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Limnology of the Great Ruaha River above Kidatu

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The building of new dams on the major rivers of Africa has provided an important stimulus to limnological research on this continent. After the closure of the Zambesi, Volta, Nile and Niger rivers, teams were set up to follow the changes taking place in the new man-made lakes. Special emphasis was laid on fish population studies and the productivity of these lakes in general. However, only seldom was the research initiated before the completion of the dam.

The author had an unique opportunity of studying the Great Ruaha River in 1971–1973, well in advance of the completion of the dams at Kidatu (closed in 1975), and at Mtera, expected to be closed in 1980. The study area included a stretch of river from below the tailrace outflow of water at Kidatu, up to the headwaters of the Little Ruaha and the Great Ruaha (or Ruaha) (Fig. 53). In this way, both the areas to be inundated, and those well outside the future lakes were covered.

During the present study the following aspects were investigated: physico-chemical limnology; occasional collections of bottom fauna; aquatic macrophytes; experimental fishing. The field work was followed by laboratory analyses and evaluation of the results. For comparison data from other reservoirs in Tanzania (Fig. 54) have sometimes been included.

This contribution is based on three earlier reports (Petr 1974*a*, *b* and *c*) which give a more detailed account of the limnology.

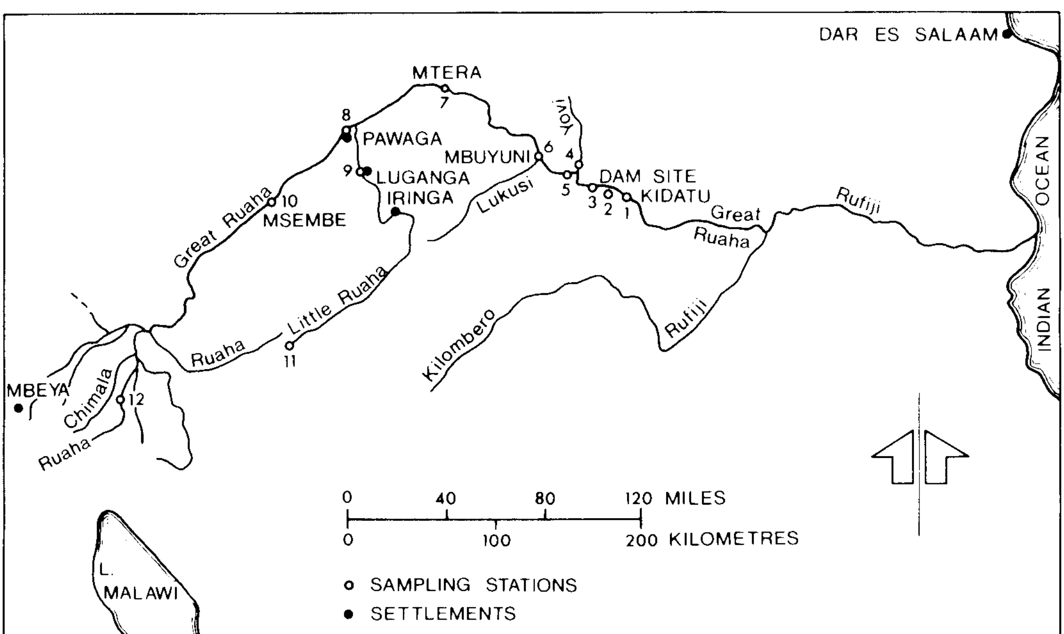

Fig. 53. Area included in the limnological study.

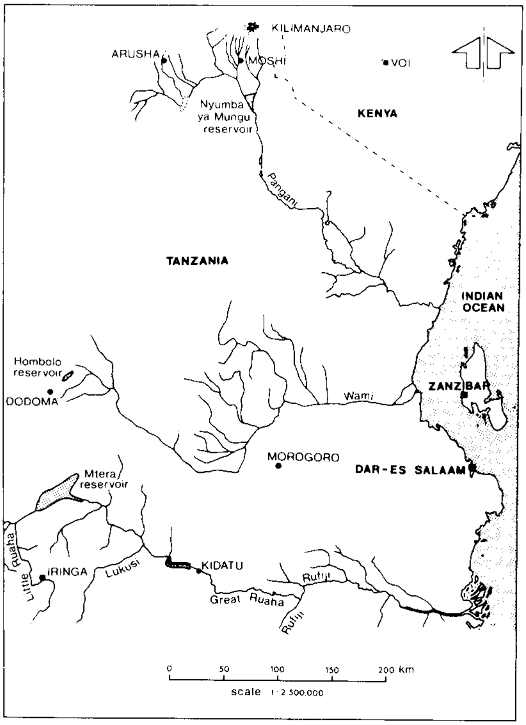

Fig. 54. The location of some Tanzanian reservoirs mentioned in the text.

Water physics and chemistry (Table 10)

In its upper reaches the Ruaha has a brown colour due to the high suspended load, whereas the Little Ruaha arising in swamps has clear water. The Little Ruaha headwaters show the characteristics of swampy water, i.e. have a low pH, and are rich in carbon dioxide but poor in oxygen. The Ruaha has a higher pH, the water is well oxygenated, and there is only very little carbon dioxide. Both rivers have a low conductivity.

In the middle reaches of the GRR (Great Ruaha River), a higher ionic content is revealed by a higher conductivity. In the Ruaha National Park (Station 10), the conductivity is between 90 and 121 $\mu S\ cm^{-1}$, i.e. two or three times higher than that of the headwaters. Further downstream, the conductivity of the water in the GRR increases slightly, with a maximum of 136 μS^{-1} measured in December 1971 at the dam site (Station 3) and at the Kidatu bridge (Station 1). Lower conductivity values are associated with high water levels.

In fast flowing rivers, such as those investigated, the water is almost always well oxygenated. The range of oxygen concentration for all visits was 6.8 to 13.0 ppm, which corresponds to 90 to 150% saturation.

Total alkalinity was between 20 and 60 ppm $CaCO_3$, usually being between 40 and 60 ppm. The pH value ranged from 6.7 to 7.8, usually being on the alkaline side. The concentrations of orthophosphates and nitrate nitrogen were low, as were those of iron, manganese and sulphate. Suspended solids ranged from 1 ppm to 580 ppm, and correspondingly the turbidity varied from 0 to 375 (Jackson units).

The chemical composition of the water throughout the GRR is within the range of unpolluted small rivers of Africa, and can be compared, for example, to that of the Nzoia River in Kenya (Walter *et al.* 1971) and the Vaal River (South Africa) above the industrial effluents (Chutter 1963). The conductivity of water in the GRR is similar to the above rivers, i.e. being close to 130 $\mu S\ cm^{-1}$ at 20°C. It was found low only in a small, clean, tributary descending from forested mountains (Station 2). The water of the GRR is always slightly alkaline, with a pH above 7.0, but the water is rather poor in carbonates. The transparency is usually low, due to the high concentration of suspended sediments which probably include clays. Such sediments may result in increased turbidity of the lake water, and this may influence the phytoplankton production. However, imported inorganic material, flooded soil, and vegetation, are known to be the three major sources of nutrients for primary producers of new lakes.

Algae and Higher Aquatic plants

Two groups of algae are widespread in the GRR and its tributaries: filamentous algae (mainly the green algae *Oedogonium* and *Spirogyra*, but also some blue green algae), and benthic diatoms, mostly *Gomphonema* and *Nitzschia*. The green filamentous algae grow attached to rocks and driftwood, usually close to the water surface, where they have sufficient light for their photosynthesis.

The transparency of the flood water, as measured by Secchi disc, is usually less than 10 cm, and this, together with the often rapid

Table 10. Physico-chemical analyses of water in the Great Ruaha River in June 1972 and April (*) 1973, stations 1–12 (see Fig. 53). UR=unreliable results.

Station	1	2	3	4	5	6	7	8	9	10	11*	12*
Temperature °C	24.2	18.5	22.9	22.3	23.1	24.5	23.8	26.6	23.0	23.8	20.0	20.2
Colour (apparent)	UR	0	250	UR	240	240	220	820	210	120	50	110
Turbidity (Jackson units)	130	0	90	375	100	120	110	275	60	40	0	22
Transmittance in %	72	100	74	31	64	77	75	–	85	90	100	95
Suspended solids (ppm)	136	1	140	580	150	–	115	–	5.0	10	–	–
Total solids (ppm)	174	55	266	683	300	–	285	–	175	122	–	–
Total dissolved solids (ppm)	38	54	127	97	150	–	170	–	170	112	–	–
Conductivity μS cm^{-1} 20°C	119	46	121	130	130	137	110	130	88	105	45	32
pH	6.9	7.3	7.8	7.5	7.4	7.4	7.7	7.8	7.8	7.8	6.3	6.9
Oxygen (ppm)	10.0	11.0	9.0	9.2	10.0	9.4	9.2	8.6	9.8	8.4	3.5	11.5
Oxygen (% saturation)	128	128	121	106	115	113	112	105	112	98	36	126
Total alkalinity (ppm $CaCO_3$)	40	35	55	65	65	55	65	60	50	50	20	15
Free carbon dioxide (ppm)	2	2	2	2	2	2	2	8	2	1	140	6
Hardness (Ca) (ppm $CaCO_3$)	0	0	0	20	20	10	0	25	15	0	0	0
Sulphate (ppm)	UR	0	25	32	24	26	27	7	17	9	2	0
Sodium (ppm)	12.0	4.25	15.6	9.9	12.6	–	11.4	–	7.9	11.4	–	–
Potassium (ppm)	2.1	0.7	2.1	1.0	2.5	–	24.0	–	1.6	2.3	–	–
Iron (ppm)	0.20	0.05	0.10	0.10	0.19	0.23	0.25	0.20	0.05	0.10	0.22	0.02
Manganese (ppm)	0.2	0.6	0.5	UR	0.3	0	0.4	0	0.4	0.5	0.5	0
Silica (ppm)	20	18	20	12	11	16	16	20	20	UR	20	14
Nitrogen nitrate (ppm)	2.2	UR	UR	9.0	6.0	7.0	8.0	2.5	10.0	8.0	12.0	7.2
Nitrogen nitrite (ppm)	0	0	0	0	0	0	0	0	0	0	0	0
Orthosphosphate (ppm)	0.20	0.22	0.18	0.90	0.15	0.18	0.17	0.13	0.05	0.10	0	0.50
Organic matter content (ppm)	70	20	70	120	45	–	60	–	32	70	–	–

changes in water-level, must greatly hinder the algal growth on rocks, driftwood and along the banks.

Towards the end of the dry season, when the low water-level has been stable for several months, the algae seem to be much more common, as well as the aquatic moss *Drepanocladus*. At that time the water is less turbid, and light penetrates deeper, which allows the algae to colonize deeper waters.

At the end of the dry season in December 1971 algae were identified from the stomachs of 10 different fish species: *Alestes affinis, Distichodus rufigiensis, Barbus macrolepis, Barilius loveridgei, Labeo cylindricus, Labeo ulangensis, Synodontis maculipinna, Schilbe mystus, Tilapia urolepis* and *Haplochromis gr. 'bloyeti'*, collected at all stations where experimental fishing was carried out. The algae were especially common in fish at Stations 1, 3, 8 and 10, i.e. in the Kidatu and Mtera areas.

In the swampy sources of the Little Ruaha (Station 11), littoral algae, such as *Scenedesmus, Pediastrum, Staurastrum, Euastrum, Botryo-*

Fig. 55. The shoreline of the Nyumba ya Mungu reservoir 6.5 years after the closure of the dam. Photo T. P. June, 1972.

coccus were abundant, and *Tilapia zillii* and *Barbus kerstenii* contained in their guts large quantities of these genera together with detritus and some filamentous green algae.

Aquatic invertebrates

Due to the shifting nature of bottom sands and high turbidity of water, aquatic invertebrates appear to be associated with rocks, driftwood, aufwuchs algae, and plants fringing the banks, rather than with the soft bottom. Insect larvae were common on gravel, and also inhabited rocks and trees collapsed into the river. Rocks in the current were often inhabited by the freshwater oyster (*Etheria elliptica*).

The aquatic invertebrates of the GRR are mostly rheophilic oxybionts, sensitive to any decrease in oxygen, and often requiring current for their existence. Although they are often exposed to rapid changes in water level, to changes in velocity of the current, and to the mechanical effect of drifting sediments, they seem to be able to survive through these extreme conditions, as evidenced by the fish stomach analysis.

The high turbidity of water makes sampling of aquatic invertebrates in tropical streams and rivers difficult. Fish are far better collectors of aquatic invertebrates than man, and if a large number of them are analysed for food, a fairly realistic picture of the invertebrate distribution in a particular area can be obtained. However, this says little or nothing of the niche from which the fish obtained their insects. A further problem arises from the tendency of most insectivorous fish to reduce the insects to fragments which makes identification difficult. However, insects were common, and, for example, the mormyrid fish, which occurred in experimental catches throughout the year, always contained aquatic insects in their stomachs regardless of the water-level in the river.

Chironomid larvae and pupae were the most frequent insect food item. They were found in fish collected at all stations and occurred in 16 different species. Ceratopogonid larvae and pupae were also common.

Light catches of adults of aquatic insects provided a modest collection of mainly chironomids, but also ephemeropterans and trichopterans, and occasionally a hemipteran. Their numbers were much smaller than those for light

Table 11. Occurrence of fish species at various stations (only fished stations are listed). *Labeo* spp. is considered here as one, although 5 species may be provisionally distinguished in this genus.

	Station no.									
Species	1	3	4	5	7	8	9	10	11	12
Mormyrus longirostris					+			+		
Gnathonemus livingstoni		+		+	+		+	+		
Gnathonemus macrolepidotus	+				+		+	+		
Gnathonemus sp.		+			+			+		
Petrocephalus catostoma	+									
Hippopatamyrus discorhynchus	+	+		+	+		+	+		
Mormyrid sp. 1	+			+						
Mormyrid sp. 2	+				+		+	+		
Alestes affinis	+	+		+	+	+	+	+		
Hydrocynus vittatus	+			+	+		+	+		
Distichodus petersii								+		
Distichodus rufigiensis	+				+	+		+		
Barbus macrolepis	+	+	+	+	+	+	+	+		
Barbus zanzibaricus	+									
Barbus jacksonii		+					+			
Barbus innocens	+			+	+		+	+		
Barbus paludinosus	+			+			+			+
Barbus lineomaculatus										+
Barbus kerstenii	+									+
Barbus neumayeri								+		
Barbus sp. 1									+	
Barilius loveridgei	+	+		+						
Labeo spp.	+	+	+	+	+	+	+	+		
Bagrus orientalis	+	+		+	+		+			
Synodontis maculipinna	+				+	+	+	+		
Synodontis matthesi							+			
Schilbe mystus				+	+	+	+			
Eutropius mobiusii	+									
Pareutropius longifilis	+									
Clarias mossambicus							+			+
Tilapia urolepis	+		+		+			+		
Tilapia zillii									+	
Haplochromis gr. '*bloyeti*'	+		+	+					+	
Total number of species	21	9	4	13	16	6	16	16	3	4
Total number of specimens	244	112	48	98	122	69	240	250	(434)	(296)

catches from the water reservoirs Nyumba Ya Mungu (NYM) and Hombolo.

During the first few years some new tropical reservoirs develop a rich fauna of aquatic invertebrates associated with periphyton (aufwuchs). Thus, in Kariba and Volta, the mayfly (*Povilla adusta*) nymphs and chironomids especially *Nilodorum*, colonized and burrowed into the submerged trees, and in Volta the vast quantities of ephemeropteran nymphs became an important food for fish such as *Alestes*, *Schilbe*, *Physailia* and the clupeid *Pelonulla* (Petr 1970, Reynolds 1970). The absence of *Povilla* among invertebrates collected from fish stomachs may indicate that it is not present in the river system. Only mud-inhabiting, burrowing ephemeropteran nymphs were found, but they will probably not spread into the lakes, as the mud there may be poorly oxygenated, at least during the first few years. However, in

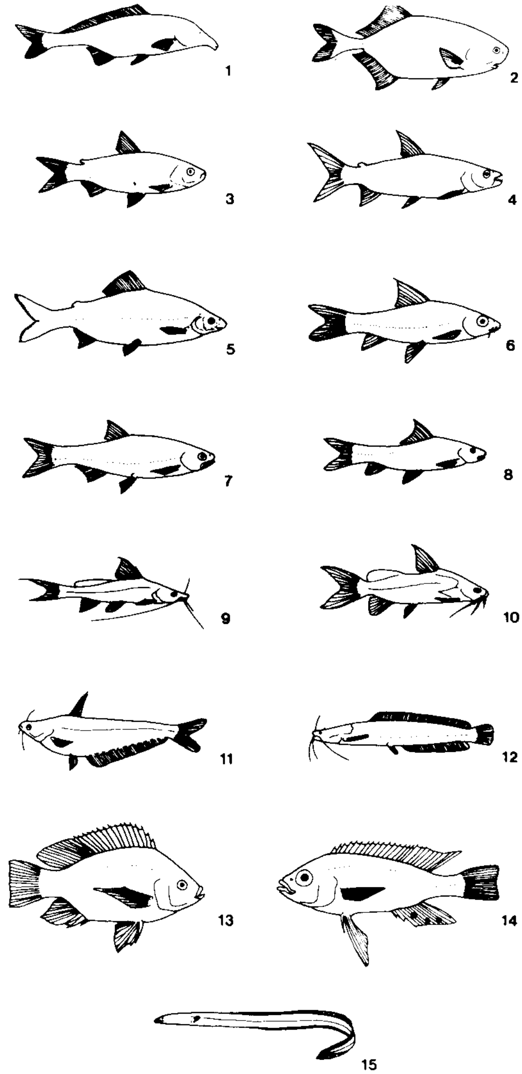

Fig. 56. General characteristics of some fish in the Great Ruaha river above Kidatu. 1. *Mormyrus*, 2. *Petrocephalus*, 3. *Alestes*, 4. *Hydrocynus*, 5. *Distichodus*, 6. *Barbus*, 7. *Barilius*, 8. *Labeo*, 9. *Bagrus*, 10. *Synodontis*, 11. *Schilbe*, 12. *Clarias*, 13. *Tilapia*, 14. *Haplochromis*, 15. *Anquilla*.

Nyumba ya Mungu man-made lake near Moshi (Fig. 55) *Povilla* was found by Dr. R. G. Bailey in 1974 (personal communication). It is possible that *Povilla* will colonize the Mtera reservoir, but in case of its failure to do so, the introduction of this periphytic algal and phytoplankton feeder should be seriously considered as it might provide insectivorous fish with an abundant food supply.

It is interesting to note that no traces of molluscs were found in fish stomachs. Crabs were eaten by fish only at Mtera (Station 9) and in the Ruaha near Kipengere Mountains (Station 12); no crabs were found below the Mtera area. Cladocera and Ostracoda were found only from the headwater swamp of the Little Ruaha, and did not appear anywhere else.

Fish

Matthes (1967), with the help of the Regional Fisheries Officer at Mbeya, surveyed the Great Ruaha River in September 1966, from near Mbeya (Mbeya–Iringa road) to its confluence with the Rufiji River. They also surveyed the Little Ruaha at Iringa and Kimande, and the River Lukusi. They captured 38 species, of which 25 were new records. Three species described by the fishermen were considered by Matthes also to be new records for the area.

A checklist of the non-cichlid fishes of the eastward-flowing Tanzanian rivers was prepared by Bailey (1969). He included in his paper all the previous literature dealing with the fish of this area.

A list of fish in the present survey (December 1971–April 1973) contains some species requiring further taxonomic studies (cp. Table 11). The general characteristics of some genera are illustrated in Fig. 56.

Altogether, 38 species were recorded, all caught in experimental gill nets from rivers. No pools, side arms, or ponds were fished. The smallest mesh size of 20 mm stretched mesh was too large to capture very small fish such as Cyprinodontidae, and perhaps some others, and the gill nets were evidently also unsuitable for the capture of smooth serpentine fish such as eels, which are probably present in the river. *Mastacembelus* may be present in the swampy region of the Little Ruaha headwaters (Station 11), but being a nocturnal species it was not captured, since this station was fished only during the day. *Clarias mossambicus* should certainly be more common than it appears from Table 13. The gill nets are not suitable for the capture of this species, which the commercial fishermen fish on hooks, and the sports fishermen with rods, especially in the Kidatu area.

Records of commercial fish landings are available for the GRR in the Iringa Region (Annual

Fig. 57. Great Ruaha river at station 8. Photo T. P.

Report 1970). A total of 81.9 metric tons of fish were caught there in 1970. During the present study very little commercial fishing was observed on the river, and the fishing pressure may be described as rather slight. This may be due to the sparse population of the area, but also to a low interest in fishing.

According to the Annual Report 1970, the following genera, in order of their abundance by weight, were commercially exploited: *Bagrus, Clarias, Mormyrus, Synodontis, Distichodus, Gnathonemus, Barbus, Labeo, Hydrocynus, Schilbe* and *Alestes*. Fish such as *Petrocephalus, Hippopatamyrus, Eutropius, Pareutropius, Tilapia* and *Haplochromis* are either too small, or too few in number and therefore not mentioned in the above report.

Some quantitative aspects of the fish distribution

The list of species for individual stations, as given in Table 11, to a certain extent reflects the intensity of the experimental fishing. Thus Stations 4 and 8 (Fig. 57) were fished only once, and also have the smallest numbers of species recorded. Stations 1, 10, 9 and 7 have the highest numbers of specimens, and correspondingly the highest numbers of species. Obviously the results may also be biased by changes in mesh size due to loss of nets during the sampling, and their replacement by the nearest size available. At high water-level not all nets were set, and they were left in the water for only a short time.

In experimental catches cyprinids dominated, forming 41% of the total biomass (Table 12). Among these, *Barbus macrolepis, Barbus paludinosus,* and *Labeo* spp. (with possibly 5 species involved) were the most common. Characids, dominated by *Alestes affinis,* were the second largest family. *Alestes affinis* gave the highest biomass of all the individual species. The few specimens of another characid, *Hydrocynus vittatus,* substantially contributed to the biomass due to the heavy weight of the specimens captured (Table 13). Citharinids were represented by several heavy specimens of *Distichodus*. Mormyridae, although including many

Table 12. The biomass of fish families in the middle course of the Great Ruaha River and its tributaries, December 1971–April 1973 (n=4) fished with a standard fleet of nets.

Family	Total biomass	%
Mormyridae	2 022.1	4.16
Characidae	14 045.5	28.86
Citharinidae	4 326.8	8.89
Cyprinidae	19 919.6	40.94
Bagridae	1 092.2	2.24
Mochocidae	776.1	1.59
Clariidae	1 644.3	3.38
Cichlidae	505.6	1.04
Total	48 661.5	100.00

species, made little contribution to the total weight of the catch, as did the rest of the families, such as Clariidae, Bagridae, Mochocidae and Cichlidae. It must be borne in mind that gill netting is not suitable for capturing *Clarias* (catfish) and *Anguilla* (eels), the latter being completely absent from experimental nets. Both fish may be quite common in the river.

Very few cichlids were caught and may be described as being of no commercial importance. But their presence in the river is of significance, because they are capable of rapid reproduction in new tropical lakes, and thus have a high commercial potential. Although only one specimen of *Tilapia esculenta* was caught in the GRR, this species nevertheless is present there, and is probably fairly common in pools and quiet backwaters from where it might spread into the new lakes. Our meagre knowledge of the ecology of *T. urolepis*, the fairly common riverine species, does not let us even guess whether this fish will be able to live in the new lakes.

In the commercial landings for the Great Ruaha (Annual Report 1970) the average catch per canoe was 1.4 tons/year. This is far less than would be expected from a lake of moderate size. In NYM at the peak of the fishing, i.e. in 1970, 3 years after impoundment, landings were from 11.3 to 28.2 tons/canoe/year (Fig. 58). This is 8 to 20 times more than landings from the GRR. In Hombolo dam, 3.5 tons/canoe/year were fished in 1972 (Annual Report 1972). These data indicate that a lake provides a higher yield per boat per year than a river.

There are considerable difficulties in fishing shallow rivers such as the GRR. Even disregarding the differences in size of nets applied at Hombolo, NYM, the GRR and the Little Ruaha,

Table 13. Feeding categories, standing crop and number of fish from the Great Ruaha River and its tributaries (middle course), December 1971–April 1973 (n=4), based on experimental catches. Feeding categories: 1=insectivore, 2=predatory, 3=omnivore, 4=plant feeder, 5=deposit feeder, 6=aufwuchs algae feeder.

Species	Feeding category	Total biomass (gm)	No.
Mormyrus longirostris	1	435.6	3
Gnathonemus livingstoni	1	688.9	27
Gnathonemus macrolepidotus	1	189.1	6
Gnathonemus sp.	1	179.8	7
Petrocephalus catostoma	1	17.0	4
Hippopatamyrus discorhynchus	1	250.8	43
Mormyrid sp. 1	1	30.5	6
Mormyrid sp. 2	1	230.4	5
Alestes affinis	3	8 580.4	297
Hydrocynus vittatus	2	5 465.1	23
Distichodus petersii	4	3 969.1	5
Distichodus rufigiensis	4	357.7	6
Barbus macrolepis	3	9 769.7	226
Barbus zanzibaricus	1	30.5	6
Barbus jacksonii	3	113.6	17
Barbus innocens	3	67.8	12
Barbus paludinosus	3	1 287.2	170
Barbus kerstenii	3	28.1	6
Barbus neumayeri	3	10.3	2
Barilius loveridgei	3	224.7	34
Labeo spp.	5	8 387.7	149
Bagrus orientalis	2	1 092.2	8
Synodontis maculipinna	3	4 075.6	26
Synodontis matthesi	3	253.7	2
Schilbe mystus	2	597.2	11
Eutropius mobiusii	1	52.5	6
Pareutropius longifilis	1	126.4	23
Clarias mossambicus	3	1 644.3	11
Tilapia urolepis	6	388.1	9
Haplochromis gr. *'bloyeti'*	3	117.5	33

Table 14. Comparison between 24 hours standing crop of fish in experimental gill-nets from riverine (GRR and LRR) and lacustrine (Nyumba ya Mungu and Hombolo) stations.

Station	GRR (St. 10)	GRR (St. 10)	LRR (St. 9)	
Date	20–21.6 1972	22–23.12 1972	13–14. 6 1972	
Biomass, gm/24 hours	4 652.3	12 443.7	4 795.7	
Nets applied (mm stretched)	20, 20, 30, 50 80, 100	20, 20, 30, 40 50, 80	20, 2C, 30, 50, 60, 80, 100	
Station	NYM-dam site (right bank)	NYM-dam site (left bank)	Hombolo	Hombolo
Date	2–3.6 1972	4–5.4 1973	17–18.6 1972	19–20.4 1973
Biomass, gm/24 hours	41 050.8	14 538.0	14 082.9	17 605.8
Nets applied (mm stretched)	20, 30, 40, 50 60, 80, 100	20, 40, 50, 70 100	20, 30, 50, 60 80, 100	20, 30, 40, 50, 70, 80

we still have an important source of error when comparing the fishing in rivers with that in lakes. Due to the current and to differences in depth over relatively short distances, the effective fishing area of nets in rivers is often considerably smaller than that of nets hanging freely in calm deep lake water.

The maximum 24 hours standing crop for NYM experimental gill netting was 41.1 kg (Petr 1974*b*), which is about 3.3 times more than the maximum standing crop for the GRR (Table 14). The lowest standing crop in NYM was about 3 times higher than the lowest riverine standing crop. Thus, there seems to be a factor of approximately 3 by which the experimental yield in the investigated river is smaller than the experimental yield in the investigated lake. The smaller fishing area of nets certainly must be responsible for a considerable reduction in the catch, but there may be other factors involved. Undoubtedly, there will be larger seasonal variations in rivers due to fish migration and higher patchiness of food distribution.

The trophic structure of the fish community

All the fish caught at the middle course Stations 1, 3, 4, 5, 7, 8, 9 and 10 were weighed, species by species, and their biomass was grouped according to feeding categories (Table 15). Each species was classified as to feeding category according to the dominant food item found in its stomach or gut. The insectivores are exclusively aquatic and terrestrial insect feeders, and the category does not separate the bottom from the surface feeders. Predators are fish feeding both on fish and insects. Plant feeding fish feed predominantly on higher plants, but aufwuchs algae are also consumed in small quantities. Aufwuchs algal feeders feed predominantly on algae, but may also take bottom deposits, especially plant debris. Moreover omnivores and deposit feeders were also

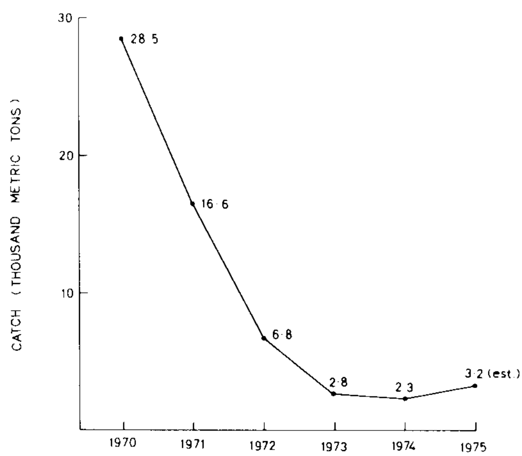

Fig. 58. Fish catch at the Nyumba ya Mungu reservoir 1970–1975. (From Natural Resources Division, Moshi).

Table 15. Feeding categories of fish for the Great Ruaha River and its tributaries middle course, December 1971–April 1973. Feeding categories: 1. insectivores, 2. predators, 3. omnivores, 4. plant feeders, 5. deposit feeders, 6. aufwuchs algae feeders.

Feeding category	Total biomass (gm)	%
1	2 231.5	4.59
2	7 154.5	14.70
3	26 172.9	53.79
4	4 326.8	8.89
5	8 457.7	17.38
6	318.1	0.67
Total	48 661.5	

assigned to separate groups. Thus six feeding categories have been established.

Some feeding categories, such as omnivores and insectivores, show consistency in their biomass in experimental nets throughout the observation period. Omnivores, which dominate all samples, and insectivores, which have one of the smallest biomasses, keep their biomass at a fairly constant level. There are large seasonal differences in the deposit feeders, which are dominated by *Labeo*. Its migratory habits, together with the fact that large numbers of small young specimens occur during certain seasons, result in considerable differences in the biomass of deposit feeders at different times of the year. To a certain extent, similar factors influence some of the omnivorous migratory fish, such as *Alestes affinis* and *Barbus macrolepis*, which form a considerable proportion of the total biomass. The occurrence of the omnivorous *Barbus paludinosus* in catches seems to be determined mainly by their habit of shoaling, so that they are sometimes numerous in one particular place and completely absent in another. Changes in the biomass within a particular feeding category may be expected to be greatest if it consists of only one or very few species, as in the aufwuchs algae feeders (*Tilapia urolepis*), predators (*Hydrocynus vittatus, Bagrus orientalis, Schilbe mystus*) and plant feeders (*Distichodus petersii* and *D. rufigiensis*).

The division into feeding categories does not indicate how much a particular food, for example algae, contributes to the total volume of food in species other than aufwuchs algae feeders. The analyses have indicated that algae are important for many omnivorous and deposit-feeding fish towards the end of the dry season, when algae are abundant on stones and driftwood. Thus, the importance of algae is much greater than is shown by the feeding category.

The riverine fish population is dominated by omnivores, followed by deposit-feeders and predators. This structure is different from that which may be expected to develop in the future lakes. If tilapias become common, the dominant feeding group will be plant eaters, feeding either on phytoplankton or plant detritus, or both. Herbivores dominated a number of tropical man-made lakes, such as Volta, Nyumba Ya Mungu and Hombolo. In Hombolo (Petr 1974*c*) there is a high biomass of bottom deposit feeders, represented by *Labeo*, and it is possible that this fish will also become very common in the new lakes on the GRR. Insectivores and zooplankton feeders may also become quite common, but this will depend on the presence of a suitable species of fish in the original fish fauna, and on the availability of abundant sources of food. The present surveys of the fish in NYM and Hombolo suggest that these lakes have no true pelagic fish (if *Tilapia* is not considered to be such) which would feed on plankton, and that the small species in Hombolo (*Haplochromis* and some *Barbus*) feed mainly on the aquatic insects of the littoral zone. In small lakes such as Hombolo these small fish are not exploited, but in L. Volta, L. Kainji and L. Kariba the introduced or endemic pelagic fish are now numerous and of increasing commercial importance. It is an open question whether the relatively shallow Mtera Lake will establish its own population of pelagic fish, either from its indigenous stock (if such species are present) or from a suitable introduced species. In large man-made lakes clupeids, originally riverine, developed huge pelagic populations, as in the Volta and Kainji lakes (Reynolds 1970, Lelek 1973). So far no clupeid is known to inhabit Ruaha waters. A small cyprinid, *Engraulicypris*, pelagic in Lake Victoria, was found in the GRR by Matthes (1967) and it would thus seem reasonable to expect that it will spread into the new lakes, especially into Mtera.

The fish fauna in the future reservoirs

In new man-made lakes the greatly enlarged space with a multitude of niches, the abundant food resources and the low predatory pressure lead to a fish population explosion. The limit to occupation of the total lake volume is the low content of dissolved oxygen in deeper water.

After one or two years, depending on the size of the lake, considerable changes take place. Fish species requiring a permanently high level of dissolved oxygen, as well as the perodicity of flooding (mostly to trigger their reproduction) concentrate at the inflows of rivers entering the reservoir. The riverine mormyrids usually withdraw from the impoundments, as they find the stagnant reservoir water unacceptable (Petr 1968*a*).

In man-made lakes such as Kariba and Volta, large sections of the lake came to be avoided. In the future Mtera lake one can assume that *Tilapia*, *Haplochromis*, *Labeo*, *Clarias* and some *Barbus* will stay in the lake while *Alestes*, *Schilbe*, *Eutropius*, *Pareutropius*, all mormyrids except perhaps *Mormyrus longirostris*, and probably even *Synodontis* will withdraw to the inflow areas. Even in the much smaller Kidatu lake there will probably be a distinct difference between the fish population in the dam area and that near the inflow.

The crucial question usually asked when the reservoirs are filling is: should additional fish species be introduced into the new lake?

Before introducing new species one should carefully consider the potential of the original fish stock: can it provide a fast breeding species capable of rapid colonization of the lake? *Tilapia* and *Haplochromis* soon dominate the new fish populations in tropical man-made lakes. In the Volta Lake, *T. galilaea*, *T. nilotica*, and the much less common *T. zillii*—all three of them present in the indigenous fauna of the river and its backwaters—became the dominant commercial fish within 2 years. In Lake Nyumba Ya Mungu, *T. jipe* and *T. pangani*, and the less common *T. esculenta*—all present in the original rivers and swamps—absolutely dominated fish catches by the 3rd year after the closure of the dam.

But some lakes may have a poor indigenous fish population. Hombolo Dam, constructed on the drying out Wami River, had poor original fish stock, so that tilapias were introduced (Mr. Mapunda, pers. comm.). In the Great Ruaha and its tributaries the only *Tilapia* regularly occurring in catches is *Tilapia urolepis*. The biology of this species is not well known, and it is rare in the river. Whether this species will adapt itself to the new lake cannot yet be predicted. It is possible that there are more species of tilapias in the backwaters, from where they may successfully colonize the lake. Tilapias of the Volta River formed less than 1 per cent of the commercial catches, but in Volta Lake, formed from this river, they constituted more than 60 per cent of all fish landed three years after closure of the dam (Petr 1968*b*).

Table 16. Surface areas and fish catches in existing and proposed reservoirs. (*Bailey 1965, all other data from annual reports.)

Reservoir	Surface area		Catch (lb/acre/year)
	Hectares	Acres	
Hombolo	1 720	3 800	94 (1965)*, 240 (1970) 99 (1972)
Nyumba ya Mungu	18 500	37 000	770 (1970) 318 (1971)
Mtera	58 500	128 700	–
Kidatu	1 000	2 200	–

Small fish of the GRR were poorly represented in this study, as the fishing method used caught only larger specimens. It is possible that some species of small fish were never caught. There is an example from Volta where the clupeid *Pelonulla afzeliusi* was never recorded from the river, but within 3–4 years was found to be very common throughout the new man-made lake (Reynolds 1970). Similarly, clupeids became very abundant in Lake Kainji on the Niger River (Lelek 1973).

All this indicates that the introduction of fish into new man-made lakes should be considered only in the second or third year after the closure of the dam, when the indigenous fish population has differentiated into lake species, lake-river transition species, and purely riverine species. Furthermore it is possible that even much later, an indigenous fish may invade the lake, where the vacant niche was filled by an introduced exotic fish. In Lake Kariba the characid *Alestes lateralis* has become an increasingly common pelagic species, probably now competing with the introduced clupeid *Limnothrissa miodon* (Balon 1971).

The construction of the dam at Kidatu may affect the migration of certain fish species, such as *Anguilla* (eel), *Labeo* spp. and *Barbus macrolepis*. Although no eels were caught during this study they are known to frequent the GRR (Matthes 1967). The construction of dams may result in their extinction in the GRR and LRR above Kidatu. It is quite possible that the elvers migrating upstream may climb the spillway as do those in Lake Kariba. Although absent from the surface waters of Lake Kariba, deep water fishing revealed that the fish is fairly common at 25–40 m depth (Balon & Coche 1974). Eels will probably continue their migrations into the Rufiji and its tributaries.

The present study indicates that *Labeo* and *Barbus macrolepis* migrate upstream to spawn during floods, with *B. macrolepis* evidently migrating to the upper reaches of the GRR, and probably also to the upper waters of some of its tributaries. *Labeo* females with ripe gonads were found only in the upper part of the middle reaches of the GRR. After the construction of the Mtera dam this fish may carry out its spawning migration from the Kidatu lake upstream to Mtera, or into some of the smaller rivers such as Yovi and Lukusi. Mann (1969) suggested that lateral rather than longitudinal migration is probably critical for *Labeo*, and cited the presence of reproducing populations of *Labeo* both below and above Merilla man-made lake on the Tana River in Kenya.

No other fish seem to undergo migrations from the lowest station upstream, probably because they are unable to overcome the turbulent Kidatu Gorge. For the majority of species females with ripe gonads were found at the lowest station indicating that spawning may take place there.

Most of the riverine fish species will stay in the upper reaches of the lakes affected by the inflowing rivers. But the new lakes may be expected to have a number of lacustrine species soon. Spawning of the riverine fish may be expected to take place on the flood plains of the GRR or the small rivers between Kidatu and Mtera. With the regulation of the river below Mtera and Kidatu there will be little seasonal difference in the flow in these stretches. However, these areas may still exhibit some seasonal changes as they will be affected by floods from smaller rivers such as the Lukusi and the Yovi. The fish population below Kidatu may migrate for spawning to the Rufiji and its tributaries, but at least some of the fish will certainly enter the GRR afterwards. It is probable that some fish will continue to spawn in the GRR below Kidatu, even when the river flow is regulated.

With the establishment of two new reservoirs on the GRR, fishing activities will expand and catches are expected to increase substantially. Before the construction of the Nyumba Ya Mungu dam it was suggested that the future lake might yield 500 to 1 000 ton/year of fish (Bailey 1965). In 1970 the annual yield was 28 508 tons, but this was followed by a rapid decline in fish catches (Fig. 58). This reduction of the catch seemed to reflect a combination of sociological and biological factors (Petr 1975). At present it is difficult to predict the fish production for Mtera. The lake will be about three to four times larger than Nyumba Ya Mungu (Table 16), but larger lakes usually give a lower harvest per unit area since the deep water further out is less productive than the shallows, and the number of boats suitable for offshore fishing is usually inadequate. However, Mtera will be a shallow reservoir, and may therefore become reasonably productive even in the offshore areas. It will probably take two to three years before fishermen settle around the lake and develop the fisheries, and by that time the fish may have established a strong lake population. The yield will depend on the fishing pressure, which may be expected to be similar to that on Nyumba Ya Mungu, where in 1971, i.e. five years after the impoundment of the area, about 3 300 fishermen were engaged in fishing. A harvest of some 15 000–30 000 tons of fish/year could be obtained at the peak of the lake's productivity, i.e. between the third and sixth years, if the indigenous fish fauna is capable of explosive development. Detailed observations should be made of the changes in the fish population from the very beginning, and if during the second year there is an indication of failure of indigenous fish such as cyprinids and cichlids, introduction of other fish should be seriously considered.

The much smaller Kidatu reservoir, with only 2.23 per cent of the area of Mtera and with a relatively small storage capacity, may harbour both riverine and lacustrine fish species. Cichlids may not favour the Kidatu lake, where considerable areas may be occasionally exposed by an intensive draw-down, especially before the Mtera dam is completed. Cyprinids and catfish may find the lake more favourable, and provide the basis for the fishery.

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