.

The next major aim listed was the investigation of the effects of the permanent *Salvinia* mat. Up to the time that this study was started *Salvinia* had been regarded as a noxious weed and was a source of irritation to human utilisation of the lake. In a system such as the Mwenda River mouth, where the *Salvinia* mat, although permanently established, extended a relatively short distance between river and lake, it was found that abiotic conditions were not necessarily limiting to productivity. Dense concentrations of zooplankton, apparently feeding on particulate organic matter derived from the mat, were found in association with the mat. The standing crop of the "performance column" was greatly increased by the presence of *Salvinia*, even though a suppression of benthos occurred underneath the mat. Similarly, the standing crop on submerged drowned trees was apparently increased and it has been presumed that this was due to the suitability of the mat for the earlier instars of the nymphs of *Povilla adusta*. Juvenile fish, particularly *Tilapia mortimeri*, were found and observed so frequently in association with *Salvinia* that this plant must have played an important role as cover to them, alleviating to some extent the very significant predator pressure exerted by *Hydrocynus* at a stage in the lake's development when little alternative cover existed. This point has now been generally accepted by fisheries workers associated with Lake Kariba, but, now that the rooted hydrophytes have become established, the acknowledged usefulness of the plant is considered retrospective. This is seemingly a premature attitude (and has resulted in the release of the South American grasshopper *Paulinia acuminata* in an attempt to control *Salvinia*) for the lake is still subject to major fluctuations that, judging by the abrupt zonation of the littoral hydrophytes where these can be seen, will probably decimate the rooted macrophytes for months at a time. Under these circumstances the alternative cover offered by *Salvinia* could only be of value to future fisheries productivity.

The third major aim, to investigate the migrations of fish in the Mwenda River, was also to some extent covered but it is patently obvious that problems posed by the migratory fishes are too complex to allow more than generalisations on the data collected, although the data are more informative at the species level than have previously been attained in Africa. The limitations imposed by method, frequency of sampling and the duration of sampling can only be overcome by concentration on this one aspect of the biology of the fishes. This line of research is currently (1973) being followed. A flume type flow gauging weir has been built across the Mwenda River, incorporating a two-way fish trapping mechanism and it is intended to collect data on fish movements and water quality throughout each rainy season for several years to come.

Two aspects of this study which are not reported here, but will be published separately, are the faunal constituents of the river and pools and the effects of fish removal on these, and the food requirements of Hydrocynus which involved a series of feeding experiments on captive fish.

One of the main reasons for an holistic approach being chosen was to find productive avenues for future more intensive studies based on the Nuffield Lake Kariba Research Station. Major avenues may be listed as follows:

1. The effects of lake level fluctuation on the rooted hydrophytes. It has been assumed herein, on the basis of abrupt zonation, that these plants are susceptible to lake level fluctuations, thus the value of Salvinia as a productive substrate is enhanced. This assumption requires investigation.
2. The role of Salvinia as cover to juvenile fishes. This project which is closely associated with the above assumption has already been started by S.A. Mitchell of the Lake Kariba Fisheries Research Institute.

3. The zooplankton density centres and utilisation of particulate organic matter by zooplankton as food. The findings herein, being based on such widely separated samples, must be regarded as suspect and evidence for the utilisation of particulate organic matter is largely circumstantial. Fortunately, an intensive study of zooplankton is currently being undertaken by Dr. M.L. Mills, Senior Research Fellow at the research station.
4. The biology of _Dinsdaliopsis capensis_. The importance of this species as a fish food indicates an underestimation of its abundance in the bottom muds and a study on this species, using equipment specifically designed to sample the various stages in its life cycle, would be valuable. An autecological study of the _Chaoborus_ is nearly completed. A similar study on _Povilla adusta_ would also be of value as there are indications that subsequent to the sampling undertaken during the course of this study, this species has greatly increased in numbers, perhaps as a result of the ever-increasing substrate suitability as the drowned trees decompose and that each generation of the nymphs of this species leaves behind it a more advantageous habitat for those which follow. This process is likely to advance far beyond the current situation and work carried out now would be of value also as a gauge for later comparative work.
5. Aquarium studies of the entomophagous fishes, particularly with respect to the electrical senses of the mormyrids and the feeding behaviour of these and _Synodontis_, which herein are described to some extent on circumstantial evidence, are needed.

It was anticipated at the outset of this survey that either the whole or certain aspects of the study would be repeated in the future. Exploratory sampling undertaken in December 1972, indicates that significant changes in the biota have already taken place, in the trees, as mentioned above, and in the vegetation. The permanent Salvinia mat has not as yet reformed, so that comparison of this aspect of the work is not yet possible, but the marginal Salvinia present at the time of recent exploratory sampling appears to carry both a greatly increased faunal biomass and a greater diversity of animals.

Since the observations on the aquatic macrophytes made when Chapter 4 was written (1970), various quite substantial changes have occurred. Magadza (1970) seems to have been correct in his forecast that Panicum repens would develop and stabilise in the marginal habitat, for Panicum is now (1973) well established on the Kariba lakeshore and, in the Mwenda area at least, even along steeply shelving shorelines. Lagarosiphon ilicifolius still maintains a domination of the rooted hydrophytes in the bay, and only very occasional weak stands of Ceratophyllum demersum and Potamogeton pusillus can be found. Two further plants now occur in the bay in some density. Potamogeton schweinfurthii A. Benn is commonly seen and Naias interrupta K. Schum occurs abundantly in pockets within the Lagarosiphon beds. Naias appears to be invasive, for it occurred infrequently when first seen in December 1971. A few stands of Phragmites now occur in positions protected from wave action and elephants and Cyperus articulatus is commonly seen along the shoreline. Typha stands are now very rare and are only seen growing on or below the soak zone, out of close association with Salvinia.

A student field guide of the aquatic animals of the Mwenda Bay, based on the reference collection, is currently in preparation but further breeding out of some imagines is necessary.

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Chapter 1. Appendix 1.

PRELIMINARY OBSERVATIONS ON SOME ASPECTS OF THE BIOLOGY OF THE SINAMWENDA ESTUARY, LAKE KARIBA

BY

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PRELIMINARY OBSERVATIONS ON SOME ASPECTS OF THE BIOLOGY OF THE SINAMWENDA ESTUARY, LAKE KARIBA

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(Read at the First Rhodesian Science Congress, Bulawayo, May 1967)

The observations are based on a single month in the field, during October and November 1966, at the start of an investigation which should be completed by the end of 1969. The author is greatly indebted to the Nuffield Foundation, the University of the Witwatersrand and the University College of Rhodesia who have made this work possible.

In order for the observations to be fully appreciated it is necessary to review the relevant findings of previous fisheries biologists with regard to the lake.

Jackson (1961) found that the limiting factor of the fish population of the middle Zambezi was largely environmental, closely linked with the intense predator pressure of the Tiger Fish *(Hydrocynus vittatus)*. During the periods when the river flooded and overflowed its banks, fish moved into flooded backwaters and areas of vegetation where both food and protection from predator pressure were available. With the fall in level, however, the fish were forced to retire to the bare river bed and at the lowest levels were considerably concentrated. The population was thus decimated both by intense competition and by predation. This condition persisted for the greater part of the year and thus the old river maintained a relatively small population of fish.

At the First Federal Science Congress in May 1960, Jackson pointed out the effects of damming in that the seasonal environmental factors were no longer of a limiting nature. Initial spawning, without subsequent predation, he forecast, would be successful to an unprecedented degree when coupled with the enormous increase in *lebensraum*.

Jackson's findings in February 1960 illustrate well the improved survival rate of juvenile fish and the improvement in condition of the adult fish in the new-formed lake as illustrated by *Hydrocynus*. The larger *Hydrocynus* were at this stage characterised by being immensely deep-bodied and massive and had to a certain extent lost their characteristically fusiform shape. Badenhuizen (1966) has shown that the growth of *Hydrocynus*, found by Jackson to be of the nature of 25 cm. in two years in the river and 22 cm. after one year in the infant lake, is now of the order of 25 to 30 cm. in two years. Although this is an improvement on the growth rate in the riverine situation, there would appear to be a considerable decrease of the growth rate experienced during the initial population explosion following closure.

It would thus appear, on available data, and on the assumption that being the major predator (other than man) *Hydrocynus* may be regarded as a gauge of reaction of the entire fish population, that the fish fauna is either in the process of, or has settled down to, a more realistic level and that the lake has therefore matured sufficiently for a certain degree of stabilisation to have taken place.

Some considerable work has already been carried out in the Sinamwenda estuary by Mitchell, working on *Salvinia auriculata*, and by McLachlan, whose work on the benthic fauna, particularly the larvae of the Chironomidae, is at present reaching its closing stages. As the present observations involve both *Salvinia* and, to a certain extent, the benthic fauna, they are tendered rather diffidently but are thought, nevertheless, to be of sufficient significance for publication.

THE MAJOR ENVIRONMENTAL DIVISIONS OF THE SINAMWENDA ESTUARY

The major environments of the Sinamwenda estuary, as affecting the fish population, may be divided as follows:

1. The Bottom Muds.
2. The Submerged Trees.
3. The Marginal and Submerged Vegetation.
4. The Permanent *Salvinia* Mat.

1. The Bottom Muds

McLachlan, as stated earlier, has carried out extensive research into the fauna of the muds, thus these comments will be limited to the bottom muds underneath the *Salvinia*, where limited careful sampling was carried out. This niche would appear to be devoid of macroscopic invertebrate life, apparently a direct result of the overlying *Salvinia* mat. An obvious assumption would be that the basic trophic levels, being deprived of light, are lacking. There are, however, detritus feeding insect larvae among the bottom muds in the vicinity of the estuary (McLachlan, unpublished) which should, if lack of light is the limiting factor, be present in the bottom muds under the mat. As these are not present, the indication is that some other factor is responsible for the lack of animal life. McLachlan (personal communication) has shown that this lack is not due to the nature of the detritus formed by *Salvinia* jetsam. The only apparent alternative factor could lie in the oxygen availability in the immediate vicinity of the bottom muds. Harding (1961) has shown that there is a reduction in oxygen tensions beneath *Salvinia*. This could, in the case of the deeply-troughed Sinamwenda estuary after eight months of stagnation, result in very low tensions in the immediate vicinity of organic decomposition in the bottom detritus. If deoxygenation is the cause of this lack of life it must be confined to waters closely opposed to the lower layers, as waters clear of the bottom certainly have sufficient dissolved oxygen to maintain ostariophysid fishes whose requirements for oxygen are quite high.

2. The Submerged Trees

As is to be expected, the nature of submerged trees has changed considerably since the initial flooding period from 1959 to 1963, in that terminal material (leaves, twigs and smaller branches) has been stripped away. Generally speaking, trees at all depths have been subjected to wave action at some stage in the formation of the lake. The submerged trees are therefore bare skeletons of their former selves and, in addition, the smaller shrubs have virtually disappeared. They thus no longer, as was initially the case, offer juvenile fishes protection from predator pressure. Interstices are now sufficiently large to allow free movement of the predator *Hydrocynus*. In the sheltered waters near the surface, however, the branches form a substrate for a dense *aufwuchs*, predominantly two species of *Spirogyra*, which support a sparse invertebrate population, dominated by the chironomid larvae and including occasional heptagenid nymphs (Ephemeroptera), the snail *Bulinus* sp. and several small species of dytiscid beetles with their larvae. The bark of these trees, which in many cases has lifted from the underlying wood, provides an environment for chironomid larvae and the earlier instars of the burrowing mayfly *Povilla adusta*. The later instars of *Povilla* burrow in the underlying wood and although found to be common are not available as fish food except during periods of emergence.

The emergent branches of submerged trees still play a part in the ecology of the estuary in retaining *Salvinia* in bodies large enough not to be over-affected by wave action, found by Mitchell (personal communication) to be one of the main causes of destruction of the *Salvinia*.

3. Marginal and Submerged Aquatic Vegetation

The estuary, and probably the lake itself, generally speaking, is characterised at this stage of its evolution by a remarkable lack of marginal sub-aquatic vegetation and submerged aquatic vegetation. The importance of the role of this vegetation in the older lakes of Africa cannot be sufficiently stressed. This vegetation plays the same role as that played by the flooded vegetation of the banks of the middle Zambezi and is of proved value in Lake Tanganyika, where amongst other species it supports the juveniles of *Lates* spp. (Coulter, 1960), in Lake Mweru, where it supports the juveniles of *Tilapia macrochir* (Carey, 1965), and in Lake Bangweulu, where the productivity is basically dependent on the marginal and submerged vegetation (Bowmaker, 1961), to quote a few of many examples. The effects of this lack on the productivity of the estuary must be far reaching indeed. Only very occasionally were aquatic submergent plants seen. There would appear to be, therefore, some nuclei of colonisation and in time this environment should establish itself, although it is surprising that this development has not taken place already.

There are also indications of the formation of the nuclei of marginal vegetation, predominantly by *Panicum repens*, a grass (Magadza, personal communication), but these are sparse.

4. The Salvinia Mat

The broad ecological characteristics of the *Salvinia* mat have been adequately reported elsewhere (Boughey, 1963; Schelpe, 1961; Mitchell, 1965) and it is thought unnecessary to comment on these findings other than to remark that the establishment of *Salvinia* mats provided the opportunity for the development of many species of plants which otherwise would not, apparently, have established themselves along the Lake shore.

The environment offered by *Salvinia* appears to support the only aquatic invertebrate population approaching richness. Although comparative density figures are not yet available, the difference in numbers and diversity of invertebrates collected in this environment and those mentioned above was very marked.

The invertebrate population of the *Salvinia* mat was dominated by the nymph of a libellulid dragonfly in all stages of development, other Odonata nymphs in various stages of development and the nymphs of various species of Ephemeroptera, in their turn dominated by predatory species. Non-predatory animals were dominated by the larvae and pupae of the mosquito *Aedlomyia africana*. Other notable components of the population included the shrimp, *Caradina nilotica*, the early instars only of *Povilla adusta*, several species of Ostracoda, Cladocera, Copepoda and Hydracarina and a small leech. The chironomids appeared to be represented only by the genus *Clinotanypus*, itself a predator.

The notable and peculiar characteristic of this population is the large preponderance of predators, not only in terms of numbers of species but more notably in terms of biomass. These predators probably subsist on their own earlier instars to a large extent which in turn probably find nourishment in the small Crustacea and Hydracarina. It is not known whether or not *Salvinia* is actually utilised by the invertebrate population, but for the most part the basis of the food chain is probably derived from the *aufwuchs* algae or planktonic algae in the interspaces in the surface layers of the mat where there is light penetration.

Large numbers of small and juvenile fish were seen to be using the *Salvinia* mat, certainly along its margins, for the purpose of feeding and protection.

The *Salvinia* mat thus supports the only population approaching richness in the estuary and shows comparatively little diversity in numbers of species.

THE FISH

No netting has actually been carried out in the estuary to date as gillnets are still being devised to surmount the physical problem of setting below the surface clear of submerged vegetation under the *Salvinia* mat. However, several observations were made of adult fish one mile from open water, deep into the mat-covered estuary. There is thus proof that fish species actually live under the mat well away from open water. There is also a concentration of fish at the edge of the mat, particularly *Hydrocynus* and *Clarias gariepinus* (= *mossambicus*?), which on being disturbed would move under the mat and not away from it. There are thus indications that (bearing in mind the juvenile fishes taken by hand net actually in amongst the *Salvinia*) full use is being made of this environment with some likelihood, based on observation only, of the permanent mat supporting a denser population of fish than any of the other environments mentioned above. Bearing in mind that the fish species are of riverine extraction it would not seem illogical to assume that a large proportion of the population would tend to concentrate along the margins and the shallower waters of the lake. This emphasises the importance of the *Salvinia* mat to the fish population, in the Sinamwenda estuary at least.

Small shoals of minute juvenile *Tilapia mossambica* were frequently seen in shallow marginal pools (one of the more favoured being elephant footprints) or very shallow terminal pools at the end of inlets. Juvenile *Hydrocynus* were invariably patrolling offshore near these pools. The very hot dry conditions prevalent in October, in combination with the receding water level, must level a considerable toll on these juvenile fish. Mortality results either from stranding, overheating or predation. These effects were very apparent as the shoals never numbered more than 15 to 20 fish, and could be representative of the survivors of a single brood, found by Coke (1966) to be in the region of 1,000 while still under adult protection. It is thought that the use of topographic rather than vegetal cover is indicative of the general paucity of cover in the estuary away from the *Salvinia* mat.

The use of small inlets along the coastline is certainly not confined to *Tilapia*. This type of cover was used extensively by juvenile *Alestes imberi* and the adult, small *Barbus barilloides* and less frequently by juvenile *Haplochromis (Sargochromis) codringtoni* and *Labeo altivelis*. Generally, however, the inlets used by these species were deeper and larger than those used by the juvenile *Tilapia*.

DISCUSSION

It would appear that the environment offered by the Sinamwenda estuary in its present stage of evolution is relatively inhospitable from a fisheries point of view and that this state of affairs is alleviated by the presence of the *Salvinia* mat.

The emergent branches of submerged trees play an important role in the maintenance of the smaller *Salvinia* mats and it is obvious that these branches will, in the not too distant future, be broken away. There should, when this occurs, be some considerable decrease in the available area of colonisation by *Salvinia*, which in all likelihood will then be found only in sheltered bays and inlets.

From the point of view of fisheries productivity, the establishment of marginal and submerged vegetation is of utmost importance and if this should take place with reasonable rapidity, the role of those mats which are liable to destruction could be taken over and improved upon by this type of vegetation. The establishment of this niche has been tardy in the extreme and this can be explained in one of three ways. Firstly, are essential nutrients (phosphates, nitrates) taken up by *Salvinia* in sufficient quantity to make them a limiting factor in the establishment of marginal or submerged vegetation? It is doubtful if this could be the case with marginal vegetation as these salts are probably made available by runoff from the shoreline in the immediate vicinity of this vegetation. This question is still unanswered with regard to submerged vegetation, and it could be that by taking up essential nutrient *Salvinia* does limit the expansion of this niche, though this is doubtful as it has been found that the [illegible] flood-waters bearing nutrient flow swiftly under the mat and would appear to be made available to the margins on recirculation from open water. Secondly, it may be that the rate of establishment of submerged and marginal vegetation for various reasons is anyway a slow process, and the normal state of affairs for any body of impounded water is being experienced. This would not appear to be the correct solution as the establishment of vegetation in new bodies of water can be alarmingly rapid. The third and most likely explanation lies in the annual drawdown, an essential concomitant of management of the lake for the generation of power.

It would appear that the environmental action on the fish population as exerted by the evolution of Lake Kariba follows this sequence of events: The riverine conditions prior to closure were particularly inhospitable, and the fish population was largely maintained by the alleviation of these conditions during the flood periods. After initial closure and while the lake was flooding the "flood" conditions persisted with a resultant explosion of the fish population. The conditions causing this explosion, namely increased *lebensraum* and extensive cover resulting in alleviation of predator pressure, have now stabilised. The size of the lake is now relatively constant and there has been a considerable decrease in cover following the decomposition of the terminal material of the trees and the disappearance of undercover. As these factors are linked with a slowness in establishment of an appreciable submerged aquatic and marginal vegetation, there has been a tendency towards reversion to inhospitable conditions. This position is at present alleviated by the presence of the *Salvinia* mat which has to a large extent assumed the function of this niche. Bearing in mind that nuclei of submerged and marginal vegetation have established themselves, it would not be illogical to assume that this vegetation will eventually expand in the shallower waters of the Lake and that when this does occur the environment will stabilise to conditions similar to those found in the mature lakes to the north. This stabilisation should reflect itself in an increased productivity.

I am indebted to Professor H. Wild for his criticism of the draft of this paper and to Mr. R. B. Drummond for identification of plant specimens. I am particularly grateful to Mr. A. J. McLachlan for some of the information used and acknowledged in this paper.

(Added July 1967)

Since the period the above observations were made there has been a considerable increase in the aquatic weeds *Ceratophyllum demersum* and *Potamogeton pusillus* with occasional specimens of *Lagarosiphon ilicifolius* in the estuary and bay and, by report, elsewhere along the lake margins. Large catches of fish have been taken in the vicinity of these weeds, particularly in the case of *C. demersum*. The aquatic invertebrate fauna harboured by these plants are spectacularly rich, in terms of both biomass and species, more so than in the *Salvinia* mat.

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THE USE OF THE WORD 'ESTUARY' IN A FRESH WATER CONTEXT

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Marine estuarine workers have recently voiced objections to the use of the word estuary in describing the area where a river enters a static body of fresh water. As I had myself used the word in this context, I have felt obliged to present the problem at this congress so that it may be aired, and, possibly, some decision reached regarding the validity of the term when used in a limnological context. The aim of this paper is therefore not dogmatically to present a single point of view, but, it is hoped, to stimulate discussion and a possible solution to what would appear to be a problem which will face limnologists with ever increasing frequency in the future.

Traditionally, "estuary" has been used to describe the area where a river enters the sea, subjected to tides, and where biological distribution patterns are primarily governed by salinity and tidal action. The internal boundaries of these estuaries are easily defined as being the point nearest the sea where the water shows no trace of saltness, or is not subjected to measurable tidal action. The external boundaries are far more difficult to define as the effects may be very appreciable far beyond the continental shelf in the case of major rivers such as the Amazon. Most estuaries are easily defined as such, but there are cases where difficulties may arise. For example, does the area immediately below a river entering as a waterfall into the sea come into this category? There are many smaller streams and rivers along the Mozambique coast which, when flowing (which they do for only a few months in each year) constitute a valid estuary in the above context, but which, when they cease to flow, may show a reversal in salinity gradient due to evaporation in the shallower landward waters. Marine workers would state that these constitute quaint, but nevertheless true, estuaries, as the word has become firmly associated with a river entering the sea.

It is normally accepted that a salinity gradient occurs within an estuarine bay, but the variations are very great. A large, permanently flowing river, with an unconstricted mouth subject to minimum tidal action, may never experience salinity concentrations of any consequence, tidal action pushing only previously expelled and unaffected fresh water back against the flow of the river. At the other extreme, narrow, weakly flowing streams subject to maximum tidal action caused by constriction, would probably be marine in character for a great many miles inland and the actual "estuarine" bay at the river mouth would be measurably unaffected by fresh water.

The point that I wish to make is that in both these cases 'estuary' would appear to be used unhesitatingly for areas with relatively constant salinity.

Estuary is derived, according to the Oxford English Dictionary, from the latin word *aestus* meaning heat, hence boiling, bubbling, tide, and is described as the tidal mouth of a great river, where the tide meets a current of fresh water. This is a relatively modern usage and in the past had wider application. To quote from the above reference: "Bacon was accustomed to take a draught of March beer towards bedtime to settle this aestuare of his mind". Heat and boiling are implications in the word that have been lost. The etymology of the word clearly does not make it more applicable to salt water rather than fresh water, nor does it in any way define the magnitude of any tide. There is no doubt that the word estuary is most commonly used for river mouths where they enter the sea. Yet the term sea has a wide number of different connotations which are independent of size or salinity. The Dead, Aral and Caspian Seas are examples of enclosed bodies of water which have the name 'sea' and with widely differing salinities.

There is no doubt about one aspect of the problem. One component must be a flowing river and the other must be a relatively static and large body of water. It has been shown that salinity may not be a factor necessary to fulfill the usage of the word in a marine context. A further point is that all bodies of water are subject to tidal action whether these are measurable or not.

If the use of a word such as estuary in a fresh water context be questioned, the use of a host of other descriptive words is also questionable. For example: lagoon, creek, delta, lake, swamp, strait and as has been stated, even sea. To take one of these examples, two accepted swamp areas, mangrove swamps and the Bangweulu swamps have less in common than marine and fresh water estuaries and must cause concern to the pedant. The term 'anadromous' was originally derived for fish which moved from the sea up fresh water rivers, normally to spawn. It is now widely used for lacustrine species which undergo an upstream spawning run and has long been used in this context.

The precedent, albeit inaccurate, has already been set for the use of the word 'estuary' in the freshwater context. H.B. Cott (1961) used it to describe an area below the Murchison Falls where he had a crocodile observation post. Harding (1964) used the word freely to describe the areas adjoining river mouths on Lake Kariba. Matthes (pers comm) has used it in parenthesis. McLachlan, in a doctoral thesis, used estuary to describe the area adjoining the Sinamwenda River on Lake Kariba and was not subjected to criticism by Dr J. Rzoska, a limnologist of international repute, although a co-examiner, Dr J. Green, objected 'mildly' (McLachlan, pers comm.) I have attempted to obtain information on the current overseas usage of the word and am still awaiting replies to a proportion of my queries. William A. Dill, Chief of the Inland Fisheries Branch of the Food and Agricultural Organisation of the United Nations, stated 'Although scientists find it very difficult to define terms I am quite sure that your use of the term 'estuary' for the ecotone of a fresh water river mouth entering a static body of fresh water is incorrect", and suggests using "river mouth". I find this term unsuitable as the concept to me of a river mouth is a very definite narrowly confined area where the river flows into a lake and does not satisfactorily reflect the gradual widespread transition of the physical, chemical and biological characteristics of the area which is reflected by the term 'estuary'.

It is necessary to acknowledge that the biological viewpoint is only one of several disciplines which are involved in this controversy, others being Geography, Geology and Hydrology. Professor G. Kay of the Department of Geography of the University College of Rhodesia, expressed the opinion that to try to define a word in general usage such as estuary is unrealistic and that the ambiguity of some descriptive terms is abrogated by the context in which they are used. Professor G. Bond of the Department of Geology expressed the same opinion and initially suggested possible usage of the term "Ria", defined by Holmes (1945) to occur where the trend of an orogenic belt is transverse to the coastline and where drowning gives an alternation of long promontories and estuaries (Rias). As the gentle structural grain at Kariba lies parallel to the coastline he felt that this term did not define the river mouth area as well as estuary did, particularly if estuary was initially defined in its fresh water context in any publication using it in this way. Mrs L.A. Lister, geomorphologist in the same Department, could find no objection to its usage in a fresh water context. W.A. Dill (pers. comm.) informs me however, that F.A.O. hydrologists generally agreed that "river mouth" would be more suitable in a fresh water context. My objection (mentioned above) to the use of the term is amplified on consideration of difficulties one would experience with this term when used as an adjective. Would it be possible to say or write "river-mouth-ine" conditions? I find this distasteful.

Use of the word estuary in a fresh water context has been described as "unfortunate" (J.R. Grindley, pers comm), and with this I can only agree. Unfortunate though it may be, however, there is no better descriptive term that I can find. This introduces the biological aspect of the problem. In the area in which I am presently working, namely the lower reaches of the *Sinamwenda* River, its "estuary" and outlying bay, there is a very definite gradation of physical and chemical characteristics. There are also two distinct invertebrate faunas in the bay and river, with a few ubiquitous species. There is also a gradation, which takes place over the distance of 1,000 to 1,500m, between these two faunas. Is this really, biologically speaking, different from the principles of distribution in a marine estuary? I submit that it is not.

Several alternatives are available for the decision of this congress. The first of these is that the use of the term 'estuary' in the *Kariba* context is self explanatory. No practicing scientist can but realise that usage is in the fresh water context. Secondly, the term may be defined during the introduction of a paper involving its usage. The third alternative is that "fresh-water" always precedes the word estuary(-ine). Fourthly, a new term such as "Limnestuary" be devised. I would suggest that the second alternative, involving definition, is the most suitable course to take.

I would like to close by stressing that this argument in semantics is most important. In most lakes the major source of nutrient arises from rivers feeding them and with the vast damming schemes at present underway and relatively recently completed, the tributary rivers are bound to play an important biological part, particularly if it is remembered that the largely riverine faunas which colonise these impoundments are sometimes dependent on the rivers at some stage in their life cycle. Fresh-water estuaries are therefore liable to be subjected to intensive research and the problem outlined in this paper is one which will inevitably occur with greater frequency in the future.

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APPENDIX 3.1

HYDROLOGICAL SAMPLING - JANUARY/FEBRUARY, 1967.

	STATION 1					STATION 2					STATION 3			STATION 4		STATION 5		LAKE Above Below Rapids Rapids	
Sample depth (m)	0	5	10	15	20	0	5	10	15	17.6*	0	5	9	0	5	0	2	0	0
Maximum depth at station (m)					[illegible]					17.6			9.6		5.0		[illegible]	-	-
Specific conductivity (umhos/cm)	80	[illegible]	82	80	81	[illegible]	[illegible]	80	83	[illegible]	81	70	67	77	[illegible]	65	78	63	63
Temperature °C	29.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.0	[illegible]	[illegible]	[illegible]
Turbidity (m)					3.0					3.0			8.0						
pH	7.9	7.9	7.9	7.8	7.8	7.5	7.5	7.5	7.0	6.9	7.5	6.9	6.9	8.0	7.5	6.7	6.9	7.0	7.0
[illegible] (mg/l)	7.86	[illegible]	[illegible]	[illegible]	1.65	[illegible]	6.19	6.85	[illegible]	0.10	6.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.70	[illegible]	[illegible]
Dissolved oxygen (corrected % sat.)	100.05	95.92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.30	[illegible]	[illegible]	[illegible]	70.40	11.46	[illegible]	[illegible]	[illegible]	[illegible]
Alkalinity, CaCO$_3$ (mg/l)	44.6	42.3	42.0	[illegible]	41.0	[illegible]	43.0	43.0	[illegible]	-	[illegible]	41.0	41.0	[illegible]	[illegible]	31.5	[illegible]	[illegible]	[illegible]
CO$_2$	1.5	1.5	1.5	5.0	5.0	3.0	3.0	5.0	6.0	-	3.0	9.0	9.5	[illegible]	[illegible]	[illegible]	[illegible]	3.0	3.0
Suspended solids (dried @ 100°C) (mg/l)	0.8	-	-	-	12	-	-	-	-	-	[illegible]	[illegible]	[illegible]	85	[illegible]	-	-	[illegible]	-
Total solid contents (dried @ 100°C) (mg/l)	67	-	-	-	66	-	-	-	-	-	85	[illegible]	81	90	[illegible]	-	-	[illegible]	-
Total solids (mg/l)	67.0	-	-	-	77	-	-	-	-	-	[illegible]	[illegible]	115	115	[illegible]	-	-	[illegible]	-
Loss on ignition (mg/l)	16	-	-	-	11	-	-	-	-	-	15	15	[illegible]	[illegible]	[illegible]	-	-	[illegible]	-
Total hardness (as CaCO$_3$) (mg/l)	60	-	[illegible]	-	[illegible]	57	-	57	57	-	57	[illegible]	57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Nitrate nitrogen (mg/l)	0.08	-	0.08	-	0.15	[illegible]	-	0.05	-	[illegible]	[illegible]	0.05	0.20	[illegible]	0.15	[illegible]	[illegible]	[illegible]	-
Nitrite nitrogen (mg/l)	[illegible]	-	[illegible]	-	[illegible]	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.15	[illegible]	[illegible]	[illegible]	-
Ammoniacal nitrogen (mg/l)	0.08	-	0.07	-	0.05	0.08	-	0.02	-	[illegible]	[illegible]	0.11	0.14	0.05	0.17	[illegible]	0.07	0.07	-
Albuminoid nitrogen (mg/l)	0.13	-	0.10	-	0.17	0.11	-	0.14	-	[illegible]	[illegible]	0.10	0.14	0.23	[illegible]	[illegible]	[illegible]	[illegible]	-
Calcium (as CaCO$_3$) (mg/l)	35	-	35	-	[illegible]	[illegible]	-	[illegible]	-	35	[illegible]	[illegible]	[illegible]	33	[illegible]	[illegible]	[illegible]	17	-
Calcium (as Ca^{++}) (mg/l)	13	-	10	-	10	10	-	10	-	9	13	12	[illegible]	13	10	[illegible]	12	7	-
Magnesium (as MgCO$_3$) (mg/l)	4	-	17	-	12	[illegible]	-	9	-	17	4	4		3	5	3	7	3	-
Magnesium (as Mg^{++}) (mg/l)	1	-	3	-	3	3	-	3	-	3	1	1	1	-	1	1	[illegible]	1	-
Potassium (K$^+$) (mg/l)	1.5	-	2.4	-	1.7	1.5	-	1.6	-	1.8	1.8	2.3	[illegible]	[illegible]	4.4	4.1	[illegible]	[illegible]	-
Sodium (as Na$^+$) (mg/l)	3.0	-	3.7	-	3.7	3.0	-	3.0	-	3.0	3.0	3.4	3.7	3.4	[illegible]	[illegible]	[illegible]	1.7	-
Phosphate (PO$_4$) (mg/l)	0.074	-	0.136	-	[illegible]	0.136	-	0.150	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
DATE			21.1.67					25.1.67				19.1.67			18.1.67		30.1.67		3.2.67
TIME			10.30					10.30				15.30			11.10		10.30		11.00

*Mud in sample

APPENDIX [illegible]

[illegible] SAMPLING : APRIL, 1957. ([illegible]). [illegible]

	STATION 1					STATION 2				STATION 3			STATION 4		STATION 5		[illegible]
Sampling depth (m)	0	5	10	15	20	0	5	10	15	0	5	10	0	5	0	5	-
Secchi disc depth (m)					[illegible]				17.[illegible]			[illegible]		[illegible]		[illegible]	-
Specific conductivity (μmhos)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Temperature °F	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Turbidity (%)					[illegible]				[illegible]			[illegible]		[illegible]		[illegible]	-
pH	[illegible]	[illegible]	7.5	[illegible]	[illegible]	[illegible]	-	7.5	7.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Dissolved oxygen (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Dissolved oxygen ([illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Alkalinity $CaCO_3$ (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
CO_2 (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Suspended solids ([illegible]) (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]		[illegible]	[illegible]	[illegible]	-	-	-
Total solid content ([illegible]) (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]		[illegible]	[illegible]	[illegible]	-	-	-
Total [illegible] (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]		[illegible]	[illegible]	[illegible]	-	-	-
Loss on ignition (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]		[illegible]	[illegible]	[illegible]	-	-	-
Total hardness (as $CaCO_3$) (mg/l)	[illegible]		-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
[illegible] nitrogen (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Nitrite nitrogen (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Ammoniacal nitrogen (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Albuminoid nitrogen (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Calcium (as $CaCO_3$) (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Calcium (as Ca^{++}) (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Magnesium (as $MgCO_3$) (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Magnesium (as Mg^{++}) (mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Potassium (as K^{+}) (mg/l)	[illegible]				[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Sodium (as Na^{+}) (mg/l)	[illegible]				[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
Phosphate (as PO_4) (mg/l)	[illegible]				[illegible]	-	-	-	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-

[illegible] 5.1

[illegible] 1967. ([illegible]) [illegible]

		STATION 1					STATION 2				STATION 3			STATION 4		STATION 5		[illegible]
Sample depth	(m)	0	5	10	15	20	0	5	10	15	0	5	10	0	5	0	3	
Maximum depth of station	(m)			[illegible]					[illegible]			[illegible]		[illegible]		[illegible]		[illegible]
Specific conductivity	([illegible])	56	-	-	-	44	-	-	-	-	75	-	[illegible]	-	-	-	-	68
Temperature °C																		
Turbidity	(m)					4.0				3.5			7.0	0.3 [illegible]	very dirty [illegible]	0.3 [illegible]	very dirty [illegible]	
pH		7.5	-	-		6.4	-	-	-	-	7.0	-	6.6	-	-	-	-	[illegible]
Dissolved oxygen	(mg/l)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible]
Dissolved oxygen (percentage of sat.)																		[illegible]
Alkalinity $CaCO_3$	(mg/l)	44.0	-	-	-	[illegible]	-	-	-	-	[illegible]	-	11.0	-	-	-	-	[illegible]
CO_2	(mg/l)	[illegible]	-	-	-	16.4	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	
Suspended solids (dried @ 105°C)	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]
Total solid residue (dried @ 105°C)	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]
Total solids		[illegible]	-	-	-	[illegible]	-	-	-	-	-	-	-	[illegible]	[illegible]	-	-	[illegible]
Loss on ignition	(mg/l)	17	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-	-	-	[illegible]
Total hardness (as $CaCO_3$)	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
[illegible] nitrogen	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
[illegible] nitrogen	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Ammoniacal nitrogen	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Albuminoid nitrogen	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Calcium (as $CaCO_3$)	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Calcium (as Ca^{++})	(mg/l)	10	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Magnesium (as $MgCO_3$)	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Magnesium (as Mg^{++})	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	1	-	[illegible]	-	-	-	-	[illegible]
Potassium (as K^{+})	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Sodium (as Na^{+})	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]
Phosphate (as PO_4)	(mg/l)	[illegible]	-	-	-	[illegible]	-	-	-	-	[illegible]	-	[illegible]	-	-	-	-	[illegible]

[illegible]

APPENDIX 3.4

LIMNOLOGICAL ANALYSES: JULY/AUGUST, 1967

	STATION 1	STATION 3		STATION 4 [illegible]		[illegible]	[illegible]	[illegible]	[illegible]
Sample depth (m)	[illegible]	1	10	1	6	1	[illegible]	[illegible]	[illegible]
Maximum depth at station (m)	19.5	11.6		7.3		1.0	-	-	-
Specific conductivity (µmhos/cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature (°C)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Turbidity (%)	4.0	3.5		-		-	-	-	-
pH	7.4	7.5	[illegible]	[illegible]	[illegible]	[illegible]	7.5	[illegible]	[illegible]
Dissolved oxygen (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dissolved oxygen (corrected % saturation)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Alkalinity as $CaCO_3$ (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Carbon dioxide (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Suspended solids dried at 105°C (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total solid residue dried at 180°C (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total solids (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Loss on ignition (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total hardness as $CaCO_3$ (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrate nitrogen (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nitrite nitrogen (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ammoniacal nitrogen (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Albuminoid nitrogen (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calcium as $CaCO_3$ (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calcium as Ca^{++} (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Magnesium as $MgCO_3$ (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Magnesium as Mg^{++} (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Potassium as K^{+} (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sodium as Na^{+} (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phosphate as PO_4^{---} (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DATE	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
TIME	1615	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX 5.6

HYDROLOGICAL SAMPLING: JANUARY/FEBRUARY, 1968

	STATION 1		STATION 3		STATION 4A		STATION 5		[illegible] Static	[illegible] Flowing
Sample depth (m)	2	21	0.2	8	0.2	4.5	1	3.5	0	0
Maximum depth at station (m)	[illegible]		11		6		4		-	
Specific conductivity (umhos/cm)	69	82	69	60	91	70	83	79	57	67
Temperature (°C)	30.8	27.2	31.0	29.5	31.2	29.0	30.5	29.9	35.5	27.0
Turbidity (m)	3.6		0.81		0.32		-		-	
pH	7.6	7.5	7.3	6.9	7.1	7.3	8.0	6.8	6.5	7.3
Dissolved oxygen (mg/l)	8.30	2.90	7.15	2.80	4.35	2.30	4.40	2.40	6.4	7.7
Dissolved oxygen (corrected % sat.)	114.0	36.0	110.0	35.4	55.0	30.6	77.1	30.8	90.0	[illegible]
Alkalinity (as $CaCO_3$) (mg/l)										
Carbon dioxide (mg/l)										
Suspended solids dried @ 100°C (mg/l)	1.6	2.0	0.8	19	25	74	16	79	159	363
Total solid residue dried @ 180°C (mg/l)	60	62	60	62	55	98	74	84	175	21[illegible]
Total solid (mg/l)	61.6	64.2	60.8	81	80	172	90	162	334	579
Loss on ignition (mg/l)	10	11	10	1[illegible]	14	19	17	18	27	31
Total hardness (as $CaCO_3$) (mg/l)	39	37	40	39	37	34	38	38	30	30
Nitrate nitrogen (mg/l)	0.29	0.30	0.14	0.30	0.19	0.40	0.18	0.95	0.58	0.60
Ammoniacal nitrogen (mg/l)	0.08	0.09	0.07	0.05	0.04	0.06	0.04	0.09	0.06	0.13
Albuminoid nitrogen (mg/l)	0.20	0.17	0.19	0.17	0.15	0.22	0.13	0.24	0.27	0.37
Calcium (as $CaCO_3$) (mg/l)	26	26	27	24	24	21	27	20	16	14
Calcium (as Ca^{++}) (mg/l)	10	10	11	10	10	8	11	8	6	6
Magnesium (as $MgCO_3$) (mg/l)	11	9	11	15	11	11	9	11	13	12
Magnesium (as Mg^{++}) (mg/l)	3	3	3	4	3	3	3	3	3	3
Potassium (as K^+) (mg/l)	1.5	1.5	1.7	2.2	2.4	4.5	2.3	4.2	6.4	6.0
Sodium (Na^+) (mg/l)	4.1	4.1	4.0	5.8	5.9	2.7	5.9	8.0	1.6	2.4
Phosphate (PO_4^{---}) (mg/l)	0.045	0.062	0.053	0.048	0.067	0.298	0.163	0.188	0.377	0.457
DATE	20/1/68		19/1/68		18/1/68		18/1/68		19/1/68	8/2/68
TIME	1500		1640		0925		1050		1230	1600

APPENDIX [illegible]

SPECIES DENSITY OF PLANKTON IN mg/m³ DRY WEIGHT ON DIFFERENT SAMPLING DATES

Contd.

	STATION I														
	0m					9m					20m				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
COPEPODA															
Diaptomid I	0.2	4.0	38.1	9.8	9.9	0.4	44.8	96.6	6.6	16.7	0.4	55.2	31.0	4.0	7.7
Diaptomid II	-	1.7	12.7	4.4	1.5	0.1	11.4	7.1	7.4	4.4	-	4.4	2.9	0.3	0.5
Cyclopoida	1.5	4.4	8.2	27.8	4.4	2.1	5.3	53.8	29.9	16.3	3.3	12.5	21.6	35.8	56.7
Copepod Nauplii	1.7	1.1	5.5	17.5	6.5	1.2	2.3	5.8	13.0	28.9	0.6	0.1	6.1	4.3	18.8
CLADOCERA															
[illegible]	3.4	2.0	8.9	7.0	2.9	0.5	3.4	1.7	8.4	5.7	1.9	5.3	4.9	4.0	7.7
[illegible] II	-	-	0.1	-	4.3	0.1	-	-	-	-	0.3	-	-	12.8	0.5
[illegible]	-	2.2	147.9	45.7	7.2	0.5	5.7	195.7	16.5	6.0	0.4	3.0	138.9	9.6	8.6
[illegible]	2.6	3.7	4.1	-	-	0.4	28.5	51.5	6.3	25.0	0.9	14.1	2.9	6.5	43.9
[illegible] I	-	-	1.4	-	-	0.2	-	2.8	0.2	-	-			2.8	P
[illegible] II	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-
[illegible] I	-	-	-	-	-	-	-	-	0.8	-	-	-	-	1.6	-
[illegible] I	-	-	2.3	1.0	-	-	-	2.7	-	-	-	-	7.1	-	-
[illegible] II	-	-	-	0.6	-	-	-	-	-	-	-	-	-	0.7	-
[illegible] III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] I	-	-	1.1	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROTIFERA															
Rotifer I	0.2	-	-	-	-	0.2	0.1	-	-	-	P	0.1	-	2.5	-
Rotifer II	0.5	-	1.1	0.6	3.9	1.0	0.5	-	7.3	11.9	0.5	0.5	0.1	6.3	7.6
Rotifer III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifer IV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifer V	-	-	0.1	-	-	-	-	0.1	1.4	-	-	-	-	-	-
Rotifer VI	-	-	-	1.9	-	-	-	-	-	2.6	-	-	-	-	-
Rotifer VII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifer VIII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	1.2	0.1	0.2	2.3	1.0	0.6	1.2	0.8	2.8	4.4	0.5	0.3	0.7	0.3	5.2
[illegible]	0.3	-	-	-	-	-	0.1		1.5	1.3	-	-	1.0	0.6	4.1
[illegible]															
[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ALGAE															
[illegible]	9.2	0.9	63.5	4.0	1.7	0.3	5.8	37.7	3.4	9.0	0.8	2.1	35.7	30.7	4.2
[illegible]	0.9	0.4	1.7	9.9	2.4	1.6	4.2	11.6	2.8	9.9	2.0	0.1	3.4	2.8	5.4

	STATION II														
	0m					5m					15-18m				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
COPEPODA															
Diaptomid I	x	2.3	64.0	39.5	10.8	x	3.9	137.2	18.6	1.2	x	4.7	13.7	18.8	5.3
Diaptomid II	x	0.2	10.3	14.0	1.0	x	0.6	24.5	5.8	-	x	-	4.4	19.3	1.0
Cyclopoida	x	2.2	24.8	64.7	75.4	x	8.5	61.5	89.2	9.5	x	3.3	42.8	121.3	77.5
Copepod Nauplii	x	2.5	10.9	99.7	1.1	x	9.2	16.6	20.5	17.7	x	14.6	19.1	14.2	19.8
CLADOCERA															
[illegible]	x	P	5.8	5.4	1.6	x	0.7	10.2	0.9	0.7	x	0.7	30.7	6.7	16.4
[illegible] II	x	0.2	0.4	9.4	-	x	-	21.4	5.6	-	x	-	-	2.4	-
[illegible]	x	P	119.3	76.2	3.8	x	1.6	190.9	23.8	2.3	x	9.3	14.3	7.5	30.4
[illegible]	x	0.2	7.2	18.7	12.9	x	1.4	24.3	11.4	1.3	x	0.3	18.6	5.3	72.5
[illegible] I	x	-	2.8	1.6	-	x	-	4.9	1.3	-	x	0.1	-	0.5	-
[illegible] II	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
[illegible] I	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
[illegible] I	x	-	-	-	-	x	-	2.3	-	-	x	-	-	-	-
[illegible] II	x	-	-	-	-	x		-	-	-	x	-	-	-	-
[illegible] III	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
[illegible] I	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
[illegible]	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
ROTIFERA															
Rotifer I	x	0.3	0.1	0.4	-	x	0.5	-	0.5	-	x	0.1	-	-	-
Rotifer II	x	0.3	-	3.0	3.8	x	0.3	0.2	3.1	4.0	x	0.8	0.4	3.3	16.4
Rotifer III	x	-	-	0.4	0.4	x	-	-	0.5	-	x	-	-	1.1	-
Rotifer IV	x	-	-	3.8	-	x	-	-	-	-	x	-	-	-	-
Rotifer V	x	-	-	-	-	x	-	-	2.0	-	x	0.1	-	-	-
Rotifer VI	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
Rotifer VII	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
Rotifer VIII	x	-	-	-	-	x	-	-	-	-	x	-	-	-	-
[illegible]	x	P	0.2	0.8	0.8	x	0.3	-	0.8	-	x	0.5	-	-	1.0
[illegible]	x	0.2	-	-	1.6	x	-	0.4	0.3	-	x	0.2	-	2.2	3.0
[illegible]															
[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ALGAE															
[illegible]	x	5.8	64.9	4.1	1.9	x	7.7	30.7	1.3	2.2	x	5.2	22.4	3.3	43.7
[illegible]	x	0.1	46.0	14.7	3.1	x	1.3	12.7	2.5	1.0	x	0.3	4.8	5.8	2.0

A : 5.2.67
B : 5.5.67
C : 31.7.67
D : 10.11.67
E : 5.2.68

X : no sample taken.
P : Present at less than 0.1 mg/m³
- : not present.

[illegible] 9.1 [illegible]

	STATION III														
	1 m					[illegible]					[illegible]				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
COPEPODA															
Copepodid I	0.6	113.5	6.2	45.0	4.4	0.4	142.5	72.0	51.4	25.5	6.7	36.0	118.7	35.4	7.1
Copepodid II	-	15.0	0.5	7.4	14.2	-	20.1	15.0	13.3	4.5	0.7	4.5	96.0	25.3	4.0
Cyclopoids	5.0	20.4	1.0	11.7	70.9	13.6	32.7	14.7	136.6	96.7	12.4	36.3	70.3	28.5	16.8
Copepod nauplii	0.8	31.6	7.6	27.3	19.3	2.7	46.5	24.1	27.1	1.6	11.0	42.8	12.1	3.2	36.2
CLADOCERA															
Daphnia															
[illegible]	0.2	0.3	-	1.7	1.2	0.2	4.7	5.9	4.6	4.0	-	7.7	3.0	3.2	1.6
[illegible] II	0.3	-	-	-	-	-	-	-	0.4	-	0.1	-	-	1.0	-
[illegible]	1.2	5.3	3.4	[illegible]	28.4	11.9	73.0	49.6	[illegible]	14.8	21.3	17.5	151.4	20.1	24.4
[illegible]	-	17.0	0.6	14.5	15.6	4.2	90.7	7.2	25.6	31.9	[illegible]	45.1	35.0	4.8	[illegible]
[illegible] I	-	0.3	2.3	P	-	-	-	10.3	1.6	-	-	-	7.9	0.6	-
[illegible] II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] I	-	-	-	P	-	-	-	-	-	-	-	-	-	-	[illegible]
[illegible] II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROTIFERA															
Rotifer I	-	-	P	-	-	-	-	-	-	0.1	-	-	-	-	-
Rotifer II	1.1	1.0	0.3	1.3	14.6	0.2	6.7	0.5	3.5	1.3	2.7	3.5	-	3.9	7.1
Rotifer III	-	-	-	1.3	-	-	-	-	4.1	-	0.3	-	-	1.5	-
Rotifer IV	-	-	[illegible]	0.7	-	-	-	-	2.0	-	0.3	-	-	1.1	-
Rotifer V	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	
Rotifer VI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotifer VII	0.1	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-
Rotifer VIII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	P	3.0	-	1.9	-	-	2.5	-	1.0	-	-	-	-	0.7	-
[illegible]	-	0.3	P	0.2	0.4	-	[illegible]	0.4	2.4	-	0.3	-	0.1	0.4	0.7
INSECTA															
Chaoborus	-	-	-	-	1.6	-	-	-	-	0.7	1.2	-	-	-	-
ALGAE															
[illegible]	0.5	12.1	34.6	P	4.1	1.1	13.0	30.6	0.6	0.4	1.0	3.3	4.3	0.4	1.9
[illegible]	0.1	6.1	31.3	3.1	0.7	-	3.3	38.7	1.2	P	0.2	10.6	20.0	0.4	P

	STATION IV										STATION V									
	1 m					[illegible]					1m					5m				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
COPEPODA																				
Copepodid I	0.7	28.1	211.2	21.4	83.9	2.7	73.7	86.4	109.5	2.1	x	79.4	198.3	18.3	0.8	x	x	36.7	33.5	6.0
Copepodid II	2.3	4.5	37.8	[illegible]	0.5	-	6.3	22.3	12.5	1.1	x	60.4	35.4	3.3	0.3	x	x	17.6	4.6	1.7
Cyclopoids	5.9	5.7	11.1	59.4	14.5	23.7	9.4	29.0	65.2	13.4	x	79.4	66.0	56.3	16.2	x	x	26.5	161.3	26.7
Copepod nauplii	2.3	13.7	5.0	44.8	4.4	9.4	52.6	4.3	31.3	5.3	x	76.4	21.9	73.5	15.4	x	x	16.3	233.5	41.0
CLADOCERA																				
Daphnia																				
[illegible]	0.8	0.9	1.4	3.9	-	1.0	3.2	25.0	65.7	0.1	x	27.8	12.0	15.9	0.7	x	x	51.4	90.3	1.4
[illegible] II	-	-	-	2.5	-	0.8	-	-	0.2	-	P	-	0.2	-	-	x	x	-	1.4	-
[illegible]	6.7	2.2	72.9	3.8	10.5	4.3	4.9	336.4	124.3	8.9	x	11.3	193.2	20.3	12.9	x	x	173.4	197.9	38.1
[illegible]	17.3	2.4	4.2	0.5	22.8	78.3	15.0	11.4	367.3	8.9	x	123.3	0.5	12.4	9.3	x	x	6.1	91.4	47.4
[illegible] I	-	0.5	3.2	-	-	-	2.0	2.7	-	-	x	1.4	6.7	-	0.2	x	x	1.3	-	4.0
[illegible] II	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	-
[illegible] I	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	-
[illegible] I	1.9	0.1	-	1.1	P	0.5	-	0.4	0.2	-	x	-	1.2	1.2	0.2	x	x	0.6	2.1	-
[illegible] II	[illegible]	-	-	-	-	7.8	-	-	-	-	x	-	0.7	0.3	-	x	x	0.6	-	-
[illegible] III	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	-
[illegible]	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	-
[illegible]	0.9	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	-
ROTIFERA																				
Rotifer I	-	0.1	-	0.2	-	-	-	0.2	1.0	-	x	-	0.3	0.3	0.1	[illegible]	x	-	0.9	-
Rotifer II	0.7	1.8	0.2	0.3	3.1	-	7.5	-	0.9	[illegible]	x	0.6	1.1	1.0	3.0	x	x	-	4.4	39.2
Rotifer III	-	0.1	-	1.1	-	-	-	-	-	-	x	0.4	-	1.1	-	x	x	-	4.3	-
Rotifer IV	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	-
Rotifer V		0.5	-	-	-	0.8	-	-	-	-	x	-	-	-	-	x	x	-	0.3	-
Rotifer VI	-	-	-	-	-	0.1	-	-	-	-	x	-	0.1	-	0.4	x	x	-	0.9	0.1
Rotifer VII	-	-	-	-	-	-	-	-	-	-	x					x	x			
Rotifer VIII	2.8	-	-	-	-	0.7	-	-	1.0	0.7	x	-	0.7	1.1	3.7	x	x	0.4	9.3	-
[illegible]	0.5	0.7	-	-	-	0.1	3.0	0.6	0.5	-	P	13.6	0.1	0.6	[illegible]	x	x	-	1.3	-
[illegible]	-	-	-	0.2	0.1	P	-	-	-	0.1	x	-	-	0.1	-	x	x	-	-	3.4
INSECTA																				
Chaoborus	0.3	-	-	-	-	0.8	-	-	-	0.2	x	0.3	0.2	-	0.5	x	x	-	-	0.3
ALGAE																				
[illegible]	0.5	3.2	267.8	4.0	20.2	-	-	46.8	-	-	x	-	20.5	-	-	x	x	9.8	-	-
[illegible]	-	-	26.7	-	-	-	-	23.6	-	-	x	-	3.9	-	-	x	x	-	-	-

APPENDIX 7.1

A LIST OF INVERTEBRATE SPECIES COLLECTED

"Species" were allocated code numbers on the basis of their sequence of appearance and in the list retain these codes. Species are listed, within families, in code order. Where a single species has been found to have been allocated two codes, the second number is included in the duplicate column. Groups were named by the following authorities to whom I am extremely grateful, after separation into tentative "species".

Coelenterata	-
Rotatoria	-
Oligochaeta	W. van Hoven
Hirudinea	-
Crustacea	J. Green
Hydracarina	C.A. Jansen van Rensburg
Odonata nymphs	-
Odonata imagines	B.I. Balinsky
Hemiptera	R.A. Poisson and F. de Sallier Dupin
Lepidoptera	-
Ephemeroptera nymphs	-
Trichoptera	K.M.F. Scott
Hydrophilidae	J. Balfour-Brown
Gyrinidae	J. Balfour-Brown
Haliplidae	J. Balfour-Brown
Dytiscidae	J. Omer-Cooper
Chironomidae (larvae)	A.J. McLachlan
Other dipteran larvae	B.R. Stuckenberg
Culicinae	B.M. McIntosh
Chaoborinae (larvae)	-
Mollusca	J.A. van Eeden

Odonata were collected as adults and are not allocated numbers unless nymphs of the species were also collected.

Species within the reference collection but without names are included for future classification.

Returns for Crustacea and Trichoptera have not yet been received. All species are kept in a reference collection which will be used for the compilation of a student field guide to the aquatic fauna of the area.

CODE	DUPLICATE	SPECIES
Phylum:	COELENTERATA	
Class:	HYDROZOA	
-		Hydra sp.
Class:	SCYPHOZOA	
-		Limnocnida sp.
Phylum:	ROTATORIA	
522		-
523		-
524		Brachionus falcatus ?
525		-
526		-
527		Trichocerca sp. ?
528		-
529		-
530		-
531		Trichocerca sp. ?
532		-
533		Colurella sp. ?
534		-
535		-
536		Trichocerca sp. ?
537		Trichocerca sp. ?
538		-
539		Filinia sp. ?
540		-
Phylum:	ANNELIDA	
Order:	OLIGOCHAETA	
Family:	NAIDIDAE	
8		Branchiodrilus hortensis (Stephenson)
29		Dero sp.
31		Pristina sp.
36		Dero dorsalis (Ferroniere)
38a		Aulophorus furcatus (Müller)
38b	29	
52	8	
71	8	
75		Pristina synclites Stephenson
100	75	
127		Allonais sp. nov.
143	127	
273	127	
Family:	TUBIFICIDAE	
37		Aulodrilus pigueti Kowalewski
192		Branchiura (?) sp.
126	37	
225		Branchiura sowerbyi (Beddard)
Family:	EUDRILIDAE	
29		Nemertodrilus sp.
Family:	LUMBRICULIDAE	
60		Lamprodilus sp. A (Hrabe)
144		Stylodrilus lemani (Grube)
Family:	GLOSSOSCOLECIDAE	
170		?
Order:	HIRUDINEA	
45		?
65		?
86		?
131		(Found on Laccotrephes fabricii exclusively)?
165		?
220		?
279		?

CODE	DUPLICATE	SPECIES
Phylum:	ARTHROPODA	
Class:	CRUSTACEA	
Order:	CONCHOSTRACA	
209		*Cyclestheria hislopi*
215	209	-
Subclass:	CLADOCERA	
235		
506		*Bosmina longirostris*
507		*Bosmina* sp.
508		*Ceriodaphnia* sp.
509		*Diaphanosoma* sp.
510		*Daphnia* sp.
511		*Daphnia* sp.
512		-
513		*Chydoris* sp. ?
514		*Chydoris* sp. ?
515		*Chydoris* sp. ?
516		*Chydoris* sp. ?
517		*Chydoris* sp. ?
518		*Chydoris* sp. ?
519		Macrothricidae
520		Macrothricidae
Subclass:	OSTRACODA	
58		*Isocypris* sp. ?
181		*Eucypris* cf *corpulenta* ?
187		*Stenocypris* sp. ?
188		*Cypris* sp. ?
202		*Homocypris* sp. ?
203		Cypridae
204		Cypridae
212		*Stenocypris* sp. ?
250		Cypridae
277		Cypridae
304		*Pseudocypris* sp. ?
546		Cypridae
547		Cypridae
551		*Isocypris* sp. ?
Subclass:	COPEPODA	
215		diaptomid
216		diaptomid
501		cyclopoid
502		Harpacticoida
503		diaptomid
504		diaptomid
505		copepod nauplius
Order:	DECAPODA	
172		*Caridina nilotica*
280	172	
Class:	ARACHNIDA	
Class:	ACARINA	
Order:	HYDRACARINA	
Family:	HYGROBATIDAE	
295		*Hygrobates* sp. nov. ?
298		*Hygrobates* sp. nov. ?
332		*Hygrobates* sp. nov. ?
333		*Hygrobates* sp. nov. ?

CODE	DUPLICATE	SPECIES
Family: ARRENURIDAE		
178		Rhinophoracarus sp. nov.
268		Arrenurus sp. nov. ?
Phylum: ARTHROPODA		
Class: INSECTA		
Order: ODONATA		
Suborder: ZYGOPTERA		
Family: COENAGRIIDAE		
		Pseudagrion massaicum Sjöst
		Pseudagrion nigerrimum Pinhey
		Pseudagrion nubicum Selys
		Ischnura senegalensis Ramb.
		Ceriagrion glabrum Burm.
Suborder: ANISOPTERA		
Family: GOMPHIDAE		
Nymphs		
		Ictinogomphus ferox Ramb.
61		Lestinogomphus africanus Fraser
93		Paragomphus hageni (Selys)
Family: AESHNIDAE		
		Anax imperator var mauricianus Ramb.
Family: CORDULIIDAE		
226		Macromia reginae Le Roi
396		Macromia picta (?) Hagen
Family: LIBELLULIDAE		
		Orthetrum chrysostigma Burm.
		Orthetrum capense falsum Longf.
		Orthetrum stemmale kalai Longf.
		Orthetrum trinacria Selys
		Palpopleura lucia Drury
		Acisoma panorpoides ascalaphoides Ramb.
		Crocothemis erythraea Brulle
		Brachythemis lacustris Kirby
		Brachythemis leucostricta Burm.
		Trithemis annulata Beauv.
		Trithemis arteriosa Burm.
		Trithemis hecate Ris.
		Zygonyx torrida Kirby
		Pantala flavescens Fraser
		Urothemis assignata Selys
		Urothemis edwardsi Selys
		Aethriamanta rezia Kirby
Order: PLECOPTERA		
322		?
Order: HEMIPTERA		
Suborder: HETEROPTERA TERRESTRIAL		
331		?
357		?
Family: MESOVELIIDAE		
21		Mesovelia vittigera Horv.
56		Mesoveliid (larva)
Family: GERRIDAE		
194		Limnogonus (limnogonoides) hypoleurus (Gerst.)
345		Limnogonus sp. (eggs and larvae)
374		Limnogonus sp. (larvae)

CODE	DUPLICATE	SPECIES
Family:	NOTONECTIDAE	
69		*Anisops mailensis* Brooks
105		*Enithares* sp. (larvae)
124		*Anisops* sp. (larvae)
125		*Nychia marshalli* (Scott)
165	125	
372a	69	
372b		*Anisops debilis* Gerst.
372c		*Anisops* sp. (♀)
372d		*Anisops* sp. (larvae)
387a		*Anisops* sp. (♀)
387b		*Anisops hancocki* Hutch.
386		*Anisops sardea* H.S.
Family:	PLEIDAE	
254		*Plea pullula* Stal
Family:	NAUCORIDAE	
147a		*Diplonychus grassii grassii* Poiss.
147b		*Laccocoris limigenus limigenus* Stal.
195		*Naucoris*... *Nerthra* sp. (♀)
244		*Laccocoris* sp. (larvae)
315		*Diplonychus* cf *grassii* Poiss.
Family:	CORIXIDAE	
109		*Micronecta scutellaris* Stal.
Family:	NEPIDAE	
196		*Laccotrephes fabricii fabricii* Stal
Order:	EPHEMEROPTERA	
53		*Euthraulus* sp.
62a)		*Cloeon* sp. (?)
62b)?		*Cloeon* sp. (?)
85		*Caenis* sp. (?)
90		*Caenis* sp. (?)
98		*Caenis* sp. (?)
102		*Caenis* sp. (?)
133		*Povilla adusta* Navas.
311		*Caenis* sp. (?)
Order:	TRICHOPTERA	
11		*Dipseudopsis capensis* (pupae)
14		*Dipseudopsis capensis* (larvae)
91		*Ecnomus thomasetti*
164		*Ecnomus* sp.
200		*Petrotlax* sp.
323		?
330		?
336		?
347		?
348		?
352		?
379		?
395		?
Order:	LEPIDOPTERA	
Family:	PYRALIDAE	
319		*Parapoynx* sp. (larvae)
320		*Parapoynx* sp. (pupae)
339		*Parapoynx* sp. (larvae)
340		Parapoynx sp. (pupae)

CODE	DUPLICATE	SPECIES
Order:	**COLEOPTERA**	
Family:	TENEBRIONIDAE	
		?
Family:	HYDROPHILIDAE	
96		Agrophydrus sp. nov.
110		Berosus corrugatus Regimbart
137		Paracymus chalceus Reg.
173		Limnebius (Bilimneus) sp. nov.
174		Laccobius revelierei Perris
190		Berosus (Enoplurus) furcatus Boheman
192		Sternolophus (Neosternolophus) angolensis Erichson
207	110	
21	110	
245	174	
248		Helochares (Hydrobaticus) indenrensus B-B.
249		Helochares (S.str.) pallens (Macleay)
255		?
260		Coelostoma phalacroides rubrocinctum Reg.
263		Regimbartia nilotica (Sharp)
264		Helochares (S.str.) dilutus (Erichson)
269	248	
290a		Enochrus (Lumetus) sp. nov.
290b		Enochrus (Methydrus) hesperidium (Sharp)
365	264	
368	96	
369		Berosus vitticollis (Boheman)
375		Hydrochus perforatus Reg.
378		Allocotocerus subaenius (Reg)
Family:	HALIPLIDAE	
240		Haliplus exsocratus Guignot
Family:	CARABIDAE	
373		?
392		?
Family:	GYRINIDAE	
380		Dineutus aereus (Klug)
383		neutus subspinosus (Klug)
384		lonogyrus caffer (Aube)
Family:	DYTISCIDAE	
95		Peschetius carinipennis Reg.
103		Yola natalensis Reg.
104		Hyphydrus impressus (Klug)
111		Yola bahaulti Pesch.
113		Clypeodytes evanescens Boh.
114		Clypeodytes meridionalis (?) Reg.
175		Uvarus peringueyi (Reg.)
193		Cybister africanus Cast.
197		Yola dohrni Shp.
198		Yola elegantula Boh.
199		Yola tuberculata
201		Hydaticus bivittatus Aube
205a		Laccophilus continentalis Gschw.
205b		Laccophilus simplicistriatus Gschw.
205c		Laccophilus pallescens Reg.
205d		Laccophilus adspersus Boh.
206		Canthydrus quadrivittatus Reg.

CODE	DUPLICATE	SPECIES
233		Yola marshalli O-C.
245a		Hydrovatus consimilis O-C.
245b		Hydrovatus continentalis Guign.
258		Bidessus toumodiensis (?)
276a		Hydrocanthus (sternocanthus) ferruginicollis Reg.
276b		Hydrocanthus wittei Gschw.
278		Guignotus transvalis
286		Uvarus vitticollis Boh.
287		Bidessus sharpi (?) Reg.
292		Clypeodytes bedeli (?) Reg.
317		Laccophilus lasticulus Reg.
365a		Guignotus zanzibarensis Reg.
365b		Guignotus transversalis Reg.
366	103	
367	104	
382		Laccophilus pellucidus Shp.
385		Clypeodytes coarticollis Reg.
389		Laccophilus vermiculosus Gerst.
390a		Rhantaticus congestus Klug
390b		Hydaticus servillianus Aube
Order: DIPTERA		
Family: TABANIDAE		
84		?
Family: DOLICHOPODIDAE		
267		?
285		?
Family: EMPIPIDAE		
146		?
Family: TIPULIDAE		
108		Limoniini ?
217		Eriopterini
229		Conosia irrorata (?) Wiedemann
230	229	
231		Gonomyia sp.
391	108	
Family: STRATIOMYIIDAE		
296		?
303		?
315		?
Order: DIPTERA		
Family: CULICIDAE		
Subfamily: CULICINAE		
135		Aëdeomyia africana Neveu-Lemaire
136		Ficalbia splendens Theob.
171		Culex cf univittatus
179		Aëdeomyia sp.
223	135	
225		Anopheles rufipes (?) (Gough)
261	136	
254		Aëdeomyia sp. (?)
335	226	
Subfamily: CHAOBORINAE		
1		Chaoborus spp. (larvae)
39		Chaoborus spp. (pupae)

Family: CHIRONOMIDAE
Subfamily: TANYPODINAE

LARVAL CODE	PUPAL CODE	LARVAL DUPLICATE	SPECIES
13			Procladius of brevipetiolatus Goetg.
25			Pentaneura sp.
33			Clinotanypus maculatus Freeman
156		33	
23	285		Clinotanypus claripennis Kieffer
130		33	
50	272		Pentaneura of (Ablabesmyia) sp.
68	294 ?	23	Pentaneura (Ablabesmyia) nilotica Kieffer
299	282 ?		Pentaneura sp.
	291		Pentaneura sp.

Subfamily: ORTHOCLADIINAE

LARVAL CODE	PUPAL CODE	LARVAL DUPLICATE	SPECIES
139	326		Cricotopus scotti Freeman
227	300		Cricotopus sp. ?
289			Cricotopus sp. ?
338			Cricotopus sp. ?
339			Cricotopus sp. ?
	342		

Family: CHIRONOMIDAE
Subfamily: CHIRONOMINAE
Tribe: TANYTARSINI

LARVAL CODE	PUPAL CODE	LARVAL DUPLICATE	SPECIES
16	241 ?		Tanytarsus (Tanytarsus) balteatus
70			Tanytarsus (Cladotanytarsus) pseudomancus Goetg.
78			Tanytarsus (Cladotanytarsus) of pseudomancus
97			Tanytarsus (Tanytarsus) zariea
122	23		Tanytarsus sp.
	123		Tanytarsus sp.
344			Tanytarsus sp.
353			Tanytarsus sp. (≡ AJM sp.D)*

Tribe: CHIRONOMINI

LARVAL CODE	PUPAL CODE	LARVAL DUPLICATE	SPECIES
3	45 ?		Polypedilum (Polypedilum) sp. (≡ AJM 10(1))
6	106		Stictochironomus caffrarius Kieffer
7	151		Chironomus of Cryptochironomus sp. (AJM 15)
9	45 ?	3	
10			Polypedilum (Polypedilum) deletum Goetg.
17	106	6	
18	106	6	
22		10	
24		10	
34			Polypedilum (Polypedilum) griseoguttatum Kieffer
35	321 ?		Polypedilum (Pentapedilum) wittei Freeman
40			Chironomus (Cryptochironomus) lindneri Freeman
47a			Chironomus (Chironomus) transvaalensis Kieffer
47b			Chironomus (Chironomus) formosipennis Kieffer
55			Polypedilum (Polypedilum) bipustulatum Freeman

*AJM refers to the codes used by A.J. McLachlan

LARVAL CODE	PUPAL CODE	LARVAL DUPLICATE	SPECIES
59			Chironomus cf (Cryptochironomus) sp. (AJM 125c)
76			Chironomus (Cryptochironomus) nocnilicola Freeman
77	106	6	
79	106	6	
83			Chironomus cf (Cryptochironomus) sp.
99			Chironomus cf (Cryptochironomus) sp.
107			Chironomus (Cryptochironomus) (AJM 9a)
112			Chironomus (Cryptochironomus) (AJM 128)
140		35	
141			Chironomus (Chironomus) calipterus Kieffer
148	337		Chironomus (Dicrotendipes) fusconotatus Kieffer
149	362 (121)		Chironomus (Nilodorum) brevibucca Kieffer
185	186		Chironomus (Nilodorum) fractilobus Kieffer
329		35 ?	
349			Chironomus (Dicrotendipes) sudanicus Freeman
355		112 ?	
358	149		Chironomus (Nilodorum) sp.

CODE		DUPLICATE	SPECIES		(Head length/width ratio)
Family: CERATOPOGONIDAE					
19			Broad-head "Culicoides"	(1.8)	1.80
46		19			1.94
61			Narrow-head "Culicoides"	(2.1-2.6)	2.59
64		61			
72	257 ?		Short-head "Probezzia"	(0.9)	0.91
73		61			2.19
74		61			2.21
80		61			2.29
81		61			2.09
82		61			2.53
210			Medium-head "Probezzia"	(1.9)	1.88
274	305 ?		Curve-head "Probezzia"	(2.4)	2.44
275			Curve-head "Probezzia"	(1.9)	1.88
334			Long-head "Probezzia"	(4.6)	4.58
	158		Pupa		
	556		Pupa		
	266		? Pupa		
	297		Pupa		
Order: MOLLUSC					
Suborder: GASTEROPODA					
Family: PLANORBIDAE					
2			Bulinus (Bulinus) depressus (Haas)		
12			Biomphalaria pfeifferi cf bridouxiana (Krauss)		
30			Bulinus (Physopsis) sp.		
49			Bulinus (Bulinus) forskalii (Ehrenberg)		
256			Anisus coretus (de Blainville)		
Family: LYMNAEIDAE					
65			Lymnaea natalensis Krauss		
109		63			
Family: MELANIIDAE					
26			Cleopatra bulimoides (Olivier)		

CODE	DUPLICATE	SPECIES
Family:	ANCYLIDAE	
308		*Ferrissia cawstoni* Walker
Order:	MOLLUSCA	
Suborder:	PELECYPODA	
Family:	CYRENIDAE	
32		*Corbicula africana* (Krause)
115	32	
224	32	
Family:	SPHAERIIDAE	
42		*Eupera ferruginea* Krause
89	42	
238	42	
Family:	MUTELIDAE	
162a		*Mutela* cf *rostrata* Scopoli
162b		*Aspatheria* (*Spathopsis*) *wahlbergi* (Krause)

APPENDIX 7.3

[illegible] ANIMALS [illegible] (numbers/m²)

SPECIES	CODE	JAN/FEB 1967 1	2	3	TOTAL	APR/MAY 1967 1	2	3	TOTAL	JUL/AUG 1967 1	2	3	TOTAL	OCT/NOV 1967 1	2	3	TOTAL	JAN 1968 1	2	3	TOTAL	GRAND TOTAL
[illegible]																						
[illegible]	8	-	-	-	-	-	-	-	-	24	-	12	36	12	-	-	12	-	-	-	-	48
[illegible] sp. A	60	-	-	-	-	-	-	-	-	-	-		-	18	-	-	18	-	-	-	-	18
[illegible]																						
[illegible]	91	-	-	-	-	-	-	-	-	12	6	-	12	-	-	-	-	-	-	-	-	18
[illegible]	133	-	-	-	-	-	-	-	-	-	6	-	6	-	-	-	-	-	-	-	-	6
[illegible]																						
[illegible]	14	10	18	-	28	-	12	-	12	12	18	6	36	6	36	-	42	6	24	-	30	148
[illegible]																						
[illegible] spp.	1	90	120	84	254	24	90	24	130	174	12	12	198	18	24	24	66	24	162	324	510	1166
[illegible] (Larvae)																						
[illegible] sp.	5	-	-	-	-	18	-	-	18	-	12	-	12	-	-	-	-	12	-	-	12	42
[illegible]	6	-	-	-	-	12	-	-	12	12	12	-	24	-	-	-	-	246	6	-	252	288
[illegible] sp.	7	-	-	-	-	-	-	-	-	90	-	-	90	-	-	-	-	42	48	-	90	180
[illegible]	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	-	18	18
[illegible]	13	-	-	-	-	18	18	-	36	6	-	-	6	6	-	-	6	30	24	-	54	102
[illegible]	16	30	18	-	48	12	6	-	18	12	132	-	144	-	-	-	-	96	12	-	108	318
[illegible]	25	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	6	-	-	-	-	6
[illegible]	33	-	-	-	-	-	-	-	-	-	36	-	36	-	-	-	-	-	6	-	6	42
[illegible]	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	6
[illegible]	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	-	18	18
[illegible]	60	-	-	-	-	-	6	-	6	-	42	6	48	-	-	-	-	-	-	-	-	54
[illegible]	76	-	-	-	-	-	-	-	-	12	18	-	30	-	-	-	-	-	-	-	-	30
[illegible]	78	30	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30
[illegible] (Pupae)																						
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	12	12
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	6	6
	119	10	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
[illegible] sp. 7	151	-	-	-	-	-	6	-	6	-	-	-	-	-	-	-	-	-	-	-	-	6
[illegible]																						
[illegible] "[illegible]"	19	-	-	-	-	-	6	-	6	-	6	-	6	-	-	-	-	6	-	-	6	18
[illegible] "[illegible]"	61	-	-	-	-	-	6	-	6	6	36	-	42	6	-	-	6	-	-	-	-	54
[illegible]																						
[illegible]	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	12	12
[illegible]																						
[illegible]	32	-	-	-	-	-	-	-	-	-	-	-	-	-	120	-	120	-	-	-	-	120
TOTAL		130	156	84	380	84	150	54	288	264	372	36	678	72	180	24	276	510	708	384	1140	2706

APPENDIX 7.4

BENTHOS FROM 10 METRES (numbers/m^2)

SPECIES/STATIONS	CODE	JAN/FEB 1967 1	2	TOTAL	APR/MAY 1967 1	2	TOTAL	JUL/AUG 1967 1	2	TOTAL	OCT/NOV 1967 1	2	TOTAL	JAN 1968 1	2	TOTAL	GRAND TOTAL
[illegible]																	
[illegible]	37	-	-	-	-	6	6	-	-	-	-	-	-	-	-	-	6
[illegible] sp. I	60	-	-	-	-	-	-	-	-	-	6	-	6	-	-	-	6
[illegible]																	
[illegible] sp.	90	-	-	-	-	-	-	18	-	18	-	-	-	-	-	-	18
[illegible]																	
[illegible]	14	6	6	12	-	30	30	30	6	36	12	-	12	18	18	36	126
[illegible]																	
[illegible] sp.	1	30	204	234	72	-	72	390	222	612	48	78	126	176	490	666	1710
[illegible] (Larvae)																	
[illegible] sp.	5	12	-	12	78	198	276	-	24	24	-	-	-	36	24	60	372
[illegible] sp.	7	-	-	-	-	-	-	-	-	-	-	-	-	-	30	30	30
[illegible]	10	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	6
[illegible]	13	-	-	-	-	-	-	-	-	-	-	-	-	18	-	18	18
[illegible]	16	-	6	6	-	-	-	-	42	42	-	-	-	-	6	6	54
[illegible]	33	-	-	-	6	12	18	-	-	-	6	30	[illegible]	-	6	6	60
[illegible]	68	-	-	-	-	-	-	-	42	42	-	-	-	-	-	-	42
[illegible]	76	-	-	-	-	-	-	6	18	24	-	-	-	-	-	-	24
[illegible]	78	18	-	18	-	-	-	-	-	-	-	-	-	-	-	-	18
[illegible] (Pupae)																	
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	6
	15	-	-	-	-	-	-	-	-	-	-	-	-	6	6	12	12
	39	-	-	-	-	-	-	6	-	6	-	-	-	-	-	-	6
	121	-	-	-	-	-	-	-	6	6	-	-	-	-	-	-	6
[illegible]																	
Broad band "[illegible]"	59	-	-	-	-	12	12	12	-	12	-	-	-	-	-	-	24
Narrow band "[illegible]"	61	-	-	-	-	144	144	12	-	12	-	-	-	-	-	-	156
[illegible]																	
[illegible]	32	-	-	-	-	-	-	-	-	-	-	18	18	-	-	-	18
TOTAL		66	216	282	156	402	558	474	360	834	72	126	198	270	576	846	2718

(numbers/m²)

APPENDIX 7.4

THE COMPOSITION OF THE BENTHIC FAUNA [illegible] JANUARY 1967 - JANUARY 1968 (numbers/m²)

STATION	[illegible] 1	2	3	4	5	5 m 1	2	3	10 m 1	2	[illegible] 1 No.	%	2 No.	%	3 No.	%	4 No.	%	5 No.	%
OLIGOCHAETA	72	158	33	365	244	54	22	0	6	6	4572	79	2319	41	114	4	45	13	44	7
[illegible]	0	50	0	0	0	0	0	0	0	0	0		0		0		7	2	6	1
[illegible]	17	110	50	53	0	0	0	0	0	0	0		0		0		2	2	0	
EPHEMEROPTERA	75	16	0	632	0	12	12	0	16	0	0		0		0		0		0	
TRICHOPTERA	0	160	0	0	0	31	130	6	66	50	6		21		54	2	12	3	6	1
PLECOPTERA	0	0	0	0	0	12	0	0	0	0	12		0		6		0		0	
COLEOPTERA	0	0	0	100	0	0	0	0	0	0	0		0		0		0		0	
TIPULIDAE	0	0	0	20	0	0	0	0	0	0	0		0		0		0		0	
[illegible]	0	12	0	67	0	790	408	468	771	984	624	11	2436	43	2860	80	145	40	420	63
CHIRONOMIDAE	427	641	681	1021	1526	630	462	6	204	450	654	11	733	13	144	5	144	40	136	21
CERATOPOGONIDAE	96	358	16	0	75	18	54	0	24	156	18		99	2	48	2	0		47	6
CRUSTACEA	0	0	0	0	20	0	0	0	0	0	0		0		0		0		0	
MOLLUSCA	32	770	64	0	0	0	120	0	0	18	6		0		6		0		6	1
TOTAL	714	1795	944	2026	1213	1050	1176	480	1944	1674	5092		5548		2832		363		662	

APPENDIX 7.7

THE COMPOSITION OF THE BENTHIC FAUNA AT THE VARIOUS STATIONS

ORGANISMS	STATION 1 0 m	STATION 1 5 m	STATION 1 10 m	STATION 1 RB	STATION 2 0 m	STATION 2 5 m	STATION 2 10 m	STATION 2 RB	STATION 3 0 m	STATION 3 5 m	STATION 3 RB	STATION 4 0 m	STATION 4 RB	STATION 5 0 m	STATION 5 RB
OLIGOCHAETA	77	24	6	4572	[illegible]	12	6	2319	33	0	134	[illegible]	49	264	44
HIRUDINEA	0	0	0	0	50	0	0	0	0	0	0	0	7	0	6
[illegible]	12	0	0	0	[illegible]	0	0	0	50	0	0	53	6	0	0
EPHEMEROPTERA	75	12	18	0	16	12	0	0	0	0	0	432	0	0	0
TRICHOPTERA	0	34	66	6	180	108	60	21	0	[illegible]	24	0	12	0	6
[illegible]	0	12	0	12	[illegible]	0	0	0	0	0	0	0	0	0	0
COLEOPTERA	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0
TIPULIDAE	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0
[illegible]	0	290	726	624	12	408	984	2436	0	468	2460	67	145	0	420
CHIRONOMIDAE	427	630	204	654	641	467	450	733	601	6	144	1022	144	1526	130
CERATOPOGONIDAE	96	18	24	18	358	54	156	39	16	0	48	0	0	25	42
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
MOLLUSCA	52	0	0	6	270	120	18	0	54	0	6	0	6	0	6
TOTAL	714	1050	1044	5692	1795	1176	1674	5548	344	490	2832	2650	363	2025	662

RB: [illegible]

APPENDIX 7.8

RIVER BED TRANSECT - JANUARY, 1967 (numbers/m^2)

SPECIES	CODE	STATIONS 1	2	3	4	5	6	6a
OLIGOCHAETA								
Branchiodrilus hortensis	8	36	24	-	-	-	-	-
Nais sp.	29	-	-	-	-	-	-	-
Nais communis	36	-	-	-	-	-	-	-
Aulodrilus pigueti	37	102	216	12	-	-	-	18
Aulophorus furcatus	38	-	-	-	-	-	-	-
Pristina synclites	75	-	-	-	-	-	-	-
Glossoscolecidae	170	-	-	-	-	-	-	6
Mixed species	-	-	-	-	-	-	-	-
Stylodrilus lemani	144							
HIRUDINEA								
?	151	-	-	-	-	-	-	-
ODONATA								
Ictinogomphus ferox	-	-	-	-	-	-	-	6
Lestinogomphus africanus	152	-	-	-	-	-	-	-
Libellulidae	160	-	-	-	-	-	-	-
HEMIPTERA								
Anisops sardea	69	-	-	-	-	-	-	18
Micronecta scutellaris	109	-	-	-	-	-	-	12
Anisops sp. nymph	124	-	-	-	-	-	-	-
Sigara marshalli	125	-	-	-	-	-	-	-
EPHEMEROPTERA								
Caenis sp.	90	-	-	-	-	-	-	-
Caenis sp.	102	-	-	-	-	-	-	12
DYTISCIDAE								
Canthydrus carinicornis	95	-	-	-	-	-	-	-
HYDROPHILIDAE								
Berosus sp. larvae	163	-	-	-	-	-	-	12
TRICHOPTERA								
Dipseudopsis capensis	14	6	-	-	-	-	-	
	139							
CULICIDAE								
Chaoborus spp.	1	36	30	708	12	-	-	-
CHIRONOMIDAE Pupa	116							
Cryptochironomus sp.	7	-	-	-	-	-	-	-
Polypedilum sp.	5	-	-	-	-	-	-	-
Procladius brevipetiolatus	13	6	-	-	-	-	-	-
Tanytarsus balteatus	16	-	-	-	-	-	-	-
Stictochironomus caffrarius	6	-	-	-	-	-	90	1164
Ablabesmyia nilotica	25	-	-	-	12	-	-	-
Clinotanypus maculatus	33	-	-	12	70	-	18	18
Cryptochironomus lindneri	40	-	-	-	-	-	-	-
Cryptochironomus sp.	59	-	-	-	-	-	-	-
Cryptochironomus nudiforceps	76	-	-	-	-	-	-	-
Pupa	154	-	-	-	-	-	-	-
CERATOPOGONIDAE								
Broad head "Culicoides"	19	-	-	-	-	-	-	-
Narrow head "Culicoides"	61	-	6	-	-	-	-	42
Short head "Probezzia"	72	-	-	-	-	-	-	-
MOLLUSCA								
Bulinus depressus	2	-	-	-	-	-	-	-
Biomphalaria pfeifferi	12	-	-	-	-	-	-	-
Corbicula africana	32	-	-	-	-	-	-	-
Lymnaea natalensis	42	-	-	-	-	-	-	-
Bulinus forskali	49	-	-	-	-	-	-	-
Unio ?	162	-	-	-	-	-	-	-
TOTAL		186	276	732	102	0	108	1308

APPENDIX 7.9

[illegible] TRANSECT - APRIL/MAY, 1967 (numbers/m²)

STATIONS

SPECIES	CODE	1	2	3	3a	3b	3c	4	5	6
[illegible]										
[illegible]	8	-	69	-	-	36	-	-	-	-
[illegible] sp.	29	-	-	-	-	-	-	-	-	-
[illegible]	36	-	-	-	-	-	-	-	-	-
[illegible]	37	4420	1050	-	-	-	-	-	-	-
[illegible]	38	-	-	-	-	-	-	12	-	-
[illegible]	75	-	-	-	-	-	-	-	-	-
[illegible]	176	-	-	-	-	-	-	-	-	-
Mixed species	-	-	-	-	-	-	-	-	-	-
[illegible]	144	-	-	-	-	-	-	-	-	47
[illegible]										
	131	-	-	-	-	-	-	-	-	-
ODONATA										
[illegible]	-	-	-	-	-	-	-	-	-	-
[illegible]	152	-	-	-	-	-	-	6	-	-
Libellulidae	160	-	-	-	-	-	-	-	-	30
[illegible]										
[illegible]	69	-	-	-	-	-	-	-	-	-
[illegible]	109	-	-	-	-	-	-	-	-	-
[illegible] sp. nymph	186	-	-	-	-	-	-	-	6	73
[illegible]	175	-	-	-	-	-	-	-	-	-
[illegible]										
[illegible] sp.	90	-	-	-	-	-	-	-	-	-
[illegible] sp.	108	-	-	-	-	-	-	-	-	15
[illegible]										
[illegible]	95	-	-	-	-	-	-	-	6	47
[illegible]										
[illegible] sp. larvae	161	-	-	-	-	-	-	-	-	73
[illegible]										
[illegible]	14	-	-	-	6	-	-	12	6	-
[illegible]	135	-	-	-	-	-	-	-	-	-
[illegible] spp.	1	36	390	36	474	430	440	102	390	-
[illegible] Pupa	114									
[illegible] sp.	7	66	-	-	-	-	-	-	-	-
[illegible] sp.	5	876	181	-	-	-	-	94	-	-
[illegible]	13	12	-	-	-	-	-	-	-	-
[illegible]	16	-	-	-	-	-	-	-	6	15
[illegible]	6	-	-	-	-	-	-	12	-	-
[illegible]	75	-	-	-	-	-	6	-	-	-
[illegible]	33	6	-	6	-	-	12	18	126	73
[illegible]	80	-	-	-	-	-	-	-	-	-
[illegible] sp.	59	-	-	-	-	-	-	-	-	-
[illegible]	76	-	-	-	-	-	-	-	-	-
Pupa	154	-	-	-	-	-	-	-	-	-
[illegible]	47	18	-	-	-	-	-	-	-	37
	153	30	-	-	-	-	-	-	-	-
Broad head "[illegible]"	18	-	-	-	-	-	-	-	-	-
Narrow head "[illegible]"	61	-	-	-	-	-	-	-	6	15
Short head "[illegible]"	70	-	-	-	-	6	6	-	6	15
[illegible]										
[illegible]	7	-	-	-	-	-	-	-	-	-
[illegible]	17	-	-	-	-	-	-	-	-	-
[illegible]	36	-	-	-	-	-	-	-	-	-
[illegible]	42	-	-	-	6	12	-	-	-	-
[illegible]	49	-	-	-	-	-	-	-	-	-
[illegible]	149	-	-	-	-	-	-	-	-	8
TOTAL		4934	2452	42	486	490	470	184	330	396

[illegible]

APPENDIX [illegible]

[illegible] - [illegible], 1960 ([illegible]/m^2)

STATIONS

SPECIES	CODE	1	1a	2	2a	2b	3	3a	3b	3c	4	4a	4b	4c	5
[illegible]															
[illegible]	6	-	30	84	76	6	-	12	6	-	-	-	-	6	-
[illegible] sp.	89	-	-	12	-	-	6	-	-	-	-	-	-	-	-
[illegible]	91	-	-	6	6	-	-	-	-	-	-	-	-	-	-
[illegible]	96	-	-	-	-	-	6	-	-	-	-	-	-	-	6
[illegible]	97	-	-	-	-	-	48	6	-	-	-	-	-	-	-
[illegible]	38	-	-	-	-	42	12	-	-	-	-	-	-	-	-
[illegible]	75	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp. (?)	99	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp. nov.	177	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	14?	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	72?	-	-				-	-	-	-	-	-	-	-	-
[illegible]															
- ?	43	-	-	-	-	-	-	-	-	-	-	-	-	-	6
- ?	226	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]															
[illegible]	214	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]															
[illegible] sp.	53	-	-	-	-	-	-	-	-	-	-	-	-	6	-
[illegible] sp.	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]															
[illegible]	24	-	-	6	-	-	6	12	-	48	-	-	-	-	-
[illegible]															
[illegible] sp.	175	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] (?)	220	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	135	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	1	18	215	72	276	1326	576	654	198	78	18	18	18	84	6
[illegible] (larvae)															
[illegible] sp.	5	-	180	-	18	-	-	-	-	-	-	-	-	-	-
[illegible]	6	-	6	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	7	-	-	12	8	-	-	-	-	-	-	-	-	-	-
[illegible]	13	-	-	6	-	-	-	-	-	-	-	-	-	-	-
[illegible]	16	-	-	-	-	-	-	-	-	-	-	-	-	-	6
[illegible]	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] spp.	47	-	-	-		-	-	-	-	-	-	-	18	6	-
[illegible] sp.	50	-	-		-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	59	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	74	-	-		-	-	-	-	-	-	-	-	-	-	-
[illegible]	78	-	-		-	-	-	-	-	-	-	-	-	-	-
[illegible]	107	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	149	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	227	-	-	-	-	-	-	-							
[illegible] (pupae)															
	5	6	-	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	63	-	6	-	-	-	-	-	-	-	-	-	-	-	-
	119	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	121	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	151	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	164	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]															
[illegible]	19	-	6	-	6	12	-	6	-	-	-	-	-	-	-
[illegible]	61	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]															
[illegible]	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	32	-	-	-	6	-	-	-	-	-	-	-	-	-	6
[illegible]	47	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	162	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL		24	222	192	966	1386	654	692	704	180	18	12	30	42	36

APPENDIX [illegible]

[illegible] (numbers/m²)

[illegible]	[illegible]	1	1a	2	2a	2b	3	3a	3b	3c	4	5	5a*
[illegible]													
[illegible]	3	-	-	-	-	14	18	-	-	-	-	-	-
[illegible] sp.	29	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	31	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	37	-	-	-	-	-	18	-	-	-	-	-	-
[illegible]	3?	-	-	-	-	-	-	30	-	-	180	7	-
[illegible]	30	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	75	-	-	-	-	-	-	-	-	-	-	-	12
[illegible] sp.	77	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	47	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	144	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	225	-	-	1050	[illegible]	-	-	-	-	-	-	-	-
[illegible]													
[illegible]	45	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	2??	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]													
[illegible]	31?	-	-	-	6	-	-	-	-	-	-	-	-
[illegible]													
[illegible] sp.	51	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	75	-	-	-	-	-	-	-	-	-	24	22	-
[illegible]													
[illegible]	14	-	-	-	-	-	12	[illegible]	[illegible]	60	[illegible]	15	48
[illegible]													
[illegible] sp.	17	-	-	-	-	-	-	-	-	-	-	15	-
[illegible]	770	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	1??	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	2	1?	30	144	142	84	78	6	66	42	84	-	18
[illegible] (larvae)													
[illegible] sp.	5	138	294	702	714	240	36	6?	540	342	294	44	-
[illegible]	6	-	-	-	-	-	-	-	-	-	-	-	66
[illegible] sp.	7	6	-	18	60	12	30	48	-	24	132	44	-
[illegible]	13	-	-	-	-	-	-	6	60	24	156	104	18
[illegible]	14	-	-	-	6	60	78	36	12	6	12	-	6
[illegible]	2?	-	-	-	-	-	-	[illegible]	6	12	-	7	18
[illegible]	33	-	6	1?	-	-	-	33	6	18	42	9	30
[illegible]	4?	-	-	24	-	24	36	-	6	-	24	-	-
[illegible] sp.	4?	-	-	-	-	-	-	-	-	-	[illegible]	-	-
[illegible] sp.	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] sp.	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	1?7	-	-	-	-	-	-	[illegible]	[illegible]	6	-	-	24
[illegible]	1??	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	
[illegible]													
	3	-	-	-	-	-	-	-	-	-	-	-	-
	1?	-	-	-	-	-	-	-	-	-	-	-	-
	4?	-	1?	3?	[illegible]	-	-	12	[illegible]	-	-	-	6
	11?	-	-	-	-	-	-	[illegible]	-	-	-	-	-
	1??	-	-	1?	-	-	-	-	-	-	-	-	-
	131	-	-	-	-	-	-	-	-	-	-	-	-
	15?	-	-	-	-	-	-	-	-	-	-	-	-
	19?	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]													
[illegible]	[illegible]	1?	6	12	-	[illegible]	[illegible]	[illegible]	1?	24	3?	15	-
[illegible]	61	-	-	-	-	-	42	-	-	[illegible]	6	15	42
[illegible]	72	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]													
[illegible]	26	-	-	-	6	-	-	-	-	-	-	-	-
[illegible] sp.	30	-	-	-	12	-	-	-	-	-	-	-	-
[illegible]	37	6	30	-	30	-	-	-	-	-	-	-	-
[illegible]	42	-	-	-	-	-	-	-	-	-	-	-	-
[illegible]	152	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL		[illegible]	984	2?1?	114?	516	360	?2?	79?	564	10?0	415	977

[illegible]

APPENDIX 8.2

RESULTS OF SAMPLING THE SALVINIA MAT : APRIL, 196[illegible] (number/m²)

SPECIES	CODE	3	3/4	4	5	TOTAL	GROUP TOTAL	GROUP %
[illegible]	65	6	8			14	14	1.3
[illegible]								
Ostracoda	58		2			2		
[illegible] (?)	809	12	78		4	94	96	8.8
HYDRACHNELLAE								
[illegible] f., nov?	868		2			2	2	0.2
EPHEMEROPTERA								
[illegible] sp.	53	61	90	32	2	185		
[illegible] sp.	62	2	4			6		
[illegible] sp.	67		2			2	195	17.8
ODONATA								
Coenagriidae	231		12	4	6	22		
Libellulidae ([illegible])	232	14	12	56	10	92		
Libellulidae ([illegible])	233	70	114	20	2	206		
Libellulidae ([illegible])	262	8				8	328	30.0
HEMIPTERA								
[illegible]	109				2	2		
Plea [illegible]	254	6	12		2	20	22	2.1
COLEOPTERA								
[illegible] spp.	205	6	2			8		
[illegible] spp.	245		34			34		
[illegible]	235				2	2		
[illegible] (?)	238		2			2		
[illegible]	239		2			2		
[illegible]	240		4			4		
[illegible]	249	2				2	54	5.0
[illegible]								
[illegible]	135	90	109			199		
[illegible] sp. [illegible]	175	4	8			12	211	19.7
[illegible]								
[illegible]	23	2	22	40		64		
[illegible] sp.	30		10			10		
[illegible]	78		4			4		
[illegible] (pupa)	265		2			2	80	7.4
CERATOPOGONIDAE								
[illegible]	61		2			2		
[illegible]	72		12			12		
[illegible]	410		2			2		
Pupa	266		4			6	22	2.1
OTHER DIPTERA								
[illegible]	761		2			2	2	0.2
[illegible]								
[illegible]	12			16		16		
[illegible]	256	14	80		6	88	104	9.6
TOTAL		297	687	160	36	1080	1080	

APPENDIX 8.3

RESULTS OF SAMPLING OF SALVINIA MAT : JULY, 1967 (numbers/m^2)

SPECIES	CODE	SAMPLING POINT 3	4	5	TOTAL	GROUP TOTAL	GROUP %
OLIGOCHAETA							
Allonais sp. nov.	273	56	21	13	98	98	4.3
HIRUDINEA	66		1		1	1	
CRUSTACEA							
[illegible] (?) sp.	101		11		11		
[illegible] (?)	209	2			2		
[illegible] (?) sp.	212		1		1		
[illegible]	277		4	20	24	38	1.7
EPHEMEROPTERA							
[illegible] sp.	53	472	93	236	801		
Povilla adusta	133	3			3	804	35.9
ODONATA							
Coenagriidae	251	21	14	5	40		
Libellulidae (Trithemis ?)	252	32	10	5	55		
Libellulidae (Trithemis ?)	253	461	114	98	627		
Libellulidae (Orthetrum ?)	262	24		106	130		
Ceriagrion sp. (?)	270	3		3	6		
Ceriagrion sp. (?)	271	3	4		7	869	38.6
HEMIPTERA							
Plea pullula	254			2	2	2	0.1
COLEOPTERA							
[illegible] spp.	249	3			3		
[illegible] spp.	276	2			2		
[illegible]	278			3	3	8	0.4
CULICIDAE							
Mansonia africana	135	67			67		
Mansonia pupa	179	3			3	70	3.1
CHIRONOMIDAE							
[illegible]	25	130	12	31	181		
[illegible] sp.	50	39	26	36	101		
[illegible] sp. pupa	278			3	3	287	12.8
CERATOPOGONIDAE							
Short head "[illegible]"	72		3	14	17		
Pupa	158		2		2		
Medium head "[illegible]"	210	7	3		10		
Curve head "[illegible]"	274	10	2	5	17		
Curve head "[illegible]"	275	3			3	49	2.2
GASTROPODA							
Anisus [illegible]	256	3	16	5	24	24	1.1
TOTAL		1394	345	541	2240	2240	

APPENDIX 4.4

THE FAUNA COLLECTED FROM [illegible] (No/Kg Vegetation, wet)

SPECIES	CODE	6/67	7/67	11/67	2/68	5/68	TOTAL	%	GROUP TOTAL	%
OLIGOCHAETA										
[illegible]	8			0		1	9	0.1		
[illegible] sp. nov.	127	4	13			5	22	0.3	31	0.37
OSTRACODA										
Ostracoda	50	1		5	4		10	0.1		
[illegible]	172	1	1	3			5	0.1		
[illegible]	209	812	26			156	993	11.8		
Ostracoda	212			11	7		22	0.3		
Ostracoda	306	5			7		12	0.1		
Ostracoda	347	1					1	-	1043	12.43
[illegible]										
[illegible] sp. ?	62	8	31		78	13	130	1.6		
[illegible] sp. ?	85			11			11	0.1		
[illegible] sp. ?	90			5		1	6	0.1		
[illegible]	135	1	9			9	18	0.2	165	1.97
TRICHOPTERA										
[illegible]	91			5	14	10	27	0.3		
?	340		1				1		28	0.33
HEMIPTERA										
[illegible] sp. [illegible]	345		17				17	0.2	17	0.20
ODONATA										
[illegible]	166					1	1	-		
[illegible]	251	26	29	234	102	105	497	5.9		
Late instar Libellulidae	252	1					1			
Mid instar Libellulidae	255			5			5			
Early instar Libellulidae	261	2	6	8	4	10	30	0.4		
[illegible] sp. ?	271		1				1			
[illegible]	306	1	10		11		22	0.3		
[illegible] sp.	305	9	10		29		57	0.6	595	7.07
[illegible]										
[illegible] (?) sp. larva	128	20	1	13	14	1	49	0.6		
[illegible] (?) sp. pupa	340	9	1	5	4	5	22	0.3	71	0.85
CHIRONOMIDAE LARVAE										
[illegible]	16	4		79		2	85	1.0		
[illegible]	25		1	3	4		8	0.1		
[illegible]	35		285	21	165	10	479	5.7		
[illegible]	40			3			3			
[illegible]		47	31	81	174	6	339	3.6		
[illegible]	70			26	14		40	0.5		
[illegible]	139	9	413	63			485	5.8		
[illegible]	148	136	780	11	330	2	1259	15.0		
[illegible] sp.	344	36	111		176	4	325	3.9		
CHIRONOMIDAE PUPAE										
[illegible] sp. ([illegible])	23	1				1	2	-		
[illegible]	294	5	9	5	14	2	35	0.4		
[illegible] sp.	318	2	331	13			346	4.1		
[illegible]	302	44	186	3	74	1	308	3.7		
[illegible]	306		1	3	4		8	0.1		
	307		3		4		7	0.1		
	308	2	1		11		14	0.2		
[illegible]	337	18	73	3	57		151	1.8		
	340	2					2	-		
	343	2		5			7	0.1	3989	45.47
[illegible]										
Larg host "[illegible]"	336				4		4	0.1	4	0.05
CULICIDAE										
[illegible]	135		1				1	-	1	0.01
MOLLUSCA										
[illegible]	12	1		200	4	4	209	2.5		
[illegible] sp.	30	480	981	409	288	51	2169	25.8		
[illegible]	63			5			5	0.1		
[illegible]	226		55		60		115	1.4		
[illegible]	300		1				1	-	2579	30.74

APPENDIX 6.7

THE FAUNA COLLECTED FROM [illegible] [illegible] (Nos/Kg vegetation, wet)

SPECIES		CODE	4/67	8/67	11/67	2/68	[illegible]	TOTAL	%	GRAND TOTAL	%
HIRUDINEA											
(?)		13-	1					1		1	0.03
HYDRACARINA											
[illegible] sp. nov.		299	9					9	0.3	9	0.28
OSTRACODA											
[illegible]		178		153		7		160	4.9		
[illegible]		309	5			3	1	10	0.3		
		304	9					9	0.3	179	5.49
HEMIPTERA											
		322	1					1		1	0.03
EPHEMEROPTERA											
Cloeon sp.		62	20	15		3		38	1.2		
[illegible] sp.		83		2		7		9	0.3		
[illegible]		155		2		5	2	7	0.2	54	1.66
TRICHOPTERA											
[illegible]		91			2	5	2	7	0.2		
	♂	323	1					1			
	♀	550				17		17	0.5	35	1.07
PYRALIDIDAE											
[illegible] (?) sp.	Larva	319	9					9	0.3		
[illegible] (?) sp.	Pupa	320	1					1		10	0.31
ODONATA											
[illegible] sp. (?)		41	1					1			
Coenagriidae		251		6	7	52	31	96	3.0		
Early instar libellulidae		261		9			6	15	0.5		
[illegible] sp.		295	1					1			
Coenagriidae		307	2					2	0.1		
Coenagriidae		324		?	2	5		7	0.2		
[illegible] sp.		325		2				2	0.1		
Final instar libellulidae		553	9					9	0.3	13?	4.0?
CHIRONOMIDAE LARVAE											
[illegible]		16	3		-	7		15	0.5		
[illegible]		33	1		2			3	0.1		
[illegible]		35				190	500	898	27.6		
[illegible]		68	5	209	2	56	73	291	8.9		
[illegible]		70	57	15	2	297	65	424	12.7		
[illegible]		139	7	13	182			202	6.2		
CHIRONOMIDAE PUPAE											
		120	1		2			3	[illegible]		
		182			7	3	?	7	0.2		
Ablabesmyia [illegible] ?		294	2					2	0.1		
[illegible] sp.		316	7		22	3	2	34	1.0		
[illegible]		303	46	56	79	203	21	385	11.8		
		306		2		3		5	0.2		
		557				38	2	40	1.2		
		330				17		17	0.5	2312	70.99
[illegible]											
[illegible] "[illegible]"		61	7					8	0.3		
[illegible] "[illegible]"		720				1		1	0.8	9	0.28
MOLLUSCA											
[illegible]		12	3	2	5	14	15	39	1.2		
[illegible] ([illegible]) sp.		50	73	11	85	306	93	468	13.6		
[illegible]		63	7	4	2	5	2	19	0.6		
[illegible]		306	2				15	17	0.5	515	15.80
PISCES											
[illegible]		-	P	P		P					
[illegible]		-		P		P					
[illegible]		-		P							
TOTAL			898	467	545	1453	779	3260			

APPENDIX 8.8

THE FAUNA COLLECTED FROM [illegible] [illegible] (Nos/Kg vegetation wet)

SPECIES	CODE	7/67	11/67	2/68	2/6	TOTAL	%	GROUP TOTAL	%
OLIGOCHAETA									
[illegible] sp.	89	33	7			40	0.7		
[illegible] sp. nov.	187	2				2		42	0.73
CRUSTACEA									
Ostracoda	187				4	4	0.1		
Ostracoda	202			20		20	0.4		
[illegible] [illegible]	209	1		39	724	764	13.2		
Ostracoda	212			27	4	31	0.5		
Ostracoda	304			2		2		821	14.22
HYDRACHNELLAE									
[illegible] sp. nov. (?)	332	1				1			
[illegible] sp. nov. (?)	333	2				2		3	0.05
EPHEMEROPTERA									
[illegible]	33		2	2		4	0.1		
[illegible] sp.	62	9	29	75	81	194	3.4		
[illegible] sp.	85	1				1			
[illegible] [illegible]	133	20	2	12	85	119	2.1	318	5.51
ODONATA									
Coenagriidae	251	15	63	231	11	320	5.5		
Early instar Libellulidae	261	1	4	6	4	15	0.3		
Coenagriidae	307		4			4	0.1		
Coenagriidae	324			6		6	0.1		
Coenagriidae	325	1	7	4		12	0.2	357	6.19
TRICHOPTERA									
[illegible] [illegible]	91		4	8	4	16	0.3		
	336				22	22	0.4	38	0.67
PYRALIDIDAE									
[illegible] sp. (?)	319		12	2		14	0.2	14	0.24
CULICIDAE									
[illegible] [illegible]	135		2	6	4	12	0.2		
[illegible] [illegible]	335		2			2		14	0.24
CHIRONOMIDAE LARVAE									
[illegible] [illegible]	16		19	2	4	25	0.4		
[illegible] [illegible]	35	253	58			311	5.4		
[illegible] [illegible]	60	89	14	45	59	207	3.6		
[illegible] [illegible]	70				7	7	0.1		
[illegible] [illegible]	78	133		10	107	250	4.[illegible]		
[illegible] [illegible] of [illegible]	7[illegible]	274	248		7	529	9.2		
[illegible] [illegible]									
[illegible] [illegible]	1[illegible]			231	92	323	5.6		
CHIRONOMIDAE PUPAE									
pupa	182	8				8	0.1		
[illegible] [illegible] ? pupa	294	1	45	8	16	70	1.2		
[illegible] sp. (?) pupa	318	80	152			232	4.0		
[illegible] [illegible] ? pupa	321	67		39	63	169	2.9		
pupa	326	9			11	20	0.4		
pupa	327	6		6	15	27	0.5		
pupa	328			2	4	6	0.1		
pupa	330	1		2		3	0.1	2187	37.89
CERATOPOGONIDAE									
Long band "[illegible]"	334		4	2	11	17	0.3	17	0.89
GASTROPODA									
[illegible] [illegible]	12	43	108	1	107	253	4.4		
[illegible] ([illegible]) sp.	30	380	810	190	99	1479	25.6		
[illegible] [illegible]	63		2	2		4	0.1		
[illegible] [illegible]	308	221			4	225	3.9	1961	33.97
TOTAL		1649	1649	925	1551	577[illegible]			

LAST PAGE MAP SEE
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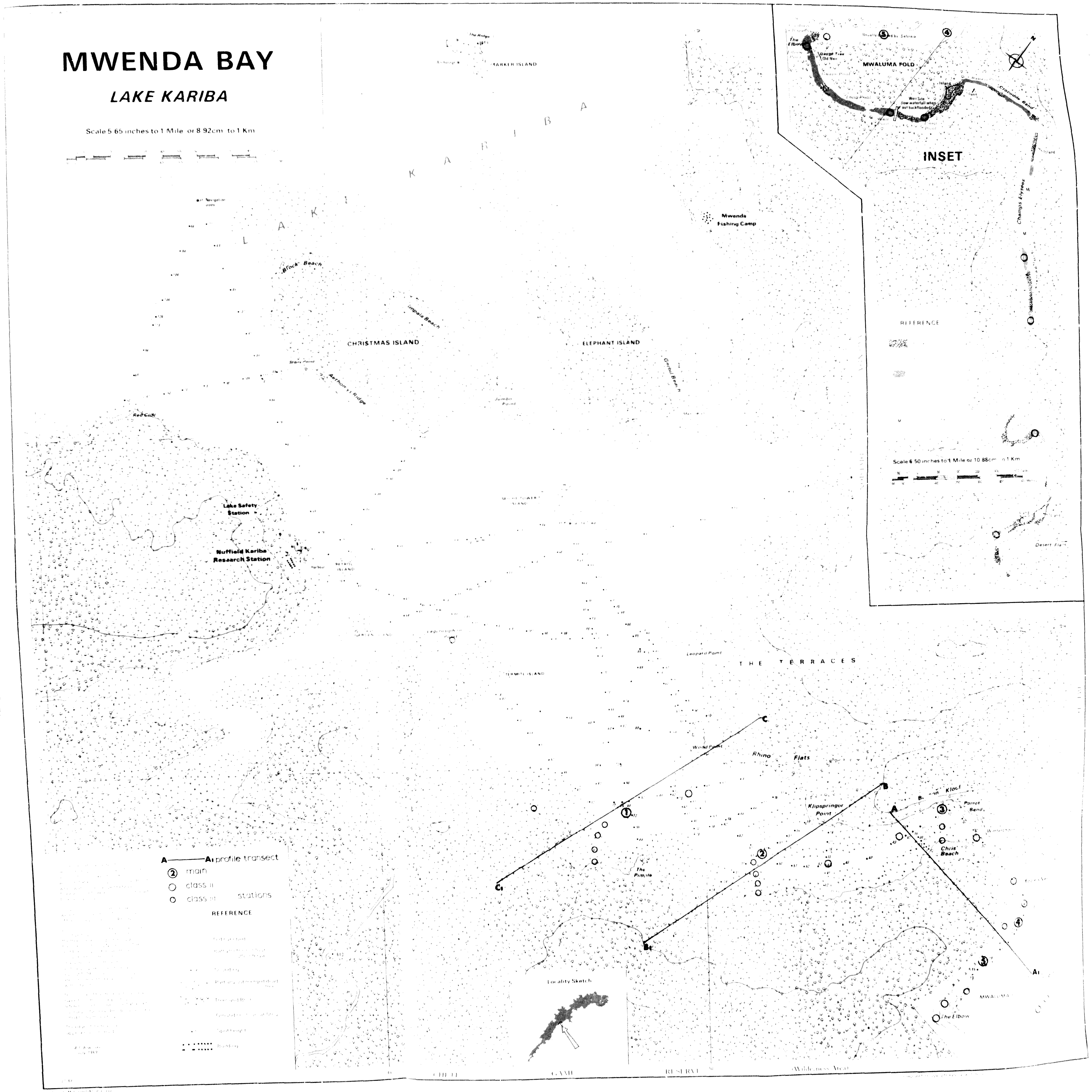
AN HYDROBIOLOGICAL STUDY OF THE MWENDA RIVER AND ITS MOUTH, LAKE KARIBA

Alan Philip Macgowan Bowmaker

A Thesis Submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, for the degree of Doctor of Philosophy

Salisbury, Rhodesia 1973

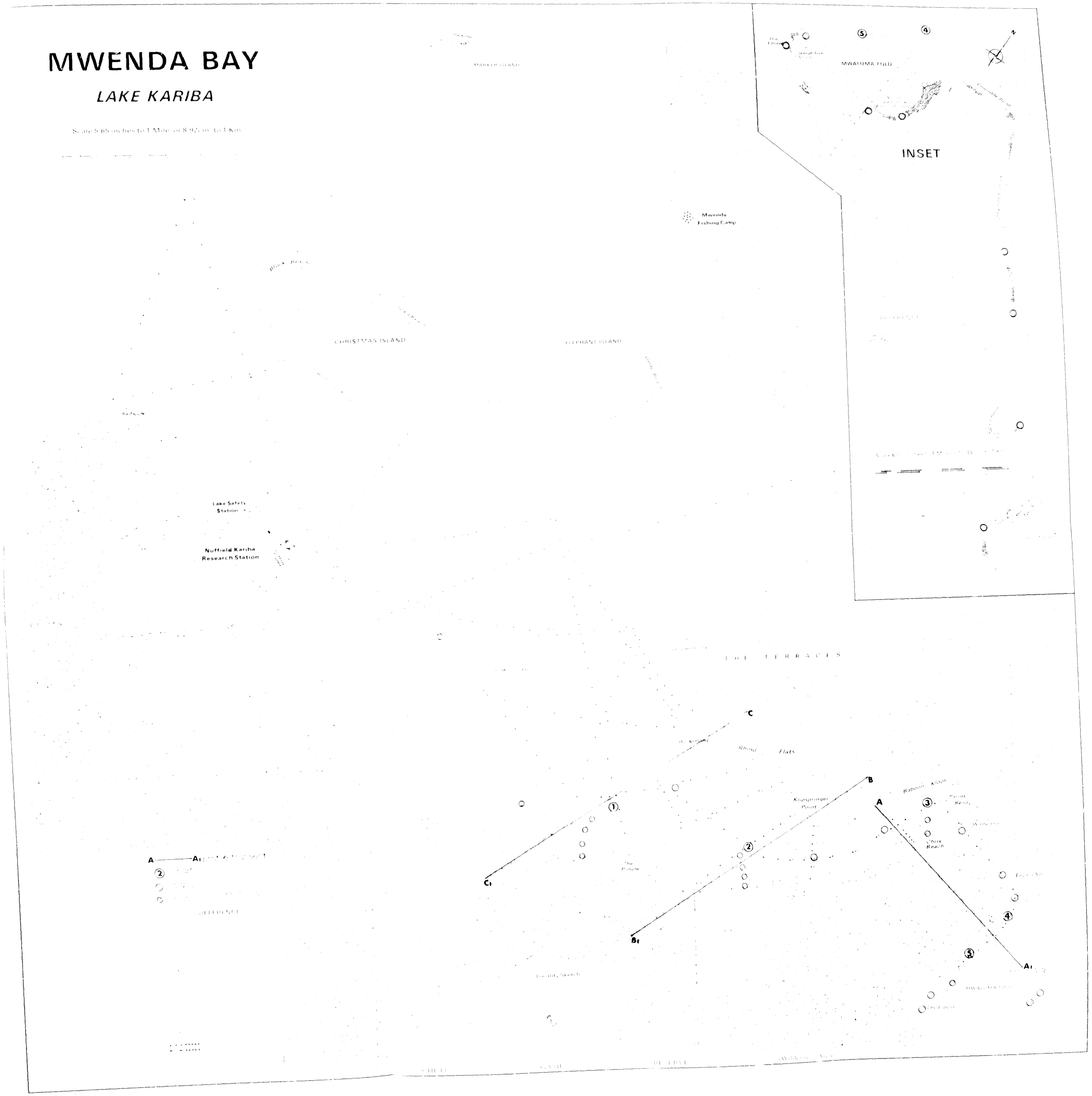


MWENDA BAY
LAKE KARIBA
Scale 5.65 inches to 1 Mile or 8.92cm to 1 Km
MARKER ISLAND
Mwenda Fishing Camp
INSET
CHRISTMAS ISLAND
ELEPHANT ISLAND
Lake Safety Station
Nuffield Kariba Research Station
THE TERRACES
Rhino Flats
Klipspringer Point
Parrot Bend
Chris' Beach
The Pinnacle
REFERENCE
A——A1 profile transect
main
class ii
class iii
stations
Locality Sketch
The Elbow

20

MWENDA BAY

LAKE KARIBA


MWENDA BAY
LAKE KARIBA
INSET
Nuffield Kariba
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Author Bowmaker Alan Philip Macgowan
Name of thesis An hydrobiological study of the Mwenda River and its mouth, Lake Kariba. 1973

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