Back to links page

CONTENTS

VOLUME II
Technical Reviews

Back to Contents

CHAPTER 7
FRESHWATER FISHES OF THE ZAMBEZI BASIN

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7.1 INTRODUCTION

The Zambezi is the largest African river flowing into the Indian Ocean, draining a basin of around 1.2 to 1.5 million km^2 (estimates vary; Davies 1986). The modern river basin is the result of various geological processes that occurred during the Quaternary, which include a dramatic series of river captures, the deposition of wind-blown sands in the western part of the basin, the formation of the Rift Valley, and the rejuvenation of the erosion cycle in the eastern part. These forces have influenced its fish fauna and contributed to its present diversity (about 160 species) in the river system proper plus several hundred endemic cichlids in Lake Malawi (Bell-Cross 1972, Jackson 1986, Skelton 1994).

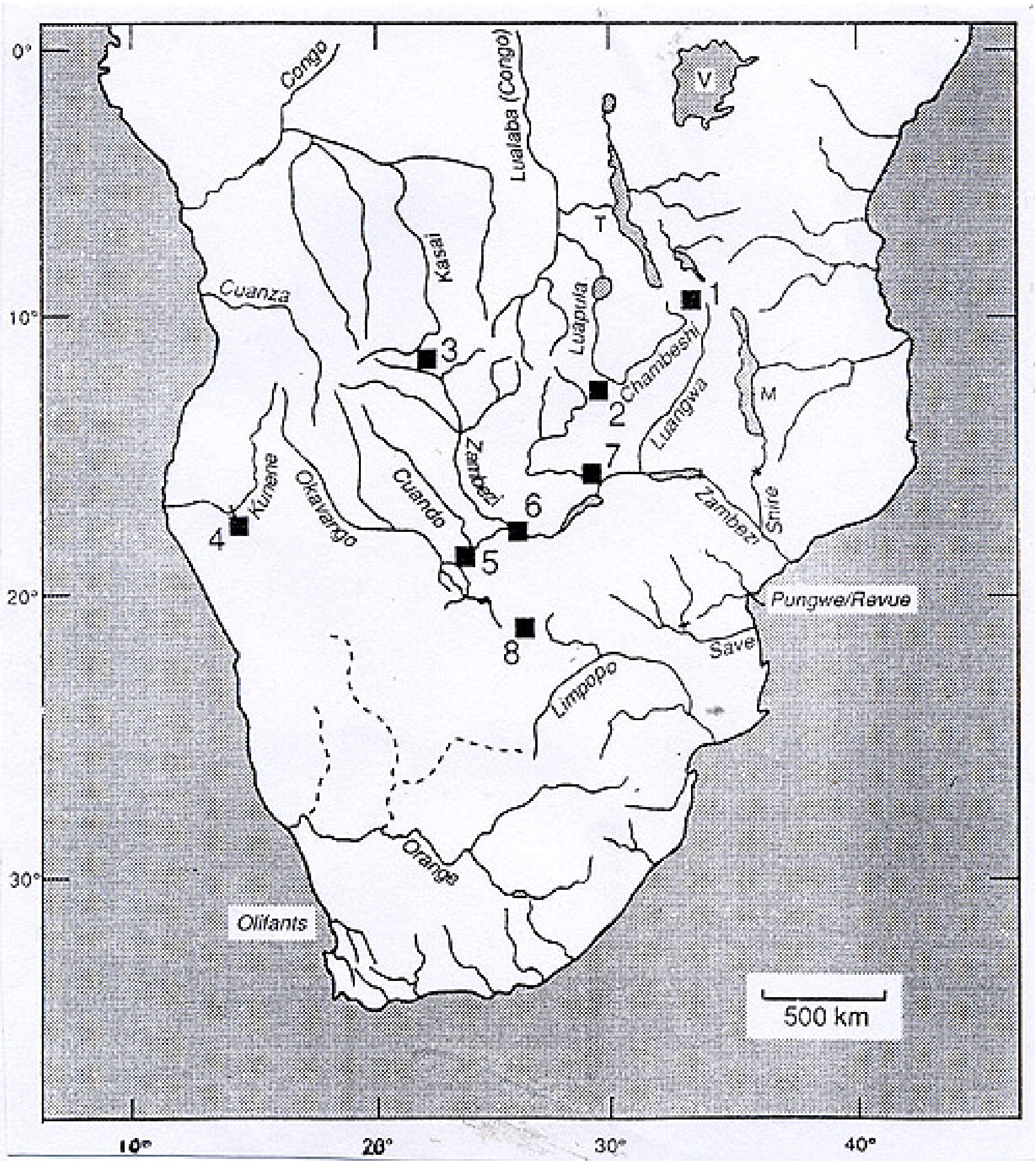
The Zambezi-Congo watershed forms a natural zoogeographical boundary that marks the northern limit of the Zambezian ichthyological province (Roberts 1975). This includes areas that were once part of the Zambezi system, such as the Cunene and Okavango basins, or the Limpopo system. Fish in the east coast rivers from the mouth of the Zambezi south to the Phongola, in northern Kwazulu-Natal, are also a part of the Zambezian system since they have been connected in various ways with the Zambezi itself. The fish populations of these rivers also include elements of the east coast fauna and they are a major component of the fauna of the Middle and Lower Zambezi as well. Some understanding of the evolution of the system and the zoogeography of the fish is essential in understanding its biodiversity and this issue is addressed in the following section.

7.2 THE ORIGIN AND ZOOGEOGRAPHY OF ZAMBEZIAN FISHES

A fundamental question in biology is why are there so many species of living things? In searching for the answer biologists need to know what determines the distribution of these species and why they occur in some areas and not others. The discipline of biogeography deals with these matters using evidence from many disciplines, including biology, geology, palaeontology and geography. This paper gives an introduction to the zoogeography of the fishes of the Zambezi Basin and it draws heavily on Skelton (1993, 1994), which should be referred to for further information.

The land surfaces of today represent the end of an immensely long period of geological activity. In the last 100 million years southern Africa has been subjected to major geological processes like the formation of the Rift Valley and associated fault systems that caused the Zambezi and Luangwa valleys. The western parts of the basin have been relatively stable over a long period of time, but the eastern parts have been subjected to considerable change, including uplifting that initiated a series of erosion cycles. In parts of Zimbabwe, for example, uplifting led to six cycles of erosion (Lister 1979) in which the eastern highlands were uplifted several times while the western Kalahari basin remained relatively static. These cycles allowed westward erosion by east coast rivers like the Limpopo and Zambezi, which captured several formerly southward-draining rivers. River capture is one of the most important geological influences on fish distribution and several major river captures in southern Africa (Figure 7.1) have influenced the distribution of fish.

Figure 7.1 The major river systems of southern Africa. The principal river captures, which are indicated by the symbol ■, are as follows: 1, the ancient link between the Upper Congo and Luangwa/pre-Lake Malawi systems, possibly via Lake Rukwa; 2, the Chambeshi-Kafue link severed by the Luapula; 3, an Upper Zambezi tributary captured by the Kasai; 4, the southward flow of the Cunene disrupted after capture by a west-flowing stream; 5, the Kwando-Okavango connection severed by tectonic movements that divert the Kwando into the Zambezi; 6, the Upper Zambezi captured by the Middle Zambezi following rejuvenation of the erosion cycle; 7, the Kafue captured by the Middle Zambezi; 8, the former link between the Upper Zambezi and Limpopo systems broken by the diversion of the former and the infilling of the Kalahari Basin. T = Lake Tanganyika, V = Lake Victoria and M = Lake Malawi.



Fish cannot move overland or live out of water for any length of time and this restricts the ways in which they can move from one river system to another. Changes in the direction of river flow, either because of earth movements or by river capture, are among the most important. Falling sea levels are also important since the courses of rivers that currently discharge separately into the sea often join at a lower sea level. For example, the Pungwe, Buzi and Zambezi rivers were probably connected when the sea level fell during the last Ice Age. The Zambezi and Pungwe are still connected by low-lying wetlands and these coastal connections must have been more extensive when the climate was wetter than it is today. Furthermore, a wetter climate may also have allowed fish to cross from one watershed to another, provided suitable marshy areas existed. Fish have been seen to move across the Congo-Zambezi watershed in this way (Bell-Cross 1965).

7.2.1 **The major fish groups**

Fish are the oldest true vertebrates and jawless fish (Agnatha) first appeared in the Silurian era (320 million years BP). They flourished for about 40 million years but most of them had disappeared by the end of the Devonian. About 60 or so species of these fish still survive today but none of them occur in Africa. The Devonian era (300 million years BP) is often called "the age of fish" since four distinct forms of jawed fish originated during this period. Only two of them have survived and flourished to the present day. The cartilaginous fish (Elasmobranchs), which include the sharks and rays, are a marine group and are found in all the oceans. A few species penetrate freshwater and one of them, the Sawfish, *Pristis microdon*, has been collected in the Lower Zambezi and the Zambezi Delta (Bell-Cross 1972). A second species, the Bull Shark, *Carcharhinus leucas*, has been taken in the Zambezi at Tete and some of its tributaries, like the Ruenya River just before the Zimbabwean border. It is said to have been taken at Chirundu (Bell-Cross & Minshull 1988), but this record is not listed in earlier books (Jubb 1960, 1967, Jackson 1961a) and it may never, in fact, have penetrated the Zambezi beyond the Cabora Bassa Gorge.

In the early Devonian, the bony fish (Osteichthyes) produced two quite distinct and possibly unrelated lineages. The first of them, the lobe-finned fish (Crossopterygii) are the ancestors of the terrestrial vertebrates. They were abundant in the Devonian but their numbers decreased after that and today they are represented only by the coelacanth and the lungfishes. The coelacanth *Coelacanthus granulatus* from the Karoo sediments of Zimbabwe, is one of the few named fossil fishes from the basin and, unusually, it was found in sediments deposited in freshwater, while all other coelacanths, including the only living species, lived in the sea (Bond 1973). The lungfish were once distributed on all continents but now have a relict distribution in Australia (1 species), South America (1 species) and Africa (4 species). One of the African species, *Protopterus annectens*, occurs in the Middle and Lower Zambezi valley while another, *P. amphibius*, is found in the floodplains of the Lower Zambezi.

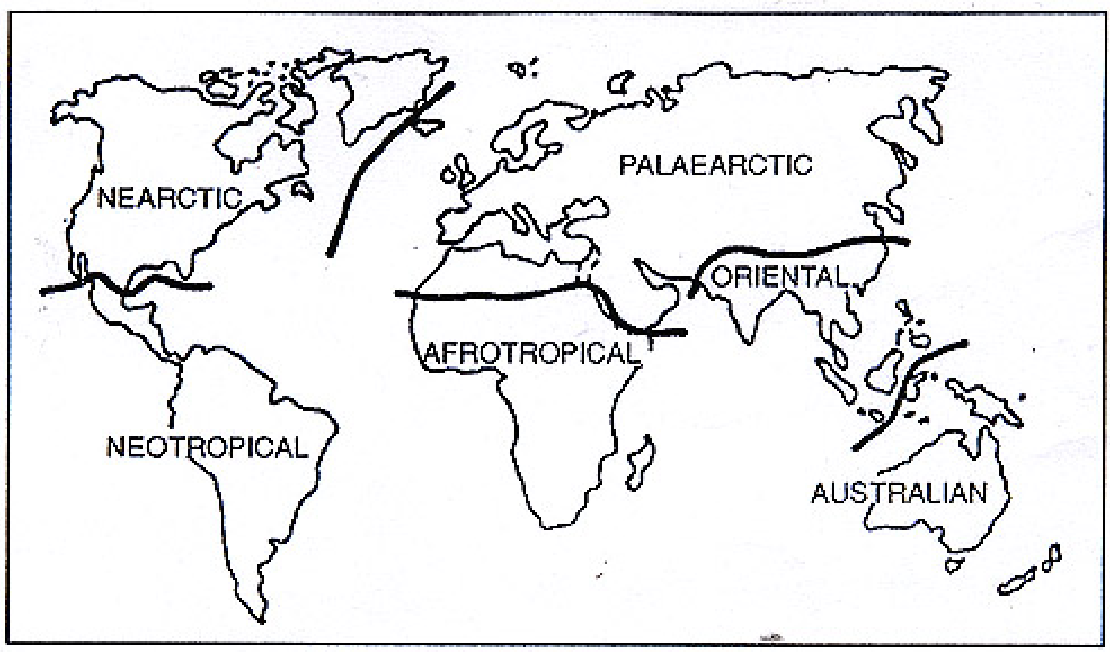
The largest and most diverse vertebrate group, with some 20,000 species, is the ray-finned fish (Actinopterygii). They come in an astonishing variety of body forms and are found in almost any water that can support fish. These range from the furthest depths of the ocean to high mountain lakes, and include inhospitable environments like hot springs and temporary pools. One of the other named fossil species found in the basin, *Namaichthys molyneuxi*, which lived in Zimbabwe about 250 million years ago (Bond 1973), is a representative of one of the most ancient bony fish groups, the Palaeoniscoidea. Primitive forms like the palaeoniscids were progressively replaced by more advanced ones during the 200 million years between the Devonian and the mid-Cretaceous. Only a few archaic bony fish have survived to the present time and none occur in the Zambezi system.

The most advanced group, the Teleostei, first appeared in the fossil record in the mid-Jurassic (130 million years BP) and by the mid-Cretaceous (90 million years BP) they had become the most abundant and successful group of bony fish. The radiation of the teleosts coincided with a period of rapid continental drift and their distribution and evolution was greatly influenced by this activity.

7.2.2 **The influence of continental drift**

In 1876 Alfred Russell Wallace divided the world into six major zoogeographical regions on the basis of their distinctive fauna that included a number of families unique to each (Figure 7.2). Although he could not have known it at the time, Wallace's regions reflect the way in which the continents moved during the last 150 million years. The linkages between the families of freshwater fishes of Africa and those in other continents clearly reflect the impact of continental drift.

Figure 7. 2 The principal zoogeographic regions of the world, after Alfred Russell Wallace. The River Nile has enabled African fish to penetrate Egypt and the Levant, and these areas could be treated as extensions of the Afrotropical.



About 150 million years ago the single supercontinent of Pangea began to break into Laurasia (North America and Eurasia) and Gondwanaland. This early split is reflected by the fact that only two Zambezian families of fish are also found in the Palaearctic and Nearctic regions (Table 7.1). One of them, the Cyprinidae, is the largest family of freshwater fish with more than 1600 species occurring throughout North America, Eurasia and Africa.

The break-up of Gondwanaland began about 70 million years ago. Australia was the first to be isolated from the rest and only one family, the Galaxiidae, occurs in both the Afrotropical and Australian regions. The sole African galaxiid species is restricted to the southern Cape and does not occur anywhere else on the continent. South America seems to have broken away next and only two families of Zambezian fish also occur in the Neotropical. The Characidae, which include well-known species like the African tigerfishes and the South American piranhas, are most diverse in the Neotropics and may have prevented the cyprinids from invading South America. The Cichlidae,

Table 7.1 The families of fish found in the Zambezi Basin and their wider distribution. N = number of species in family in the basin, FW = freshwater, M = marine.

		Afrotropical	Oriental	Neotropical	Palaearctic	Nearctic	Australian	N	Origin
Protopteridae	Lungfish	■						2	FW
Mormyridae	Snoutfish	■						9	FW
Kneriidae	Knerias	■						4	FW
Cyprinidae	Carp, barbs	■	■		■	■		46	FW
Distichodontidae	Citharinids	■						5	FW
Characidae	Characins	■		■				6	FW
Hepsteidae	African pike	■						1	FW
Claroteidae	Claroteid catfish	■						1	FW
Amphiliidae	Amphiliid catfish	■						4	FW
Schilbeidae	Butter catfish	■	■					2	FW
Clariidae	Air-breathing catfish	■	■					7	FW
Malapteruridae	Electric catfish	■						1	FW
Mochokidae	Squeakers	■						13	FW
Aplocheilidae	Killifish	■	■					4	FW
Cyprinodontidae	Topminnows	■	■		■	■		4	FW
Cichlidae	Tilapias, bream	■	■	■				31	FW
Anabantidae	Climbing perch	■	■					2	FW
Mastacembalidae	Spiny eels	■	■					3	FW
Anguillidae	Eels	■	■	■	■	■	■	4	secondary FW
Gobiidae	Gobies	■	■	■	■	■	■	2	secondary FW
Megalopidae	Tarpons	■	■	■	■	■	■	1	M
Eleotridae	Sleepers	■	■	■	■	■	■	2	M
Ambassidae	Glassies	■	■	■	■	■	■	2	M
Mugilidae	Mullets	■	■	■	■	■	■	2	M
Syngnathidae	Pipefish	■	■	■	■	■	■	2	M
Monodactylidae	Moonies	■	■	■	■	■	■	2	M
Sparidae	Sea bream	■	■	■	■	■	■	1	M
Carcharhinidae	Sharks	■	■	■	■	■	■	1	M
Pristidae	Sawfish	■	■	■	■	■	■	1	M

which include the tilapias and their allies, are most diverse in Africa and also extend into Asia with a few species in the Middle East and India.

Cichlids are one of eight families that occur in southern Asia as well as in Africa. The link between the Afrotropical and Oriental regions seems, therefore, to be rather stronger than the link between the Afrotropics and the Neotropics. Other families that occur in both regions include the air-breathing catfishes (Clariidae), many of which are similar to the well-known African catfish, *Clarias gariepinus*, the climbing perch (Anabantidae) and the spiny eels (Mastacembalidae).

Most of the evolution of African fish over the last 60 million years or so took place within the continent. Consequently, half of the fish families found in the Zambezi Basin are of African origin and are found nowhere else. Madagascar evidently broke away from Africa before this radiation took place and only three Zambezian families also occur on that island.

Finally, another eight families are of marine origin and have a global distribution in all oceans. Two goby species (Gobiidae) are found in the Zambezi and breed in fresh water. Four species of eels (Anguillidae) occur in the system but they breed at sea after spending up to 15 years in rivers and streams. The remaining six families represent estuarine species (including the shark) that occasionally penetrate fresh water and all have been collected in the lower reaches of the Zambezi.

7.2.3 **Post-Gondwana dispersion**

The freshwater fish fauna of the Zambezi Basin is made up of two major elements, the Zambezian and the East Coast. These elements evolved during the early Tertiary (about 50-60 million years BP) when the drainage patterns of southern Africa were quite different from those of the present (Figure 7.3a). The Zambezian fish fauna arose and evolved in the area of Upper Zambezi as it was then. This includes the present-day Cunene, as well as the Upper Kasai and the Chambeshi that were formerly part of the system but were later isolated through river capture. The Blotched Catfish, *Clarias stappersii*, is an example of a species whose distribution reflects its Zambezian origin (Figure 7.3b). The East Coast fauna lived in the then relatively short rivers that drained into the Indian Ocean. A few species, like the East Coast Barb, *Barbus toppini*, still retain this distribution (Figure 7.3b). Most others have been greatly modified, principally by penetrating inland along the Zambezi and Limpopo rivers.

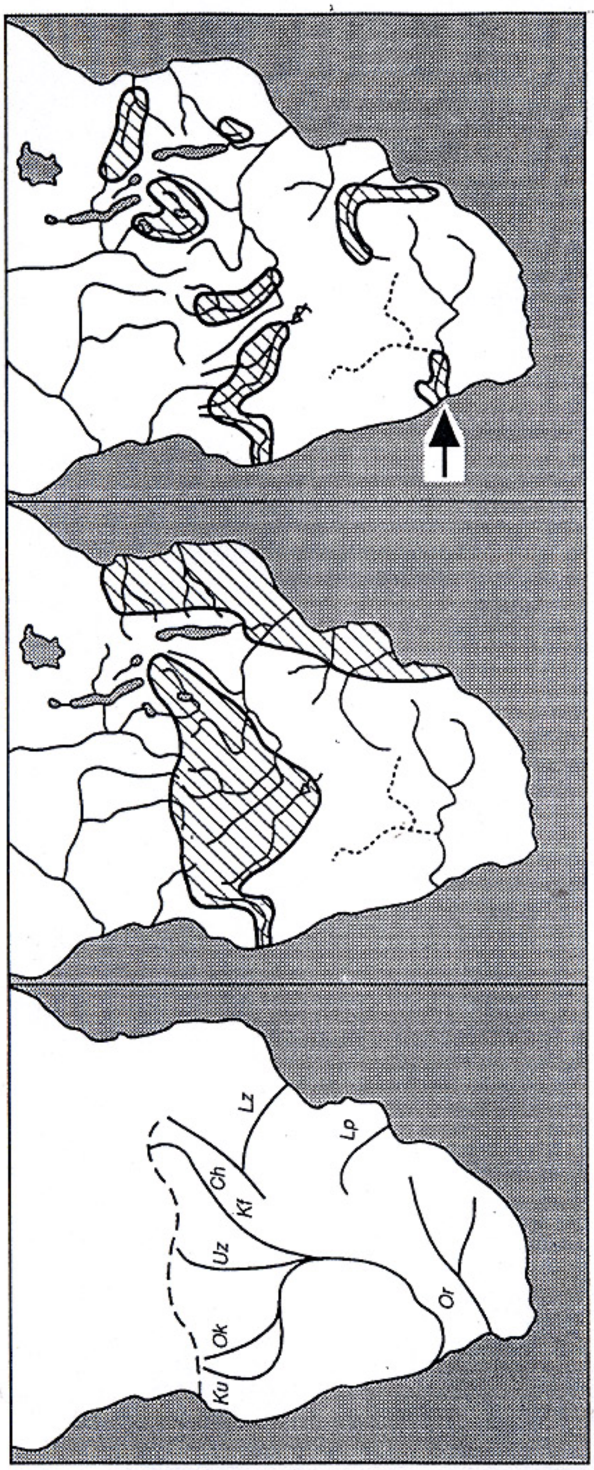
During this time, the Zambezi evidently drained into the Atlantic Ocean somewhere near the present-day mouth of the Orange River. Supporting evidence for this is provided by some species with a universal distribution in southern Africa or others like the River Sardine, *Mesobola brevianalis*, which has a fragmented but widespread distribution. It includes an isolated population in the Lower Orange (Figure 7.3c) which probably dates from the time the Zambezi discharged in this area.

Drainage patterns changed dramatically during the mid-Tertiary (about 20-30 million years BP). The course of the Upper Zambezi was diverted from the south to the southeast, i.e. from the Orange to the Limpopo. This event seems to have coincided with the infilling of the Kalahari basin (Figure 7.4a). The link between the Kafue and Chambeshi rivers was severed when the Chambeshi was captured by the Luapula to become part of the Congo drainage. The connection between the Kafue and the Upper Zambezi was severed when the former was captured by the Middle Zambezi. Evidence that the Zambezi once flowed to the Indian Ocean via the Limpopo is provided by the distribution of some Upper Zambezi fish in the Limpopo, such as the River Sardine (Figure 7.3c)

Figure 7.3 (a) Drainage patterns in southern Africa during the early Tertiary. Ku = Cunene, Ok = Okavango, Uz = Upper Zambezi, Kf = Kafue, Ch = Chambeshi, Lz = Lower Zambezi, Lp = Limpopo, Or = Orange.

(b) The typically Zambezian distribution of the Blotched Catfish, *Clarias stappersii* (left), which includes the Cunene, the upper Kasai and the Lake Bangweulu/Chambeshi system, and the typical east coast distribution of the East Coast Barb, *Barbus toppini* (right).

(c) The distribution of the River Sardine, *Mesobola brevianalis*; the isolated population in the Lower Orange (arrow) suggests an ancestral link with the Zambezi via the Kalahari.



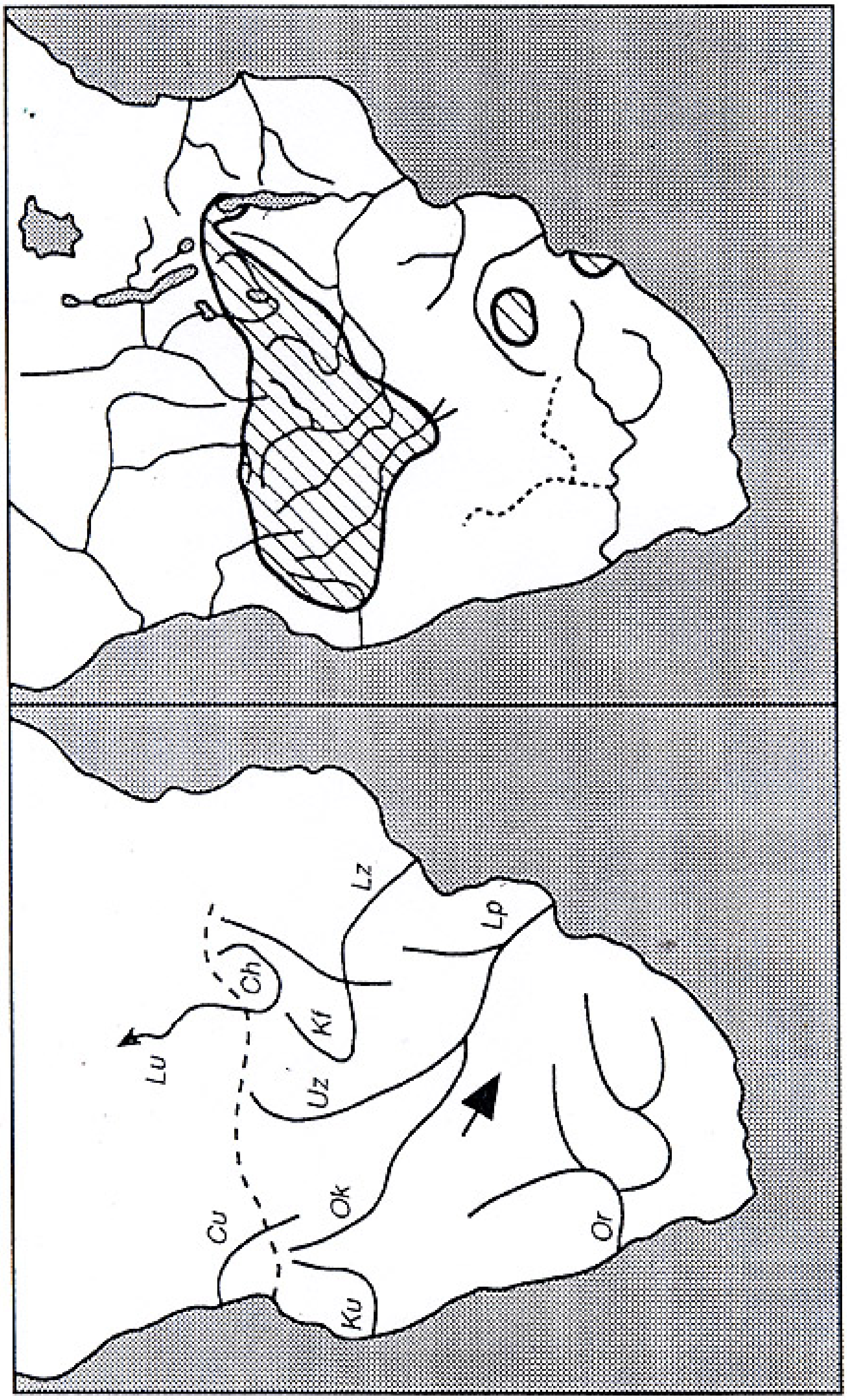
7.3(c)

7.3(b)

7.3(a)

Figure 7.4 (a) Drainage patterns in southern Africa during the mid-Tertiary. Abbreviations as in Fig. 7.3, plus Cu = Cuanza, Lu = Luapula.

(b) The distribution of the Hyphen barb, *Barbus bifrenatus*, showing its presence in rivers now isolated from the Zambezi, a relic of the former Zambezi-Limpopo connection.



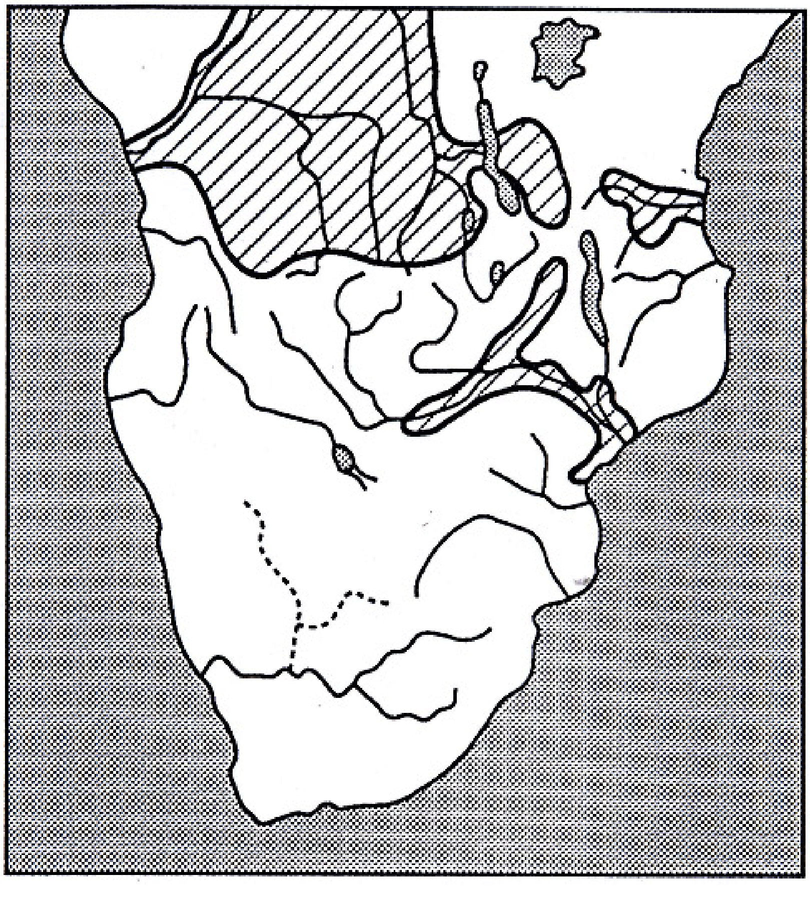
7.4(b)

7.4(a)

and the Hyphen Barb, *Barbus bifrenatus*. The latter are widespread in the Upper Zambezi and occur in the Cunene, Cuanza, Kafue and Chambeshi rivers, all streams isolated from the Zambezi by river capture. In the south an isolated population in the high-altitude tributaries of the Limpopo reflects the former connection between the two systems (Figure 7.4b).

The Hyphen Barb also occurs in the upper reaches of Lake Malawi and there was evidently a connection between the Chambeshi, the Congo and the Lower Zambezi systems in this region. The exact nature of this connection is unclear since the tectonic movements that formed the Rift Valley have obscured the evidence. Nevertheless several Upper Zambezi and Congo fish species have reached the Lake Malawi system by this route, while others have reached the Middle and Lower Zambezi, possibly via the Luangwa. They include well-known species like the Manyame labeo, *Labeo altivelis*, and the Vundu, *Heterobranchus longifilis* (Figure 7.5).

Figure 7.5 The distribution of the Vundu, *Heterobranchus longifilis*, a Congo species that was able to colonize the Middle and Lower Zambezi from the north.



The connection between the Zambezi and the Limpopo was severed in the late Tertiary when uplift during the Pliocene (about 5 million years BP) rejuvenated the erosion cycle, enabling the Middle Zambezi to capture the Upper Zambezi, creating the Victoria Falls and the Batoka Gorge (Figure 7.6a). This enabled a number of Upper Zambezi fish to colonise the Middle and Lower sections of the river. The Sickle-fin Barb, *Barbus haasianus*, found in the Upper Zambezi and the Chambeshi as well as the Lower Zambezi, Lower Shire and Pungwe rivers, is an example (Figure 7.6b).

Figure 7.6 (a) Evolution of the modern drainage pattern in southern Africa during the late Tertiary, with the capture of the Upper Zambezi by the Middle Zambezi. Abbreviations as in Figs. 3 and 4, plus Lm = Lake Malawi. The broken line indicates the ancestral Zambezi-Congo watershed.

(b) The distribution of the Sickle-fin barb, *Barbus haasianus*, an Upper Zambezi species that was able to reach the floodplains of the Lower Zambezi.

(c) The southern distribution of the Tigerfish, *Hydrocynus vittatus*, another invader of the Middle Zambezi. It was unable to reach the Kafue or Lake Malawi because of physical barriers to its upstream movement.

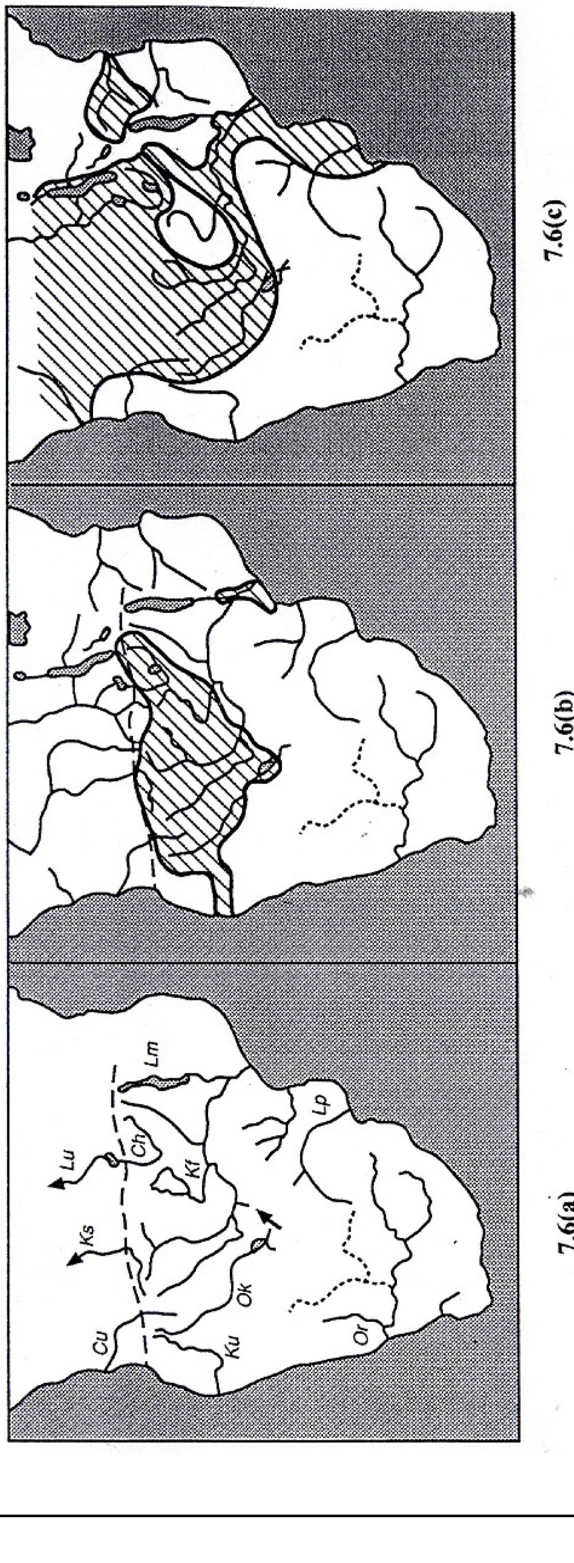
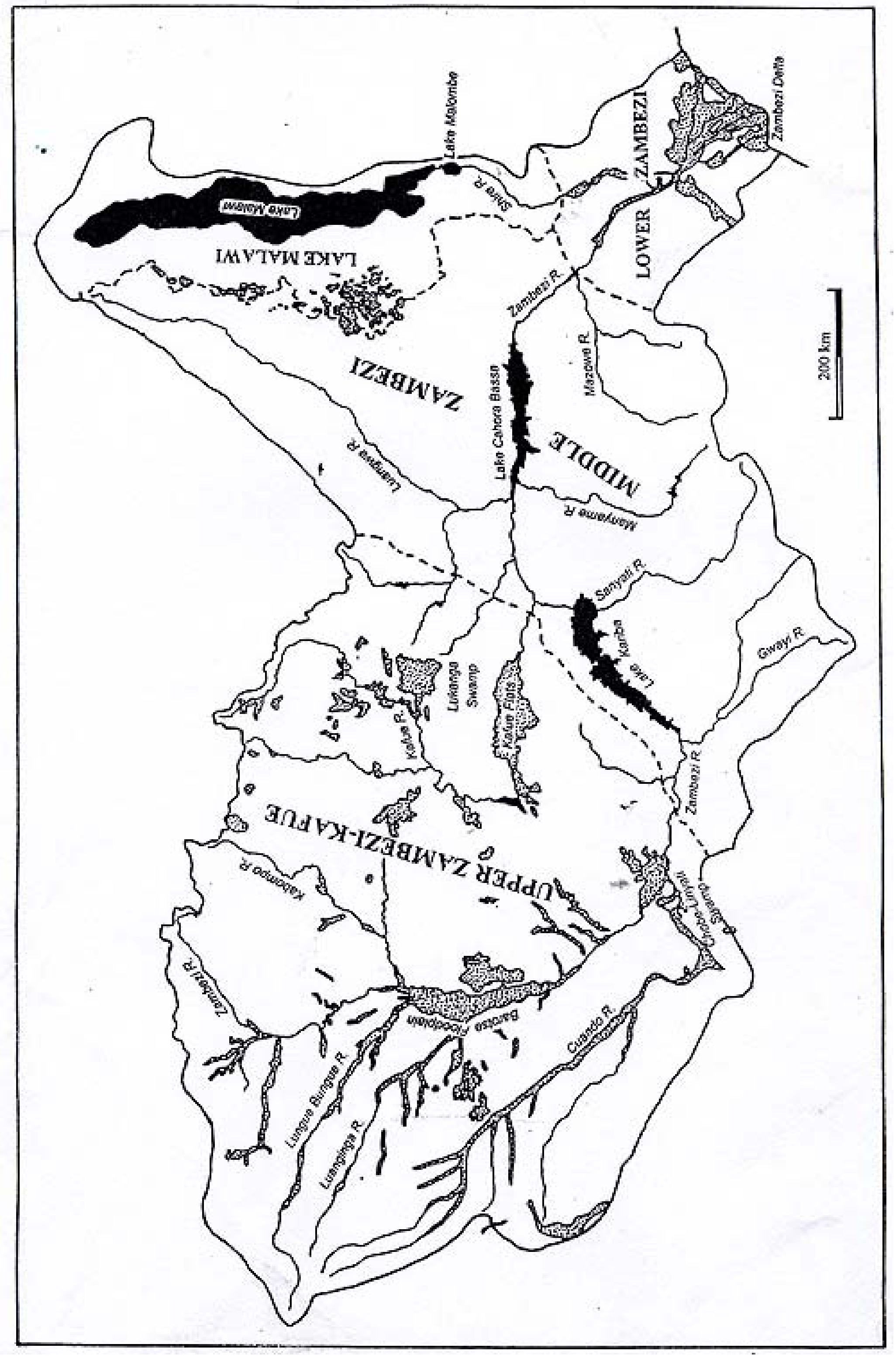


Figure 7.7 The Zambezi Basin and its four major ichthyological divisions. The principal floodplains and wetlands are indicated by stippling, while the larger lakes and reservoirs are indicated by black shading. Based on a map drawn from data in Hughes & Hughes (1992). Note that the Okavango system is excluded, but it resembles the Upper Zambezi-Kafue by having extensive wetlands and floodplains.



The interrupted distribution of the Sickle-fin Barb came about because of its habitat preferences. It is a species that inhabits swamps and floodplains. These are widespread in the Upper Zambezi but absent in the lower river except along the coast and along the Lower Shire. Here the Sickle-fin Barb has been able to establish itself. One reason why the Middle Zambezi was so inhospitable to many Upper Zambezi species was a lack of vegetation growing in the water. This made them vulnerable to predation by the Tigerfish, *Hydrocynus vittatus*, itself an invader (Figure 7.6c). After the capture of the Upper Zambezi, it colonized the river downstream and its major tributary, the Luangwa and spread southwards into rivers of the east coast. The tigerfish could not invade the Kafue or go up the Shire into Lake Malawi because waterfalls on these rivers prevented them from moving upstream.

7.3 ICHTHYOLOGICAL REGIONS OF THE ZAMBEZI

The hydrological basin of the Zambezi can be divided into four principal ichthyological regions, each with its own distinctive fish species and families (Figure 7.7). The fish fauna in some other areas is still dominated by fish of Zambezian origin even though they are no longer linked hydrologically to the Zambezi system. The nature of these regions, and the evolution of their fish fauna, has been described in detail elsewhere (e.g. Bell-Cross 1972, Bowmaker, Jackson & Jubb 1978, Jackson 1986, Skelton 1994).

7.3.1 **The Upper Zambezi-Kafue system**

The Zambezi Basin can be divided into two distinct regions by a line extending from the Victoria Falls north-eastwards along the northern escarpment of the mid-Zambezi valley in Zambia to the northern watershed of the Luangwa. To the north and west of this line lie the drainage basins of the Upper Zambezi and Kafue rivers, the first of its four ichthyological regions. These rivers drain one of the most ancient African land surfaces that has been subjected to rather gentle pressures over millennia, leading to gradual uplift and subsidence and resulting in a landscape of "swells and depressions" and low relief (Handlos 1982). The gradients of the main rivers are gentle; the Zambezi falls by only 500 m over a distance of 1080 km from its source to the Victoria Falls (Davies 1986), while the Kafue falls by 380 m in the 1500 km between its source and the Kafue Gorge (Handlos 1982).

This topography, combined with relatively high rainfall, has produced extensive swamps and floodplains that regulate the flow of the rivers so that they seldom exhibit large variations in height. The floodplains have water on them for long periods, while the low water flows are of relatively short duration. Marginal vegetation is abundant and provides cover for small fish species, and juveniles of larger ones. These rivers have been termed "reservoir" rivers (Jackson 1986) and favour the evolution of fish species. Consequently, there are more fish species in the Upper Zambezi than in any other part of the system, except for Lake Malawi, and many of them are adapted to living in marshes.

Special features of the fish fauna include a radiation of serranochromine cichlids in the genera *Serranochromis* (6 species) and *Sargochromis* (5 species) and of mochokid catfishes in the genus *Synodontis* (7 species), while there is a larger number of small cyprinids and characids compared to the rest of the river. Other distinctive fish in this basin include the African Pike, *Hepsetus odoe*, two anabantids (*Ctenopoma multispine* and *C. intermedium*) and two mastacembelids (*Aethiomastacembelus frenatus* and *A. vanderwaali*).

In this region, the Zambezi River and its tributaries support the most species, 89 in total, of which 29.2% are cyprinids, 21.3% are cichlids and 10.1% mochokids (Table 7.2 - see end of review). The fish fauna of the Okavango is virtually the same as that of the Upper Zambezi and reflects the fact that the two systems are still intermittently connected via the Selinda spillway, which joins the Okavango and the Chobe-Linyati at periods of very high flood. Also, some of the Upper Zambezi species are only known from single specimens, e.g. *Paramormyrops jacksoni*, or a few from isolated localities, e.g. *Barbus mattozi, Schilbe yangambianus*. There are essentially no significant differences between the two systems, which is not the case as far as the Kafue system is concerned.

The Kafue was thought to have been isolated from the Upper Zambezi in the mid-Tertiary and it has fewer species than the latter (Table 7.2). It was also isolated from what is now the Zambian Congo drainage when the Chambeshi River was captured by the Luapula at about the same time. Consequently, it was not colonized by Congo species that invaded the Upper Zambezi, e.g. *Hippoptamyrus discorhynchus* and *Hydrocynus vittatus*, or the Middle Zambezi via the Chambeshi/Lake Rukwa/Luangwa River connection, e.g. *Labeo altivelis*, *Brycinus imberi* and *Heterobranchus longifilis*. The radiation of serranochromine cichlids in the Kafue is very similar to that of the Upper Zambezi, with nine species in the former compared to eleven species in the latter (*Serranochromis altus* and *S.longimanus* are absent from the Kafue). But the mochokid catfishes differ markedly, as there are only two species in the Kafue compared to eleven in the Upper Zambezi. Despite its relatively long isolation from the Zambezi, there is only one endemic species in the Kafue system, the killifish *Nothobranchius kafuensis* (although it may extend to the East Caprivi strip, in which case it loses this status).

The Cunene was isolated from the Zambezi at about the same time as the Kafue but its fish fauna is considerably different from both of those systems. Like the Kafue, it only has 66 fish species, but 9 of them (13.6%) do not occur anywhere else in the Zambezi system, and there are many more endemics. Six species, including four cichlids, are endemic to the Cunene system, namely *Kneria maydelli*, *Barbus breviceps*, *Orthochromis machadoi*, *Thoracochromis albolabrus*, *T. buysi* and *Sargochromis coulteri*. Two of the remainder have relict distributions that reflect the ancient connection between the Upper Zambezi and the Limpopo; *Labeo ruddi* occurs also in the Limpopo and Incomati systems, and there is a localised population of *Barbus argenteus* in the northern Drakensberg escarpment of South Africa. Finally, *Labeo ansorgii*, occurs in the Kwanza system in Angola as well as the Cunene.

The Chambeshi River, which once flowed into the Zambezi via the Kafue, was isolated some time in the early Tertiary when it was captured by the Luapula to become part of the Congo system. The Chambeshi and Lake Bangweulu were cut off from the Lower Luapula by the Johnston and Mumbatuta Falls and therefore have fewer species than the Lake Mweru/Luapula system (Table 7.3). Some typical Congo forms like the clupeids (sardines) failed to reach the Bangweulu system but others, like the tigerfish, *H. vittatus* and the Vundu, *H. longifilis*, did so. Nevertheless, the Chambeshi may have been a route for some of these Congo species to invade the Middle and Lower Zambezi.

7.3.2 **The Upper/Middle Zambezi boundary: waterfalls as barriers**

The transition from the Upper to the Middle Zambezi is abrupt and sharply demarcated. At the Victoria Falls the Zambezi drops by about 100 m while the Kafue falls by about 600 m in the 30 km stretch of the Kafue Gorge. Smaller tributaries of the Zambezi and the Luangwa which rise on the western plateau, such as the Kalomo, Mulungushi and Lunsemfwa, also drop steeply over the

Table 7.3 The number of species in each family in the Mweru/Luapula and Bangweulu/ Chambeshi systems of the Zambian Congo. Based on Jackson (1961a), updated as far as possible from CLOFFA (Daget *et al*. 1984, 1986, 1991). The list is probably incomplete.

	Mweru/ Luapula	Bangweulu/ Chambeshi
Protopteridae	1	
Mormyridae	15	8
Clupeidae	3	
Kneriidae	2	
Cyprinidae	25	20
Distichodontidae	2	1
Characidae	11	8
Hepsetidae	1	
Claroteidae	1	1
Amphiliidae	3	2
Schilbeidae	3	3
Clariidae	8	6
Mochokidae	8	5
Aplocheilidae	2	1
Cyprinodontidae	4	3
Cichlidae	15	10
Anabantidae	2	2
Mastacembelidae	2	1
Total number of species	103	67

escarpment. These rivers have Upper Zambezi or Kafue species in their plateau sections, but Middle Zambezi species below (Bell-Cross 1972, Balon 1974a), and the waterfalls that separate the two systems have always been regarded as major barriers.

The appearance in Lake Kariba during the late 1960s of several fish species typically found in the Upper Zambezi opened a debate on the nature of the Victoria Falls as a zoogeographical boundary. Balon (1974a, 1974b, 1978) asserted that the falls were not a major barrier to fish movements, as previous workers had thought, because fish had always been able to survive the drop over them but could not live in the harsh conditions of the river below. He postulated that the creation of Lake Kariba had changed this situation by providing a favourable habitat and, consequently, these fish were in the process of invading the system. Southern African workers challenged this view. They argued that (a) many of the alleged invaders were species that were widespread elsewhere in the Middle Zambezi, and (b) the few true Upper Zambezi invaders were more likely to have by-passed the falls through the turbines at the hydroelectric power station (Jubb 1976, Bowmaker *et al*. 1978, Marshall 1979, Kenmuir 1984). The importance of this debate, of course, lies in the general view that human activities, in the form of hydroelectric power stations, were breaking down major zoogeographical barriers in the system, which would change the species composition downstream of them.

Now, two decades later, these ideas can be examined again and there has clearly been little movement of fish across the barrier of the Victoria Falls. Twelve Upper Zambezi species have now been recorded from the Batoka Gorge below the Victoria Falls and from Lake Kariba (Table 7.4). But only two of them, the characid *Brycinus lateralis*, which may already have been in the river, and the cichlid *Serranochromis macrocephalus*, have successfully established themselves in the lake and invaded the river below the Kariba dam (Balon 1971, Marshall 1998). They almost certainly did this by passing through the hydroelectric turbines; the only other species to have done so was the introduced sardine *Limnothrissa miodon* (Junor & Begg 1971). Movement in the reverse direction, i.e. upstream, is obviously more difficult but may not be impossible since the only eel, *Anguilla bengalensis*, to have been collected from the Upper Zambezi was collected in the header dam at the Victoria Falls power station (Bell-Cross 1974).

The fact that only a few species have been able to invade the Middle Zambezi via hydroelectric turbines calls into question the importance of these structures as a means of breaking down zoogeographical barriers. Furthermore, there are no records of fish species invading the Middle Zambezi through other hydropower schemes, like that on the Kafue Gorge. Other explanations for the presence of Upper Zambezi species below the Victoria Falls should therefore be considered and the distribution of one of them, the Dash-tailed Barb, *Barbus poechii*, may provide one.

This fish is widely distributed in the Upper Zambezi and Upper Kafue drainage basins but it has also been taken from a number of places in the Zambezi system below the Victoria Falls (Figure 7.8). It occurs in the Kalomo River above the Siengwazi Falls (which has a typically Upper Zambezi fauna; Balon 1974b), in the Batoka Gorge, and again in the headwaters of the Matetsi and Deka Rivers. This distribution pattern suggests that the Batoka Gorge may be a transitional zone between the Upper and Middle Zambezi systems. It may also reflect the drainage system in the mid-Tertiary when the Zambezi flowed southwest into what is now the Kalahari Basin (another remnant of which is visible in the Ngwezi River that flows southwest to join the Zambezi west of the Victoria Falls). This drainage pattern was severed when the Middle Zambezi captured the Upper Zambezi to create the Victoria Falls, and the existing populations of *B. poechii* may therefore be relicts from this time. The same could apply to the other Upper Zambezi species and their appearance in Lake Kariba in 1968-69 may reflect the existence of some relict populations below the Batoka Gorge. Balon (1974a, 1974b, 1978) suggested that the survival of Upper Zambezi species would be assured by the new and more favourable environment of the lake, but this does not seem to have been the case. Those species collected only in the Batoka Gorge have not moved into the lake, while those collected from the lake itself seem to have disappeared or, if present, occur in very small numbers. Evidently, the lake has not offered an especially favourable environment for them and they may have failed to compete with the more numerous native species. This behaviour is more consistent with that of relict species, rather than that of strongly invasive ones.

Table 7.4 Records of Upper Zambezi fish species from the Zambezi River below Victoria Falls (Batoka Gorge) and Lake Kariba. From data in Balon (1974a, 1974b), Kenmuir (1983), Sanyanga & Feresu (1994), Anon. (1995a), Sanyanga *et al*. (1995) and Marshall (1998), as well as unpublished records from the Natural History Museum of Zimbabwe, Bulawayo (NMZB).

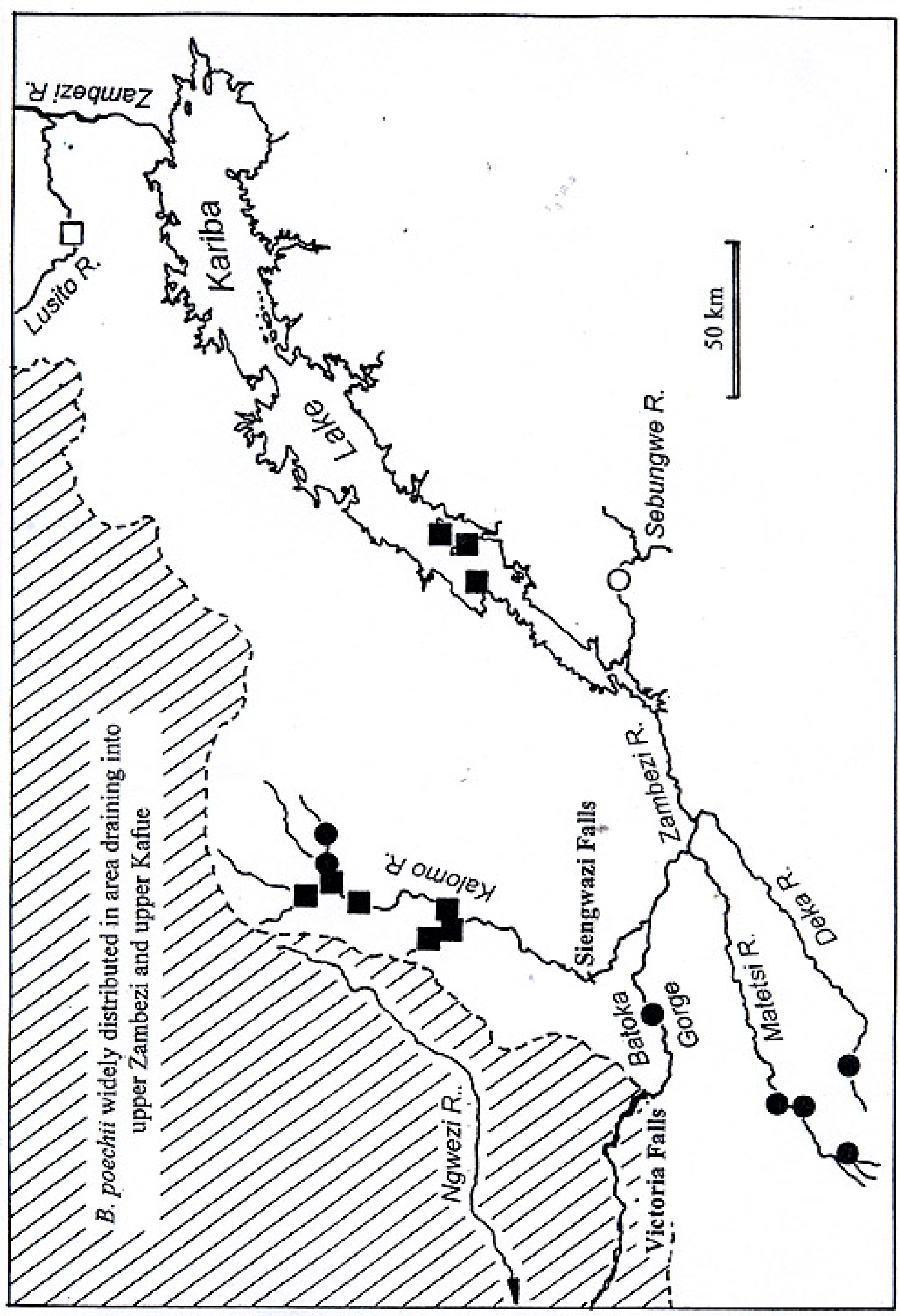
Species	Batoka Gorge	Lake Kariba	Remarks (number of specimens in brackets)
Mormyrus lacerda	●		Specimen in NMZB
Brycinus lateralis	●	●	Abundant throughout middle Zambezi
Hepsetus odoe		●	Deka R. (2) and Lake Kariba (1).
Barbus poechii	●	●	Lake Kariba, 1968-69 (9); no further records. Batoka specimen in NMZB
Barbus afrovernayi	●		Specimen in NMZB
Labeo lunatus		●	Lake Kariba, 1968-69 (1); possibly misidentified as specimen weighed only 14 g, no further records.
Hemichromis elongatus	●		Specimen in NMZB
Serranochromis robustus		●	Lake Kariba, 1968-69 (2); no further records
Serranochromis macrocephalus		●	Lake Kariba, 1966; now widespread and has reached Zambezi R. downstream
Sargochromis giardi		●	Lake Kariba, 1968-69 (127) and 1997 (1)
Sargochromis carlottae		●	Lake Kariba, 1968-69 (24); no further records
Oreochromis andersonii		●	Lake Kariba, 1968-69 (15); no further records
Aethiomastecembalus vanderwaali	●		Specimen in NMZB

The Churchill, *Petrocephalus catostoma*, is another species with a possibly relict distribution in the Middle Zambezi. It is widespread in the Upper Zambezi and is said to occur throughout the Middle Zambezi (Skelton 1993). But in Zambia it occurs only on the plateau sections of Zambezi tributaries (Jackson 1961a) and there are no records from the Zambezi itself or Lake Kariba (Jackson 1961b, Kenmuir 1983), or any of the Zimbabwean tributaries of the Zambezi (unpublished records, Natural History Museum, Bulawayo). Finally, Bell-Cross (1972) noted the presence of a catfish, which he referred to as *Clarias submarginatus*, in Lake Lusiwashi, a small waterbody on a tributary of the Luangwa. This species is not, in fact, *C. submarginatus* but probably *C. stappersii*, which occurs in the Chambeshi but not the Middle Zambezi. This probably represents a relict distribution from a time when the upper reaches of some Luangwa tributaries drained into the Chambeshi.

7.3.3 **The Middle Zambezi system**

Conditions to the east and south of the line that divides the Upper Zambezi and Kafue dividing line are very different from each other. The Middle Zambezi flows through a part of the continent that has been broken into deep troughs by the processes associated with the evolution of the African Rift Valley. The Middle Zambezi trough extends from the Victoria Falls to the Cabora Bassa Gorge, with a north-eastern extension up the Luangwa Valley. Its floor is much lower than the upper Zambezi-Kafue plateau and both rivers drop precipitously into it. The Middle Zambezi flows through several deep gorges, two of which (Kariba and Cabora Bassa) have been dammed to create huge artificial lakes.

Figure 7.8 Records of the Dash-tailed Barb, *Barbus poechii*, in the Zambezi system below the Victoria Falls. The circles denote records from the Natural History Museum, Bulawayo (NMZB) and the squares are records from Balon (1974). The open circle and square on the Sebungwe and Lusito rivers, respectively, are records for which the exact locality is not known. The shaded area is that part of the basin draining into the Upper Zambezi and Upper Kafue, where *B. poechii* is widespread.



This part of the basin is more arid than the Upper Zambezi, and its topography is more varied and geologically heterogeneous. There are few floodplains or swamps and the flow of the rivers is much more variable with short-lived floods and long periods of low flow. Their erosive power is much greater and they have little marginal vegetation, being termed "sandbank" rivers (Jackson 1986). In these rivers small fish are exposed to severe predation, because of the lack of cover (Jackson 1963), and there are fewer species than in the Upper Zambezi (a total of 56 *vs* 84). A feature of the Middle Zambezi is the lack of cichlids, with only eight species compared to 19 in the Upper Zambezi (Table 7.2). Particularly noteworthy is the absence of *Serranochromis* (although this is changing as *S. macrocephalus* is invading the system) and only one *Sargochromis* species (*S. codringtonii*). The diversity of catfish is also lower, with only two clariids (compared to six in the Upper Zambezi) and two *Synodontis* species (against seven in the upper river). Another characteristic feature is the lack of small barbs (only 17 compared to 25), that indicates the importance of predation in the sandbank rivers of the Middle Zambezi.

Families that are present in the Upper Zambezi/Kafue but absent from the Middle Zambezi, except for the transitional zone of the Batoka Gorge (Table 7.4), include the Kneriidae (possibly), Hepsetidae, Claroteidae, Aplocheilidae, Anabantidae and Mastacembelidae. Families that occur in the Middle Zambezi, but not in the Kafue or Upper Zambezi, include some of marine origin like the Anguillidae, Megalopidae and Gobiidae, and the Electric Catfish (*Malapterurus*), which is of Congo origin. This ancient connection with the Congo is reflected in the distribution of a number of Middle Zambezi species. They include the Lungfish, *Protopterus annectens*, the Cornish Jack, *Mormyrops anguilloides*, the Manyame Labeo, *Labeo altivelis*, Nkupe and Chessa (*Distichodus* spp.), which are represented in the Chambeshi by related species, the Imberi *Brycinus imberi* (Figure 7.9) and the Vundu *Heterobranchus longifilis*.

7.3.4 **The Lower Zambezi system**

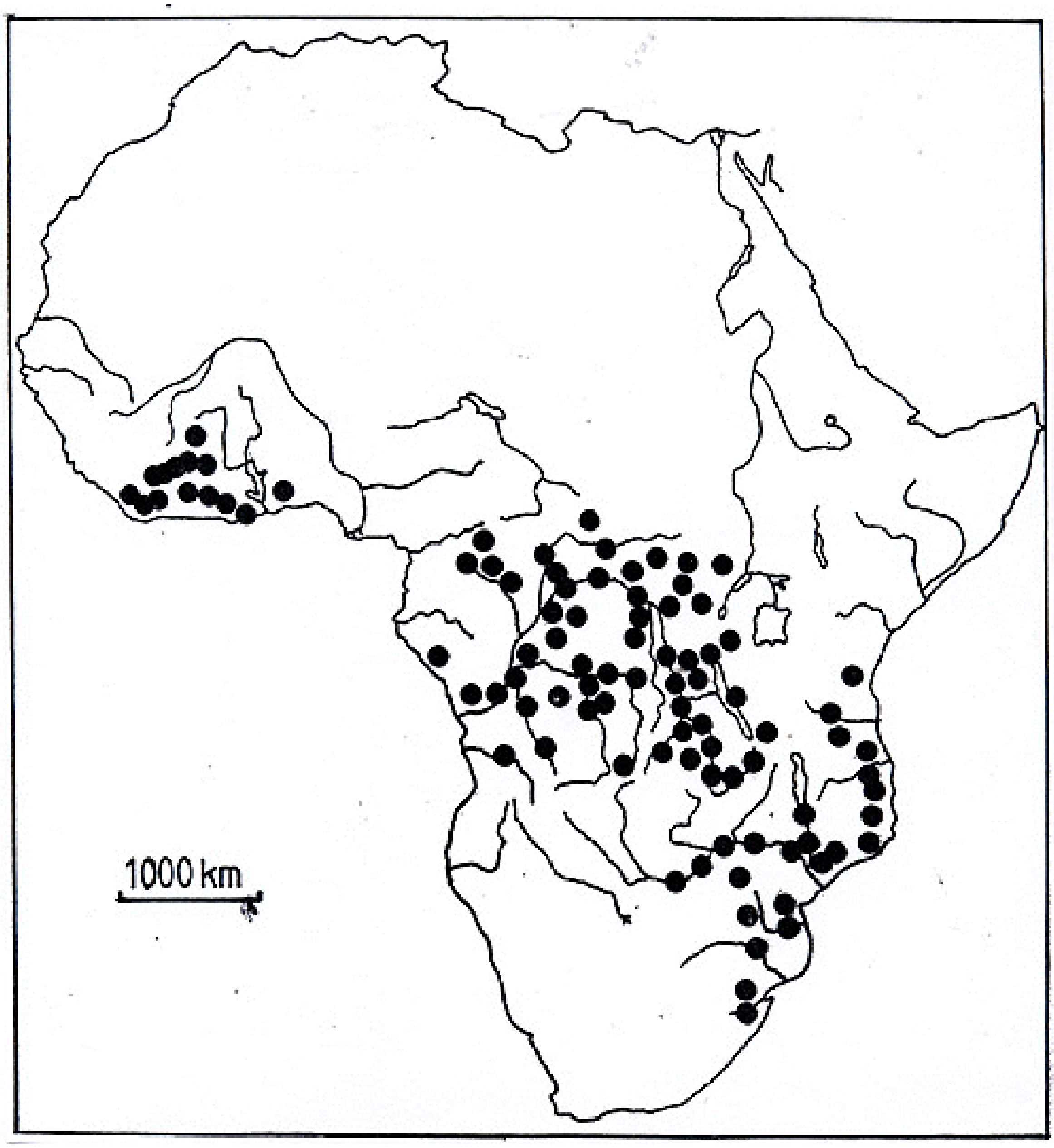
The boundary between the Middle and Lower Zambezi is poorly defined as there are no major natural barriers. The Cabora Bassa Gorge is conventionally regarded as the boundary (Bell-Cross 1972, Jackson 1986) and some marine groups, like the gobies (Gobiidae), tarpon *Megalops cyprinoides* and, occasionally, the Bull Shark *Carcharhinus leucas*, may occur inland as far as the gorge, but not beyond it. It is important to note that the Zambezi River itself, and its tributaries in particular, are still typical sandbank rivers for some distance below the gorge. The Lupata Gorge, downstream of the Zambezi-Mazowe confluence, is probably a better boundary because it marks the point where the Zambezi debouches onto the Mozambique Plain and once again becomes a floodplain system with much greater habitat diversity (Figure 7.7). These floodplains, which distinguish the Lower Zambezi, extend into the Zambezi Delta and up the Shire River almost to the Kapachira Falls.

The fish fauna contains all the elements of the Middle Zambezi, but the number of species is larger (Table 7.2), with the total rising to 83. There are several reasons for this:

(a) Some marine species enter the river from the delta (about 14 are listed in Skelton (1993) and some others have recently been collected);
(b) The occurrence of some east coast species which are typically found in the floodplains, including the East African Lungfish, *Protopterus amphibius*, the barbs *Barbus viviparus, B. toppini, B. afrohamiltoni* and *B. macrotaenia*, Barnard's Robber *Hemigrammopetersius barnardi*, the killifish *Nothobranchius orthonotus* and *N. rachovii*, the Eastern Bream *Astatotilapia calliptera* and the Black Tilapia *Oreochromis placidus*;

(c) Some species that are more typical of the Malawi region enter the Lower Zambezi in the Shire and its tributaries close to the waterfalls that separate the two systems. They include the barred minnow *Opsaridium tweddleorum*, the Silver Barb *Barbus choloensis*, the Pungwe Chiselmouth *Varicorhinus pungweensis* and the Shire Tilapia *Oreochromis shiranus*.

Figure 7. 9 The distribution of the Imberi, *Brycinus imberi*, (Paugy, 1986). Note how a species with a widespread African distribution was able to colonize the Middle and Lower Zambezi via the Chambeshi/Lake Rukwa route, but was unable to move upstream into the Upper Zambezi and Kafue because of the physical barriers on those rivers.



Some species typical of the Upper Zambezi floodplain systems reappear in the floodplains of the Lower Zambezi, having been unable to survive in the Middle Zambezi where floodplains are absent. They include the mormyrids, *Hippopotamyrus ansorgii* and *Petrocephalus catostoma*, the barbs, *Barbus haasianus* and *B. eutaenia* (Shire tributaries only), the Blunt-toothed and Snake catfishes, *Clarias ngamensis* and *C. theodorae*, the Mesh-scaled Topminnow, *Aplocheilichthys hutereaui*, and the two anabantids, *Ctenopoma multispine* and *C. intermedium*. Another family of the Upper Zambezi, the mastacembalids, is represented by *Aethiomastecembemus shiranus*, which is similar to – and possibly the same as – the Upper Zambezi species *A. frenatus* (Skelton 1993).

The fishes of the Pungwe and Buzi rivers are closely linked to those of the Lower Zambezi (Table 7.2) with a similarity index of 0.86. This reflects an ancient connection between the two rivers systems, as they were probably connected during glacial periods when the sea level was lower (Bell-Cross 1973). More recent connections may also exist via a trough of low-lying wetlands connecting the Zambezi and Pungwe as well as the coastal wetlands.

7.3.5 **The Lake Malawi system**

Lake Malawi is the southernmost lake of the African Rift Valley system and the third largest on the continent. It is estimated to be several million years old and its level is believed to have risen and fallen extensively over this period, which has contributed to the evolution of its distinctive and unique fish fauna (Owen *et al*. 1990). The lake is hydrologically a part of the Zambezi system but its fish fauna is isolated from it by the Kapachira Falls on the Shire River. Few Zambezian fish species have been able to penetrate this barrier and move into the Upper Shire or the lake itself (Tweddle, Lewis & Willoughby 1979, Tweddle & Willoughby 1979). Lake Malawi is best known for its large and diverse fauna of haplochromine cichlids, numbering perhaps 400-500 endemic species, but its non-cichlid species are equally distinct (Table 7.5).

A particular feature of the fish fauna of the Lake Malawi basin is the high degree of endemicity. The extraordinary endemicity of the cichlids – at least 99% and probably more as new species, especially from the poorly-studied Tanzanian and Mozambican shores, are described - is well known. But the same applies to the non-cichlids, where 23 of the 46 species (50%) are endemic. Many of the non-endemic species are those with a wide distribution, like the mormyrid *Mormyrops anguilloides*, the minnow *Barbus paludinosus* and the African Catfish *Clarias gariepinus*, which all occur extensively across the African continent.

7.3.6 **Similarities between components of the system**

The relationships discussed in the preceding sections can be illustrated by determining the number of species common to each sub-basin, and calculating a similarity index, as follows:

$$S = C/(N_1 + N_2 - C)$$

where S = similarity index, N_1 and N_2 = the total number of fish species in each sub-basin, and C = the number of fish species common to both.

The Lake Malawi system, because of its high endemicity, is least similar to any of the other sub-basins (Table 7.6). Similarities between the Chambeshi/Lake Bangweulu system and other parts of the basin are relatively low and rather uniform, probably because this system has fish from both the Upper and Lower Zambezi, as well as other species of Congo origin. The Chambeshi system is least similar to the Lower Zambezi because of the appearance of marine species in the latter, but rather

Table 7.5 Fishes of the Lake Malawi basin with their distributions in other systems. Based on Bell-Cross (1972) with additions from CLOFFA. The number of endemic cichlid species (281) is undoubtedly too low because many new ones have been discovered since CLOFFA 4 (Daget *et al*. 1991) was published.

Family	Species	Lower/Mid-Zambezi	Upper Zambezi	Zambian Congo	Rovuma/Rufigi rivers	Endemic
Anguillidae	*Anguilla bengalensis*	●			●	
Mormyridae	*Mormyrops anguilloides*	●		●	●	
	Petrocephalus catostoma	●	●	●	●	
	Hippopotamyrus discorhynchus	●	●	●	●	
	Marcusenius macrolepidotus	●	●	●	●	
	Marcusenius nyasensis					●
	Mormyrus longirostris	●		●	●	
Characidae	*Brycinus imberi*	●		●	●	
Cyprinidae	*Barbus arcislongae*					●
	Barbus eurystomus					●
	Barbus eutaenia	●				
	Barbus innocens			●		
	Barbus johnstonii					●
	Barbus macrotaenia	●				
	Barbus paludinosus	●	●	●	●	
	Barbus radiatus	●	●		●	
	Barbus litamba					●
	Barbus toppini	●			●	
	Barbus trimaculatus	●				
	Labeo cylindricus	●	●	●	●	
	Labeo mesops					●
	Labeo worthingtonii					●
	Opsaridium microlepis					●
	Opsaridium microcephalum					●
	Opsaridium tweddlorum	●				
	Engraulicypris sardella					●
Bagridae	*Bagrus meridionalis*					●
Amphiliidae	*Leptoglanis rotundiceps*	●	●	●	●	
	Amphilius uranoscopus	●			●	
Clariidae	*Clarias liocephalus*		●	●		
	Clarias gariepinus	●	●	●	●	

Family	Species	Lower/Mid-Zambezi	Upper Zambezi	Zambian Congo	Rovuma/Rufigi rivers	Endemic
	Clarias ngamensis	●	●	●		
	Bathyclarias (11 spp)					●
Mochokidae	*Chiloglanis neumanni*	●	●	●	●	
	Synodontis njassae					●
Cyprinodontidae	*Aplocheilichthys johnstonii*		●		●	
Aplocheilidae	*Nothobranchius orthonotus*	●				
Cichlidae	*Tilapia rendalli*	●	●	●	●	
	Tilapia sparrmanii		●	●	●	
	Astatotilapia calliptera	●				
	Pseuodocrenilabrus philander	●	●			
	Serranochromis robustus		●	●		
	Alticorpus (5 spp)					●
	Aristochromis (1 sp)					●
	Aulonacara (17 spp)					●
	Buccochromis (7 spp)					●
	Caprichromis (2 spp)					●
	Champsochromis (2 spp)					●
	Cheilochromis (1 sp)					●
	Chilotilapia (1 sp)					●
	Copadiachromis (20 spp)					●
	Corematodus (1 sp)					●
	Ctenopharynx (3 spp)					●
	Cyathochromis (1 sp)					●
	Cynotilapia (2 spp)					●
	Cyrtocara (1 sp)					●
	Dimidiochromis (4 spp)					●
	Diplotaxodon (3 sp)					●
	Docimodus (2 sp)					●
	Eclectochromis (3 spp)					●
	Exochromis (1 sp)					●
	Fossorochromis (1 sp)					●
	Genyrochromis (1 sp)					●
	Hemitaeniochromis (1 sp)					●
	Hemitilapia (1 sp)					●
	Iodotropheus (2 spp)					●

Family	Species	Lower/Mid-Zambezi	Upper Zambezi	Zambian Congo	Rovuma/Rufigi rivers	Endemic
	Labeotropheus (2 spp)					●
	Labidochromis (19 spp)					●
	Lethrinops (24 spp)					●
	Limnochromis (1 sp)					●
	Maravichromis (16 spp)					●
	Melanochromis (15 spp)					●
	Microchromis (1 sp)					●
	Naevochromis (1 sp)					●
	Nimbochromis (7 spp)					●
	Nyassachromis (6 spp)					●
	Oreochromis (5 spp)					●
	Otopharynx (12 spp)					●
	Petrotilapia (3 spp)					●
	Placidochromis (7 spp)					●
	Platygnathochromis (1 sp)					●
	Protomelas (14 spp)					●
	Pseudotropheus (31 spp)					●
	Rhamphochromis (8 spp)					●
	Sciaenochromis (3 spp)					●
	Stigmatochromis (4 spp)					●
	Taeniochromis (1 sp)					●
	Taeniolethrinops (4 spp)					●
	Tramitichromis (5 spp)					●
	Trematocranus (3 spp)					●
	Tyrannochromis (4 spp)					●
Mastacembalidae	*Aethiomastacembelus shiranus*	●				

more similar to the various basins of the Upper Zambezi, especially the Kafue, which reflects the historic connection between them.

The basins of the Upper Zambezi are all strongly similar to each other and their fish faunas are essentially the same. This applies to the Okavango but less so to the Kafue, where the similarities are lower, which is explained by the fact that it has been isolated from the Zambezi over a longer period. The Cunene is also relatively similar to the Upper Zambezi, but not to the middle and lower basins; this, too, reflects is derivation from the Upper Zambezi and lack of connection with the rest of the system.

As might be expected there are strong similarities between the basins of the Middle Zambezi. If the Upper Zambezi species that occur in the west of the Kariba area (Table 7.4) were excluded, then the similarity index between the Kariba and Cabora Bassa catchment would be considerably higher. The similarity between the two Lower Zambezi basins is also very strong, and would be higher if the marine species that occur in the Lower Zambezi were excluded. But the similarity indices between the two Middle Zambezi basins and the two Lower Zambezi ones were quite low (0.39-0.45), which reflects the presence of some Upper Zambezi and east coast species in the latter.

7.4 THREATS TO BIODIVERSITY

The continuing growth of the human population in the Zambezi Basin, and the demand for water for agriculture, industry and domestic uses, will increasingly strain water resources in some parts of the basin. These pressures will, in turn, adversely affect the biodiversity of the freshwater fishes. Stiassny (1997) has pointed out that freshwater fishes are amongst the most threatened animal groups and their biodiversity is decreasing at a faster rate than any other group. This situation will only be reversed through concerted programmes of catchment management. Setting aside protected areas is less likely to be effective for fish because rivers are linear systems whose ecology is determined by catchment processes that may have a downstream effect far distant from their origin. It is extremely difficult, therefore, to conserve particular sections of a river system unless problems elsewhere in the catchment can be controlled.

The Kruger National Park in South Africa illustrates these problems since it has a north-south orientation but its major rivers flow in an east-west direction and only a small proportion of their lengths is protected. Outside the Park, the rivers are heavily exploited for industry, mining and agriculture, and their flow ceases during the dry season (Allanson *et al*. 1990). These rivers were formerly perennial and the change has led to the extinction of six fish species (14%) out of a total of 42 in the Park (A. Deacon, pers. comm.).

7.4.1 **Climate change**

All aquatic environments depend on water and there are questions about its long-term availability, owing to climate change, throughout the basin. It is not possible to predict how global warming will influence rainfall, and therefore the water resources, of the Zambezi Basin. In Zimbabwe, the average temperature has risen by about 0.8ºC in 60 years while the average precipitation decreased by 10% in the period 1900-1994 (Unganai 1996). Records from 24 meteorological stations in Zambia, extending for periods of 30-50 years, indicate a declining trend at 24 of them, no change at six and an increasing trend at four (Anon. 1995b). The combination of reduced precipitation and increased evaporation (because of higher temperatures) has serious implications for the availability of water, and thus for fish habitats.

It is not clear if these trends are reflected in the flow of the main rivers, even though they have decreased sharply in recent years. The flow of the Zambezi at Victoria Falls, for example, seemed to increase slightly from the time records were first kept in 1907/08 until the mid-1940s (Figure 7.10). The flow then increased sharply until about 1960 and remained relatively high, but with considerable fluctuations until the end of the 1980s. Since then it has decreased rapidly and the flow in the 1990s was lower than at any time during the period of historical records. These alterations in river flow presumably reflect large-scale climatic changes but whether these represent the effect of human-induced climatic change, or some longer-term climatic cycle is still unknown.

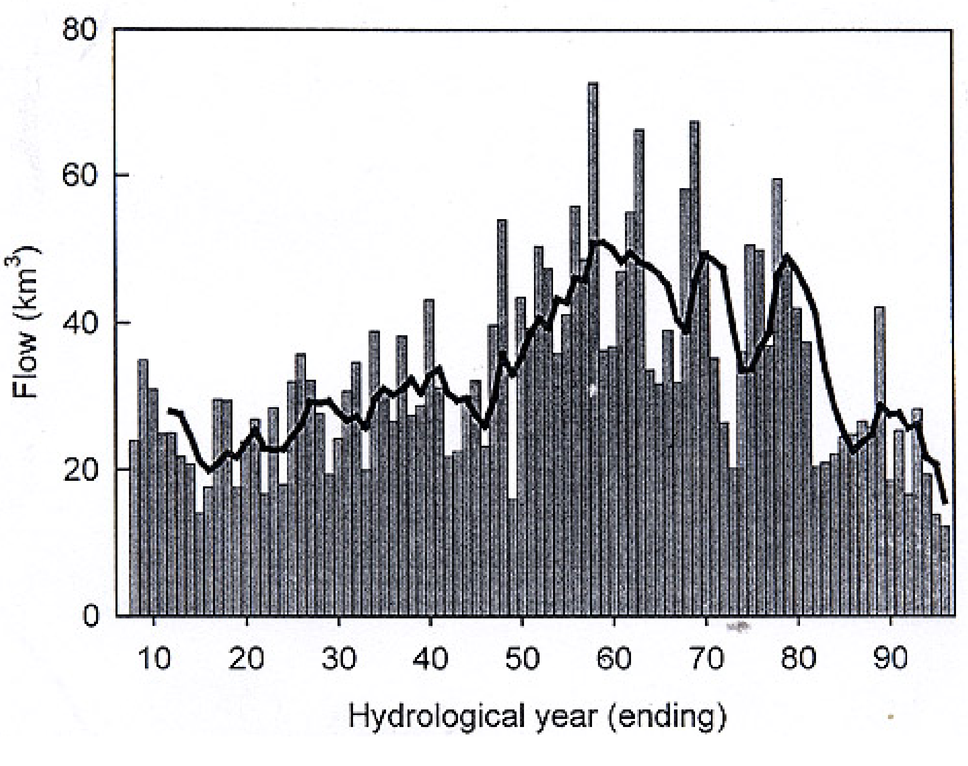
Table 7.6 The number of species in common in each of the main sections of the Zambezi Basin, including the Cunene, Chambeshi/Lake Bangweulu and Lake Malawi systems. The values in brackets are the similarity indices for each system, and the highest indices are indicated in bold type.

	L. Malawi	Chambeshi	Lower Zambezi	Lower Shire	L. Cabora Bassa & catchment	L. Kariba/ Mid- Zambezi	Kafue	Chobe/Caprivi	Barotse floodplain	Okavango	Zambezi headwaters
Cunene	16 (0.04)	29 (0.28)	22 (0.17)	22 (0.19)	17 (0.17)	25 (0.24)	45 (0.53)	51 (0.52)	52 (0.54)	54 (0.55)	54 (0.54)
Zambezi headwaters	18 (0.04)	36 (0.31)	29 (0.21)	29 (0.22)	24 (0.21)	33 (0.29)	61 (**0.68**)	78 (**0.86**)	78 (**0.87**)	79 (**0.85**)	
Okavango	17 (0.04)	35 (0.30)	28 (0.21)	28 0.22)	23 (0.21)	29 (0.25)	61 (**0.69**)	80 (**0.92**)	79 (**0.91**)		
Barotse floodplain	17 (0.04)	34 (0.30)	28 (0.20)	28 (0.22)	23 (0.21)	34 (0.31)	59 (**0.68**)	75 (**0.85**)			
Chobe/Caprivi	17 (0.04)	34 (0.29)	30 (0.23)	30 (0.24)	25 (0.24)	35 (0.32)	59 (**0.68**)				
Kafue	16 (0.04)	32 (0.32)	24 (0.21)	24 (0.21)	19 (0.20)	27 (0.28)					
Lake Kariba/Middle Zambezi	17 (0.04)	24 (0.23)	39 (0.39)	39 (0.41)	46 (**0.72**)						
Lake Cabora Bassa & catchment	22 (0.05)	22 (0.25)	39 (0.45)	40 (0.41)							
Lower Shire	22 (0.06)	28 (0.25)	66 (**0.80**)								
Lower Zambezi	18 (0.06)	28 (0.18)									
Chambeshi	18 (0.05)										

7.4.2 **Reservoir construction**

While the construction of hydroelectric power stations has not, as yet, significantly changed the fish fauna of the Zambezi Basin the same cannot be said of another, more widespread, human activity, the construction of dams. The Middle Zambezi has been completely changed by the construction of two great reservoirs, Lakes Kariba (c. 5400 km^2 when full) and Cabora Bassa (c. 2600 km^2). The construction of dams at Mupata, Devil's and Batoka Gorges, as well as some sites below Cabora Bassa, could destroy its last remaining riverine sections. It has long been feared that this activity will affect the Lower Zambezi by reducing floods and drying out the floodplains and delta (Davies, Hall & Jackson 1975), but little is known about these issues at present. Similar fears have been expressed about the Kafue Flats, which are now regulated by the Itezhi-Tezhi Dam at their western end and the Kafue Gorge Dam at their eastern end (Handlos 1982).

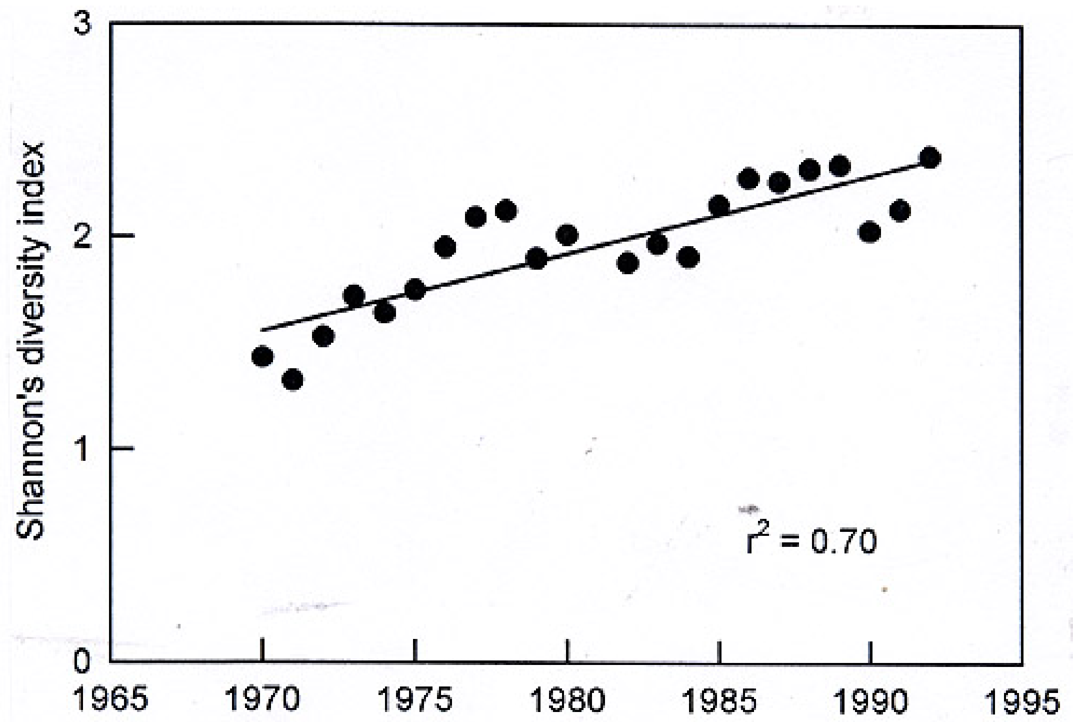
Figure 7.10 The flow of the Zambezi River (km^3) at Victoria Falls from 1907/08 to 1995/96 (columns) with a 5-year moving average (solid line) (data from Zambezi River Authority).



The most important impact of these reservoirs has been to change the composition of the fish species in the portions of the river drowned by them. Prior to the construction of Kariba, the Zambezi River was dominated by rheophilic fish species like cyprinids and distichodids (Jackson 1961b), but they declined rapidly after the dam was built. Some specialised riverine forms like the cyprinids, *Opsaridium zambezense* and *Barbus marequensis*, and the catlet *Chiloglanis neumanni*, disappeared completely from the lake. This meant that they have not been able to recolonize smaller rivers after periods of drought and the contraction in their range may have been rather greater than just the drowned section of the main river. The decline of *Labeo* and *Distichodus* was more pronounced in the larger, more lacustrine sections of the reservoir and they survive in greater numbers in the more riverine, western basins of the lake (Begg 1974).

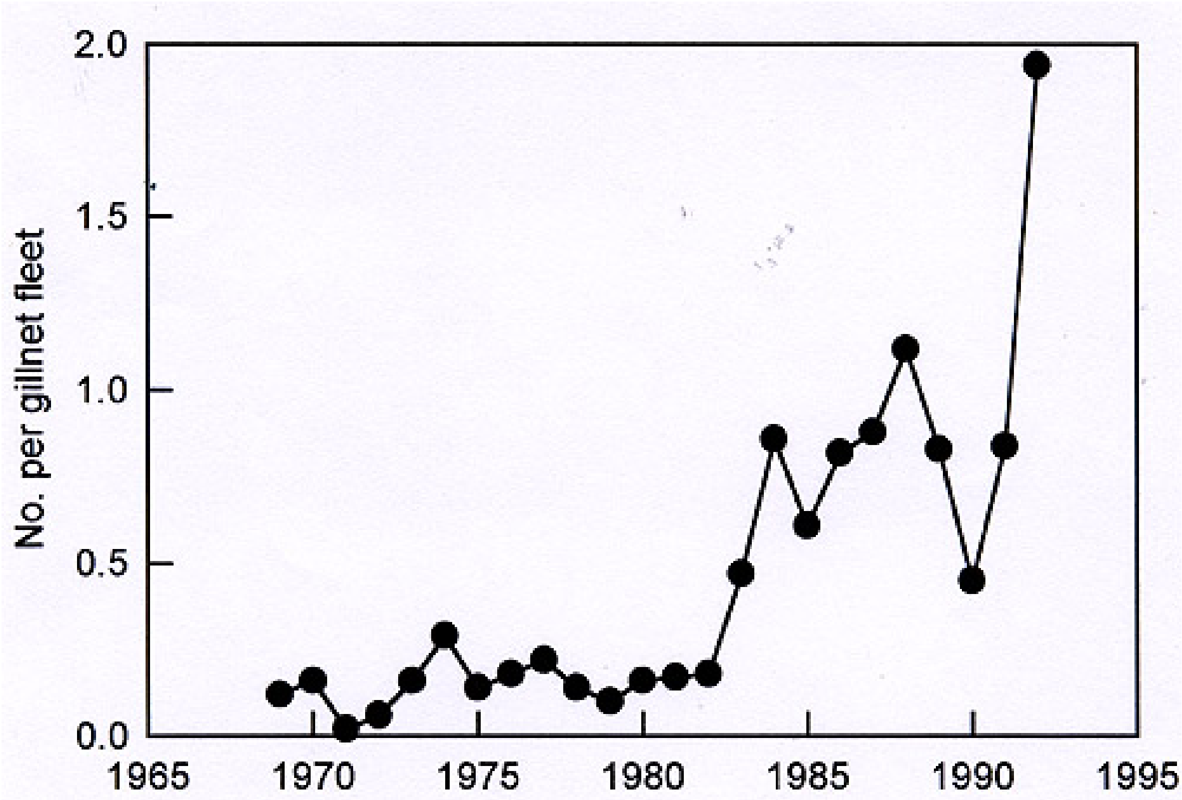
The principal beneficiaries of these reservoirs are species that can adapt to standing water. Jackson (1961b) collected very few cichlids from the river before the dam was built, and it was on the basis of these findings that the decision to stock them into the new lake was made. In reality, cichlid populations increased rapidly and they soon became the most important inshore species (Begg 1974, Kenmuir 1983, 1984). The fish fauna of Lake Kariba is still in a process of change and there seems to be a general increase in diversity (Figure 7.11). In the early years of the lake, it was dominated by only a few species of fish but others have gradually become increasingly abundant; a good example is the squeaker *Synodontis zambezensis*, which increased in abundance during the 1980s (Figure 7.12). Some of these changes may have been brought about by fishing, as suggested by Sanyanga *et al*. (1995), but perhaps more probably reflect the maturation process of the lake. These processes include the development and growth of submerged macrophytes, which have benefited some species like *Serranochromis macrocephalus* which was rare in the 1960s but is now abundant and widely distributed throughout the lake (Marshall 1998).

Figure 7. 11 Changes in the diversity of fish species in Lake Kariba, 1970-1992, indicated by Shannon's diversity index. The data are based on a weekly sampling programme using a standard fleet of gill nets ranging in size from 2" (50 mm) to 7" (175 mm) stretched mesh (redrawn from Kolding 1994).



Much of the interest in reservoirs has centred on Lake Kariba and, to a smaller extent, on Lake Cabora Bassa. Smaller reservoirs have been studied in much less detail but they may have had a significant impact on the species composition and diversity of fish. Small reservoirs are especially important in the Zimbabwean part of the Middle Zambezi, where about 7000 of them, ranging from 1 ha or less to 8000 ha in area, have been built (Figure 7.13). These reservoirs have become important features of the landscape and must have significantly changed the patterns of river flow and fish distribution. Unfortunately, little is known about these aspects and much remains to be learned about their impact.

Figure 7.12 The increase in the numbers of the squeaker *Synodontis zambezensis* in Lake Kariba, 1969-1992. Based on data from a standard fleet of gill nets ranging in size from 2" (50 mm) to 7" (175 mm) stretched mesh (redrawn from Sanyanga 1996).



The general trends among the fish fauna of small reservoirs seems to be largely similar to that in the large ones, i.e. a decline in rheophilic species like the labeos and other cyprinids, and an increase in cichlids. But they have another, and perhaps more significant, impact by providing suitable habitats for introduced species. Small reservoirs in Zimbabwe tend to have fewer species than large reservoirs but with a higher proportion of them being introduced exotics (Table 7.7). They may, indeed, be crucial to the survival of exotic species that might not be able to establish themselves in undammed rivers. If this is the case, then the construction of small reservoirs may prove to be one of the most important influences on the diversity and species composition of the Zambezi Basin.

7.4.3 **Introduced fish species**

The introduction of exotic species has the potential to change the fish fauna of the Zambezi Basin to a greater extent than almost any other human activity. The dramatic impact of the Nile perch, *Lates niloticus*, on the endemic haplochromines of Lake Victoria has heightened awareness of the potentially disastrous impact of introduced species and emphasised the need for vigilance, especially in sensitive areas like Lake Malawi (Lowe-McConnell 1993). While most of the countries in the basin have promulgated regulations to control or prohibit the importation of exotic fish species, and to monitor the movements of local fish species, they lack the capacity to enforce them and exotic fish species continue to be brought into the basin.

Figure 7.13 The distribution of reservoirs in the Zambezi Basin. Their concentration in Zimbabwe is noteworthy and greater than anywhere else in the basin (drawn from data in the FAO-ALCOM data base on inland waters).

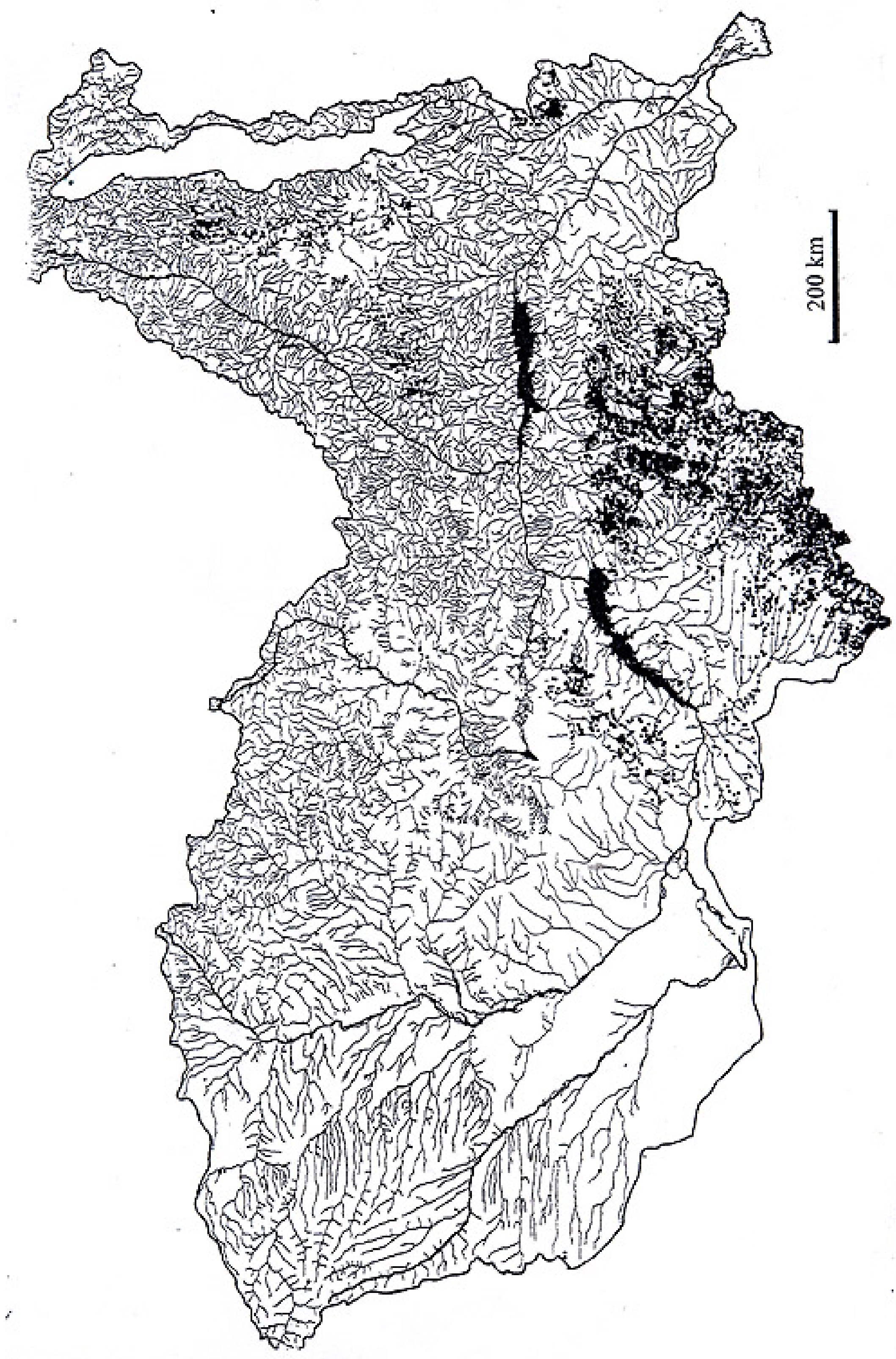


Table 7.7 The total number of fish species, and the proportion of introduced ones, in three Zimbabwean reservoirs (data from Ludbrook 1974, Marshall 1982, Marshall, Junor & Langerman 1982, Kenmuir 1983, Evans 1982, Kolding & Karenge 1985, Sanyanga & Feresu 1994 and unpublished data).

	Area (km^2)	Total no. species	No. introduced species
Lake Kariba	*c* 5400	47	4 (8.5%)
Lake Mutirikwe [1]	91.1	19	8 (42.1%)
Lake Chivero	23.6	29	8 (27.6%)
Savory dam	0.1	15	9 (60.0%)

Note: [1] Formerly known as Lake Kyle, this reservoir is not in the Zambezi Basin.

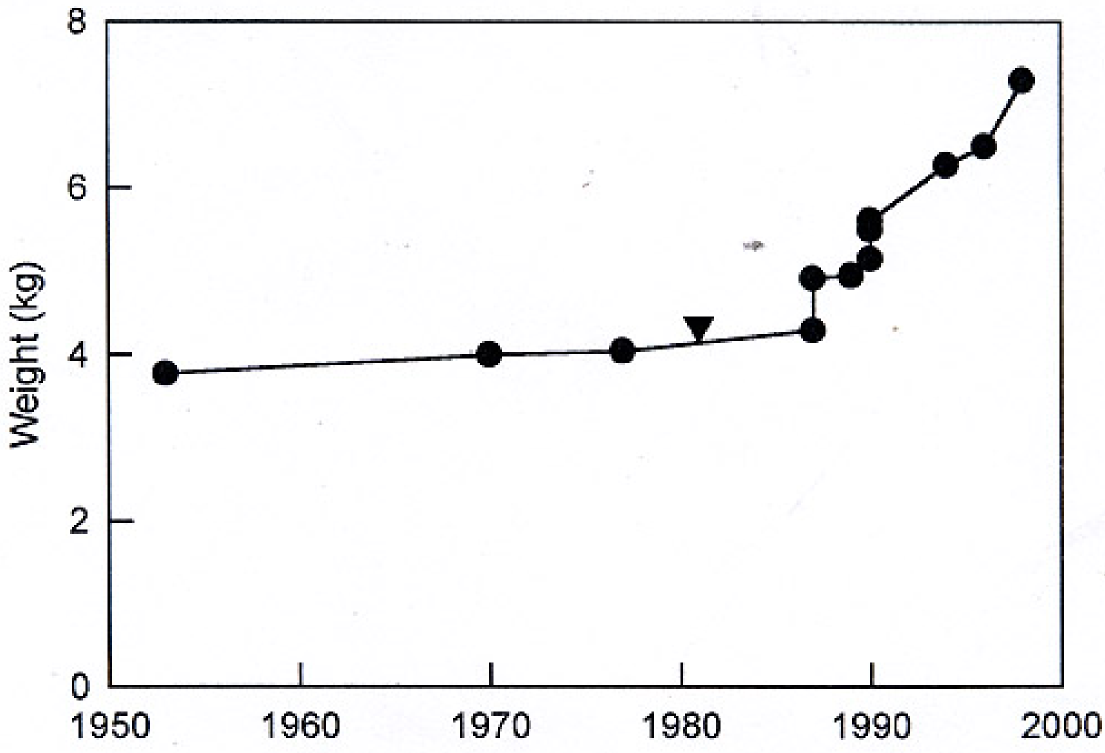
Table 7.8 Exotic fish species of non-African origin known to have been introduced into the Zambezi Basin (data from Turnbull-Kemp 1957, Toots 1970, Bell-Cross & Minshull 1988, Thys van den Audenaerde 1994 and unpublished sources).

Species	Remarks
Carassius auratus (Goldfish)	Zimbabwe; aquarium fish, occasional wild ones
Cyprinus carpio (Common Carp)	Zimbabwe *c*. 1925; widely distributed in small numbers (increasing recently in some areas) Malawi; present in Zomba area Zambia, 1946; limited distribution
Tinca tinca (Tench)	Zimbabwe *c*. 1938; extinct Zambia, 1946; failed
Catla catla (Indian Carp)	Zimbabwe *c*. 1968; failed
Ctenopharyngodon idella (Grass Carp)	Zimbabwe *c*. 1982; in fish ponds, not yet stocked Zambia, *c*. 1980s; a few in fish ponds
Salmo trutta (Brown Trout)	Zimbabwe *c*. 1907; montane waters, uncommon
Oncorhynchus mykiss (Rainbow Trout)	Zimbabwe *c*. 1910; montane waters, commonest species Malawi, 1905; montane waters. Zambia, 1942, 1947; unsuccessful
Salvilenus fontinalis (Brook Trout)	Zimbabwe, 1955; montane waters, possibly extinct
Gambusia affinis (Mosquitofish)	Zimbabwe, 1925; local populations in reservoirs around Harare Zambia, *c*. 1940s; apparently extinct
Poecilia reticulata (Guppy)	Zimbabwe; aquarium fish, now in small reservoirs around Harare Zambia; aquarium fish, apparently in streams near Kitwe
Xiphophorus helleri (Swordtail)	Zambia; aquarium fish, present in some ponds
Micropterus salmoides (Largemouth Bass)	Zimbabwe, 1932; now widespread, has reached, or been stocked into, Lake Kariba
Micropterus dolomieu (Smallmouth Bass)	Zimbabwe, 1941; probably extinct Zambia, 1947; probably extinct
Micropterus punctulatus (Spotted Bass)	Zimbabwe, 1945; probably extinct Zambia, 1945; probably extinct
Lepomis macrochirus (Bluegill Sunfish)	Zimbabwe, 1948; small, isolated populations still exist
Perca fluviatilis (Perch)	Zimbabwe, 1938; failed
Oreochromis aureus (Israeli Tilapia)	Zambia, 1983; may survive in ponds and may have escaped into the Kafue River

Until about 1950, most of the introductions were of European or North American species which were thought to be superior to the native ones, or which were valued because of their familiarity to European settlers. This attitude was encapsulated by a correspondent who wrote "to have our rivers full of trout would ... prove of the greatest benefit to our country in many ways, e.g. ... a new and very real attraction to settlers ... [allowing] the settler to indulge in the sport for which he has pined so long" (Dobell 1921). Altogether, about 17 non-African fish species are known to have introduced into the basin, principally in Zimbabwe, but also in Zambia and Malawi (Table 7.8). Fortunately, few of them have been successful.

Rainbow Trout, *Oncorhynchus mykiss*, are restricted to mountain streams in eastern Zimbabwe and in Malawi, but the other trout species have not done as well. Of the bass species, only the Largemouth Bass, *Micropterus salmoides*, has become established and is widespread in reservoirs in Zimbabwe, and has also been introduced into Lake Kariba. It is generally thought to have had little impact on the native species, but this situation may have changed following the introduction of the Florida strain in 1981. This introduction seems to have changed the character of the population, with fish growing more rapidly and to a larger size (Figure 7.14), and they appear to have become more abundant. Unpublished data from river surveys in the Harare area (Zimbabwe) indicate that bass have a severe effect on the populations of indigenous fish, especially *Barbus* species.

Figure 7. 14 Changes in the angling record for Largemouth Bass, *Micropterus salmoides*, in Zimbabwe, 1952-1998. The symbol denotes the introduction of the Florida strain to Zimbabwe in 1981 (data from Anon. 1998).



The remaining exotics that are not extinct tend to occur in small populations with a low reproductive rate. For example, in November 1958 sixty common carp, *Cyprinus carpio*, weighing an average of 1 kg each were introduced into the Savory Dam near Harare. When the dam was drained in January 1980 there were found to be only 118 carp, only one of which weighed less than 6 kg and was estimated to be 15 years old (Evans 1982). Their failure to reproduce may have resulted from a high level of predation on their eggs and fry by the cichlids and other native species in the dam. Similarly, 1000 Bluegill sunfish, *Lepomis macrochirus*, were stocked into the dam in 1961 but only three, with an average weight of 0.8 kg, were found in 1980.

Attempts to introduce further non-African species can be expected. Aquaculturists continue to examine species like the Chinese or Indian carps, and the grass carp, *Ctenopharyngodon idella*, is currently being reared in both Zimbabwe and Zambia although it has not yet been released. Escaped aquarium fish may also be increasingly important in future and isolated populations of guppies, *Poecilia reticulata*, already occur in parts of Zambia and Zimbabwe (Thys van den Audenaerdd 1994, Gratwicke, in prep.).

Since the 1950s, the introduction of exotic species from elsewhere in Africa, including the translocation of species within the Zambezi Basin, has become much more important and is likely to have a far greater impact. So far, about 18 species are involved with nine of them being intra-basin translocations (Table 7.9). In some cases, these introductions were made for obscure or whimsical reasons; the lungfish, *Protopterus annectens*, was accidentally translocated to the Lake Malawi area, while *Tilapia zillii* were brought to Zimbabwe by President Mugabe who was persuaded – by someone in Uganda – that they would control water hyacinth (Anon. 1990). But in most cases they were done to improve fishery productivity or angling and, in contrast to the non-African species, with much more success.

The most spectacular introduction was that of the clupeid *Limnothrissa miodon* from Lake Tanganyika to Lake Kariba. Within two years of its introduction, *Limnothrissa* had colonised the entire lake and invaded the Zambezi River below the Kariba dam (Junor & Begg 1971). It later invaded Lake Cabora Bassa. The fishery on Kariba began in 1973 and now produces around 30,000 t per annum (Marshall 1995), while that on Cabora Bassa began in 1993, reached 3000 t by 1995 (FAO 1996) and may now have reached 10,000 t per annum. It may be one of the most cost-effective fishery projects ever carried out in Africa (Jackson, cited in Eccles 1985) and its ecological impacts were relatively small. It certainly had no impact on the diversity and abundance of most other fish species in the system, except for predators like *Hydrocynus vittatus* which increased in abundance (Marshall 1991). Attempts have been made to introduce *Limnothrissa* into the Itezhi-Tezhi Dam in Zambia (Mubamba 1993) but it is unclear whether they have succeeded or not.

The only other important non-cichlid introduction was that of the small sardine-like cyprinid *Mesobola brevianalis* into a small reservoir in the Eastern Highlands of Zimbabwe as a forage fish for trout. Although this species occurs in the Upper Zambezi, the stock for this introduction originally came from the Limpopo. The introduction was successful and it has since become established in the Inyangombe River (A.I. Payne & S. Temple, unpublished data) which flows into the Lower Zambezi via the Mazowe. The ecological impact of this species is unknown and it may compete with the native minnows (*Barbus* spp.), although it might have the effect of enhancing the similarities between the Upper and Lower Zambezi which already share many species.

Table 7.9 Exotic fish species of African origin known to have been introduced into the Zambezi basin. The symbol * denotes translocations within the basin (data from Toots 1970, Evans 1982, Bell-Cross & Minshull 1988, Thys van den Audenaerde 1994, Anon. 1996a and unpublished sources).

Species	Remarks
*Protopterus annectens**	Malawi; accidentally introduced to Bua River, near Nkota-Kota
Limnothrissa miodon	Lake Kariba, 1967-68; widespread and invaded Lake Cabora Bassa Zambia, 1992; Lake Itezhi-Tezhi, apparently failed
Mesobola brevianalis	Zimbabwe, *c*. 1970s; Inyangombe R., now invading Lower Zambezi
Barbus kimberleyensis	Zimbabwe, 1928; some may have briefly survived but probably extinct now
Tilapia zillii	Zimbabwe, 1990; fate unknown, possibly held in ponds
*Tilapia rendalli**	Zimbabwe, 1959; now widespread
*Serranochromis robustus**	Zimbabwe, 1965; now widespread on central plateau
*Serranochromis thumbergi**	Zimbabwe, 1 specimen, Lake Manyame (origin unknown)
*Sargochromis giardi**	Zimbabwe, 1970s; 1 specimen near Gweru (origin unknown)
*Sargochromis codringtonii**	Zimbabwe, *c*. 1978; Lake Chivero, present but rare
Astatoreochromis alluadi	Zambia, 1979; apparently unsuccessful
Boulengerochromis microlepis	Zambia, 1989; apparently unsuccessful
*Oreochromis mossambicus**	Zimbabwe, widely distributed on central plateau
Oreochromis placidus	Zimbabwe, 1955; restricted distribution in Harare area
*Oreochromis mortimeri**	Zimbabwe, widely distributed Zambia, 1950; from mid-Zambezi to Kafue system
*Oreochromis andersonii**	Zimbabwe, 1944; status uncertain, possibly abundant in some areas
*Oreochromis macrochir**	Zimbabwe, 1952; now widespread in all areas; also in lake Kariba Zambia; 1950; Congo strain into Kafue system
Oreochromis niloticus	Zimbabwe, *c*. 1982; now widespread, including Lake Kariba and Zambezi River Zambia, 1983; now established in Kafue River

The central plateau of Zimbabwe seems to have supported few cichlids prior to European settlement (Thys van den Audenaerde 1988) and extensive introductions of various species followed the construction of the reservoirs that provided suitable habitat for them. The first priority was given to enhancing tilapia stocks and *Oreochromis mossambicus, O. andersonii* and *O. macrochir* were bred in hatcheries and widely introduced into small reservoirs (Toots 1970). The latter was perhaps the most successful species and in Lake Chivero it displaced *O. mossambicus*, possibly because it was better able to deal with the increasingly eutrophic state of the lake (Marshall 1982), but it has become the dominant species in other lakes as well. Other successful species include *Tilapia rendalli* and *Serranochromis robustus*, which are now widely distributed throughout the country.

The ecological impacts of these introductions are unclear. *Tilapia rendalli* has been blamed for the destruction of vegetation and a consequent a loss of habitat for some fish and bird species (Junor 1969). In some small reservoirs on the Zimbabwean plateau, *S. robustus* replaced Largemouth Bass but became severely stunted, leading to a deterioration in their angling value (Toots & Bowmaker 1976, Evans 1982). Hybridisation of the various *Oreochromis* species is thought to have taken place, and it is generally believed that there are no longer any pure stocks left on the Zimbabwean plateau. However, the extent of hybridisation has never been fully investigated and it may have been less extensive than feared.

The translocation of these *Oreochromis* species could perhaps be justified on the grounds that they are Zambezian species that are extending their ranges with human assistance. But the same cannot be said of the most recent arrival, *Oreochromis niloticus*, which was brought to the region in the early 1980s by fish farmers in both Zambia and Zimbabwe (Thys van den Audenaerde 1994). It escaped from fish farms and is now present in the Kafue River and Lake Kariba (Thys van den Audenaerde 1994, Chifamba 1998) and in the Zambezi River below the Kariba dam. In addition, it has been enthusiastically – but illegally – translocated throughout Zimbabwe by anglers with whom it is popular because it grows larger than most of the other tilapias (Anon. 1996b). It tends to replace the other tilapias, primarily *O. mossambicus* and *O. macrochir*, and it is now the dominant species in many reservoirs. It is almost certainly in all of the major Zimbabwean tributaries of the Zambezi and can therefore be expected anywhere in the Middle or Lower Zambezi systems.

7.4.4 **Other alien species**

It is not only exotic fish that can threaten aquatic environments. Aquatic weeds like the water hyacinth (*Eichhornia crassipes*), Kariba weed (*Salvinia molesta*) and carpet weed (*Azolla filiculoides*) have caused problems throughout the basin. They can cover small water bodies and smother habitats, reducing light and oxygen and ultimately eliminating fish populations. Water hyacinth is by far the most intractable of these plants and it has become a serious problem in many parts of the Zambezi Basin. It is widespread in the Middle and Lower Zambezi, and in the Kafue system. At present, it is still largely absent from the Upper Zambezi and its tributaries and every effort should be made to prevent it from invading these areas. It is also present in the Zambezi Delta but it cannot tolerate saline water and is therefore unlikely to become a serious problem. It occurs in the Lilongwe River (Malawi), from where it could invade Lake Malawi, and the plant has indeed been found in the lake but it has not so far established itself there.

The effects of floating plants on the biota are ambiguous. They provide shelter for small fish and a habitat for invertebrates on which fish can feed but dense mats prevent photosynthesis, which makes the water below them anoxic. Recent data from the Gwebi River near Harare showed that the diversity and abundance of fish, amphibia and invertebrates was much reduced under floating mats of *Azolla filiculoides* (Gratwicke & Marshall, in prep.).

7.4.5 **Overfishing**

Overfishing is a complex term and can mean biological overfishing in which the stock is destroyed, or economic overfishing in which the catches fall to such a low level that fishing is no longer profitable. The extent of overfishing and its possible impact on biodiversity has not been well documented in the Zambezi Basin, although some information is available. Intensive fishing with small-meshed nets in shallow Lake Malombe in Malawi led to the destruction of important habitats, notably that of submerged and marginal vegetation. This contributed to the loss of the chambo (*Oreochromis* spp.) fishery and its replacement by less valuable haplochromines (Banda & Hara 1997). Another group of fish that are vulnerable to overfishing are those species that run up flooding rivers to breed, when they can be caught in large numbers, often before they have spawned. Labeos in large lakes are especially sensitive to this type of fishing and the fisheries for *Labeo victorianus* in Lake Victoria, *L. altivelis* in Lake Mweru and *L. mesops* in Lake Malawi all collapsed because of it (Jackson 1961a, Cadwalladr 1965, Msiska 1990). Overfishing may have more subtle effects, as in Lake Malawi where intensive fishing in inshore waters has reduced the number of snail-eating species, allowing snails to become more abundant and bringing schistosomiasis to areas where it did not occur previously (McKaye, Stauffer & Louda 1986). None of these fish are as yet extinct so biodiversity if measured as the presence or absence of species has not changed. Nevertheless, their abundance is much lower and the structure of the populations has changed, so they may now be much more vulnerable than before.

7.4.6 **Water abstraction and drainage of floodplains**

As the demand for water grows more will be consumed by agriculture and industry and reduce the flow in the rivers. The effects of reduced flows in southern African rivers are poorly understood although some work on these aspects is being done in South Africa (Allanson *et al.* 1990). In general, reductions in flow lead to the restriction of habitat in a stream. Adequate flows are necessary to stimulate breeding in many species of fish and it is these that are likely to decline if flows are reduced (Welcomme 1985). They will be replaced by species with a more flexible breeding pattern; in the Zambezi Basin this would entail the replacement of cyprinids by cichlids, for example.

The consumption of water and reduction of river flows will also increase fluctuations in the water levels of lakes and reservoirs, and decrease the extent of flooding on floodplains. The effects of water level fluctuations in lakes are complex and not necessarily detrimental. These fluctuations have a major impact on the mobilisation of nutrients in the littoral, which leads to an increase in invertebrate populations that are eaten by fish (McLachlan, A.J. 1970, McLachlan, S.M. 1970). On the other hand, severe fluctuations retard the development of communities of submerged vegetation, which are important substrates for invertebrates and refuges for small fish (McLachlan, A.J. 1969, Bowmaker 1973).

The impact of water level fluctuations on fish in lakes is less obvious since most of the fish species in the Zambezi system are adapted to highly changeable environments. Early workers on Lake Kariba (Jackson 1966, Harding 1966, Begg 1973) felt that large fluctuations in water level were deleterious to fishery production. These ideas were contradicted by Karenge & Kolding (1995) who found that fish catches were closely correlated with seasonal fluctuations, possibly because of their effect on nutrient inputs, but no correlation with the water levels during periods of drought.

The cycle of productivity on floodplains is, of course, determined by the hydrological cycle. The fish species are well adapted to this cycle and time their breeding to coincide with the rise and fall of the water. Fish catches on these floodplain systems are determined by the magnitude of the flood, although data from those in the Zambezi Basin are generally scarce. On the Barotse floodplain, van Gils (1988) showed that there was a positive correlation between the annual fish catch and the length of the flood season during the previous year. Thus, in 1983 and 1985, when the preceding flood season lasted only 130 days, the annual fish catch was 3500 and 4000 t respectively. In 1980 and 1981, when the flood season lasted for 210 days, the catch rose to about 6500 t. Similarly, Welcomme (1985) obtained highly significant correlations between the annual fish catches from the Kafue and Shire floodplains and the flood regime in the preceding year. However, because most of the fish caught in these fisheries were likely to be from one to two years old, he found that the best fit linear regression lines were obtained using data for both the preceding year and the year before. The equations were:

$$\text{Kafue: } C_y = 2962 + 70.54\,(0.7HI_{y-1} + 0.3HI_{y-2})$$
$$\text{Shire: } C_y = 5857 + 38.11\,(0.9HI_{y-1} + 0.3HI_{y-2})$$

where C_y = annual catch (t), HI_{y-1} = the hydrological index (a measure of flood intensity) in the preceding year while HI_{y-2} = the hydrological index two years before (Welcomme 1985).

These equations demonstrate the relationship between flooding and fisheries productivity on floodplains. In most cases, reduced flows are presently brought about by natural causes like drought, but the impact of human activities is likely to become more pronounced. Water supply to the Kafue Flats, for example, is regulated by the Itezhi-Tezhi dam upstream and by the Kafue Gorge downstream and these dams may have affected the floodplain quite considerably. Dam construction and power generation upstream might affect the floodplains of the Lower Shire, while the Zambezi Delta is affected by the Cabora Bassa dam.

The drainage and channelization of floodplains is associated with the abstraction of water, and these practices are responsible for major degradation of riverine environments and the destruction of fisheries in many parts of the world. In general, fish populations decrease in both numbers and diversity, as in the following examples (from Welcomme 1985):

(a) fish catches in the Missouri River were 2-2.5 times higher in undisturbed sections than they were in channelized ones;
(b) channelized streams in North Carolina supported a fish biomass of 55 kg/ha, compared to 175 kg/ha in unchanneled ones;
(c) the biomass of fish in the Blackwater River, Missouri, was reduced from 633 kg/ha to 147 kg/ha by channelization.

Data from African systems are generally lacking and African rivers have not so far been channelized to any significant degree. An exception is the proposal to draw water from the Okavango system (see Scudder *et al*. 1993 for details), which could have a significant impact on the biodiversity of fish. River "improvement" here is likely to cause a 60-80% decrease in fish populations (Table 7.10). A dredged section of the Boro River lacked aquatic vegetation and the associated floodplain had dried out and was severely overgrazed. The number of fish taken in December was considerably higher than the number caught in July, partly because fish are more difficult to catch in cold water and partly because only gillnets were used during the July survey.

7.4.7 **Pollution**

The continuing growth of cities in southern Africa and the commitment of its countries' governments to development means that pollution and eutrophication will become increasingly serious problems. Some pollution occurs as a result of the use of water bodies by humans as in Lesotho, for example, where dams around towns are used for washing clothes, cars and engines and for the general disposal of waste. As a result, they have become so polluted that they can support few fish other than the carp *Cyprinus carpio* (ALCOM, pers. comm.). On a larger scale, pollution from the discharge of organic matter of various kinds, acid discharges from mines and factories, and contamination by heavy metals are likely to have more serious effects on biodiversity. These problems have begun to appear in the Middle Zambezi around cities like Harare (see Moyo 1997 for examples) and in the Kafue system around the Zambian Copperbelt and Lusaka. Raw sewage discharged into the Zambezi from Livingstone (Zambia) and Victoria Falls (Zimbabwe) has contaminated the Zambezi River for a long way downstream (Feresu & van Sickle 1990). Studies to quantify the levels of heavy metal contamination have been made in Lake Kariba (Berg & Kautsky 1997) but in very few other places.

Pesticides have been widely applied throughout the region in an attempt to control tsetse fly. The aerial application of endosulphan has caused fish kills in the Okavango Delta in Botswana (Russel-Smith 1976, Fox & Matthiessen 1982), but it is not the short-term application of pesticides that poses the greatest threat to fish populations. Far more important are the long-term effects of persistent pesticides such as DDT, which is widely distributed in aquatic systems throughout the region (Greichus *et al*. 1977, 1978a, 1978b, Matthiessen 1985). Fortunately, the use of most persistent pesticides is banned in many countries and their concentrations declined after the bans were enforced (Table 7.11).

Eutrophication is likely to become a major problem and has been widely reported from parts of South Africa and Zimbabwe. The problem is mostly caused by the discharge of sewage, or sewage effluents, into the streams that flow into lakes. Eutrophication is manifested by enhanced capacity for plant growth, either in the form of rooted or floating macrophytes, or as phytoplankton which gives the water a green colouration. Primary productivity is high in eutrophic systems and in its early stages, at least, fish production is greatly increased, but if the process continues, conditions worsen and lead to a decrease in fish species diversity. In the hypertrophic Hartbeespoort Dam, for example, the fish fauna is dominated by only three species, *Oreochromis mossambicus*, *Clarias gariepinus* and *Cyprinus carpio*, and there is some evidence that their growth rates are slower than in less eutrophic systems (Cochrane 1985). Anaerobic conditions in the hypolimnion tend to become more extensive and to last longer in eutrophic systems, which increases the risk of fish kills, like the one that occurred in Lake Chivero in 1996 (Marshall 1997).

7.4.8 **Siltation**

The increasing rate of deforestation and land clearance in Africa, combined with poor agricultural practices and the unrelenting growth of the human population, is perhaps the most serious threat to small water bodies. Whitlow (1983) has shown that soil losses through erosion were over 20 times greater from cleared plots compared to protected ones at a sandveld site in Zimbabwe. There is little doubt that soil erosion is becoming an increasingly serious problem in much of southern Africa and is having a serious impact on its aquatic environments.

Large water bodies are not immune. There is evidence to show that the littoral areas of Lake Tanganyika are beginning to suffer from the blanketing effect of sediment carried into the lake (Cohen *et al*. 1993), and there are fears that something similar is happening in Lake Malawi (A.J. Ribbink, pers. comm.). This could have a serious effect on the complex community of endemic rock-dwelling cichlids ("mbuna") in the lake, all of which depend on the algal mat that grows on the rocks. In addition to blanketing the algal mats, silt reduces the food supply by preventing animals from establishing themselves on rocks, fills in refuges leading to increased juvenile mortality, and reduces light penetration which reduces available food and disrupts the breeding behaviour of cichlids. But the effect of sediments is much more detrimental in small water bodies, which, in some areas, have lost significant quantities of their storage capacities. In parts of Zimbabwe, for example, a number of small dams lost, on average, 39% of their capacity in 20 years (Magadza 1984, 1992). One dam lost 100% of its storage capacity in less than 2 years, and habitat destruction on this scale will have a severe impact on fish populations.

Table 7.10 The numbers of individual fish (N) and the number of fish species (S) caught in dredged and undredged sections of the Boro River, Okavango Delta, Botswana (data from JLB Smith Institute of Ichthyology (unpublished)). nd = no data.

	Dec1982		July1985	
	N	S	N	S
Nxaragha Lagoon (upstream)	n/d	n/d	56	15
Thamalakane River (downstream)	1126	22	53	9
Boro River (dredged)	145	18	9	5

Table 7.11 Changes in the concentration of DDT (Fg/g dry weight) in sediments and two species of fish in Lake Chivero, showing the rapid decrease in concentrations following the banning of DDT for agricultural use in 1983 (n/d = no data) (data from Greichus *et al*. 1978, Greichus 1982 and Mhlanga & Madziva 1990). The apparent increase in DDT in the sediments may reflect experimental error.

	1974	1979	1988/89
Sediments	57	n/d	76
Oreochromis macrochir >500 g	450	1270	210
Clarias gariepinus	n/d	1510	180

Table 7.12 Some indicator chemical qualities of the Middle and Lower Zambezi and major tributaries arranged in successive order from Victoria Falls to below the Shire confluence (from Bell-Cross 1974 and Davies 1986).

	Upper Zambezi (Bell-Cross)	Upper Zambezi	Kafue River	Luangwa River	Zambezi River (Tete)	Shire River	Lower Zambezi
PH		7.6	7.5	7.9	7.8	7.5	7.8
Conductivity (mS/cm)	84	75	231	147	119	315	153
Total alkalinity (mg/l $CaCO_3$)	40	33	124	57	53	110	73
Nitrate (mg/l NO_3-N)	-	0.01	-	0.15	0.16	0.18	0.13
Phosphate (mg/l PO_4-P)	3	13	-	78	121	69	78
Transparency (Secchi disc, m)	-	5.4	1.1	0.4	0.3	0.3	0.2

7.4.9 **Conclusions**

There is little doubt that conditions in the Zambezi Basin will continue to change. Human activities such as reservoir construction, the introduction of exotic species and the translocation of indigenous ones will continue. Aquatic systems will continue to be stressed even more as the human population grows and the need to balance the demand for water against the need to conserve biodiversity will become an increasing challenge for fish biologists. Added to this are the unpredictable consequences of climate change, which could lead to reduced rainfall throughout much of the basin (Unganai 1996).

Nevertheless, the magnitude of change is likely to vary in different parts of the basin. The Upper Zambezi is relatively undeveloped and its fish fauna is still intact. It generally lacks mineral resources, has limited agricultural potential and few significant dam sites, and the pace of change is likely to be relatively slow. There is a real chance, therefore, that its fish fauna can be kept in its relatively intact state, provided safeguards are instituted and maintained. The control of exotic fish species, especially *O. niloticus* should be given a high priority and fish farmers should not be allowed to use it anywhere in the basin.

The Kafue system is less secure since a large proportion of Zambia's population and most of its urban centres and industrial potential lies in its drainage basin. The Kafue Flats, a complex and important wetland (Handlos 1982), has already been affected by the construction of dams at Itezhi-Tezhi and Kafue Gorge. The influence of these dams is still unclear; they are said to have reduced the yield of fish, especially tilapias (Subramaniam 1992), but this may also be a consequence of drought and overfishing. More importantly, *O. niloticus* is now established in the Kafue (Thys van den Audenaerde 1994) and it is likely to spread throughout the Kafue Flats to the detriment of the native species, *O. andersonii* and *O. macrochir*.

The Middle Zambezi is by far the most seriously altered part of the basin and is likely to remain so since it includes its most advanced agricultural sites, and some of its largest urban areas with extensive mining and industrial areas. While the Lower Zambezi is a relatively undeveloped area, it is influenced by developments upstream, notably flow regulation and introduced species. Few of these changes can be reversed, but every effort should be made to ensure that their impact is minimised and to preserve any relatively unaltered systems that may still occur in the basin.

Finally, the Lake Malawi basin remains intact, although the species composition in the lake may be changing because of commercial fishing (Turner *et al*. 1995). The extraordinary diversity of the lake's endemic haplochromines makes it one of the world's greatest biological resources and the need to preserve it is widely recognised. The events in Lake Victoria have shown that these endemic cichlid species-flocks may be extremely vulnerable to the impact of introduced predators and it is essential that all exotic species are kept out of the lake (Lowe-McConnell 1995). So far, these efforts have been successful, but nobody should lower their guard because the pressures to spread exotic fish around are unlikely to decrease. The growing population, and increasing poverty, of Malawi may revive the suggestion that species like *Limnothrissa* should be introduced (Turner 1982) while the continuing use of *O. niloticus* in aquaculture makes it almost inevitable that it will reach Malawi.

7.5 WETLANDS OF SPECIAL INTEREST

7.5.1 The Barotse Floodplain

The Upper Zambezi system drains the basin from its source to the Victoria Falls. This stretch of the river is about 1440 km long, of which about 384 km flows through Angola (Bell-Cross 1974). Fishing has long been an important activity among the Lozi people of the area with a distinct social function, as well as providing a source of food (Gluckman 1941). A variety of traditional fishing gear, including gill nets made from tree bark, lift-nets, barriers, traps and baskets, are used in the fishery, but the introduction of beach seines and nylon gill nets has greatly improved productivity (Bell-Cross 1974). The Upper Zambezi is now a major source of fish in Zambia, providing about 8000 tonnes per annum or about 11.0% of the country's total supply. Most of this catch comes from the two most important wetlands in the system, (a) the Central Barotse floodplain and (b) the Southern Barotse floodplain.

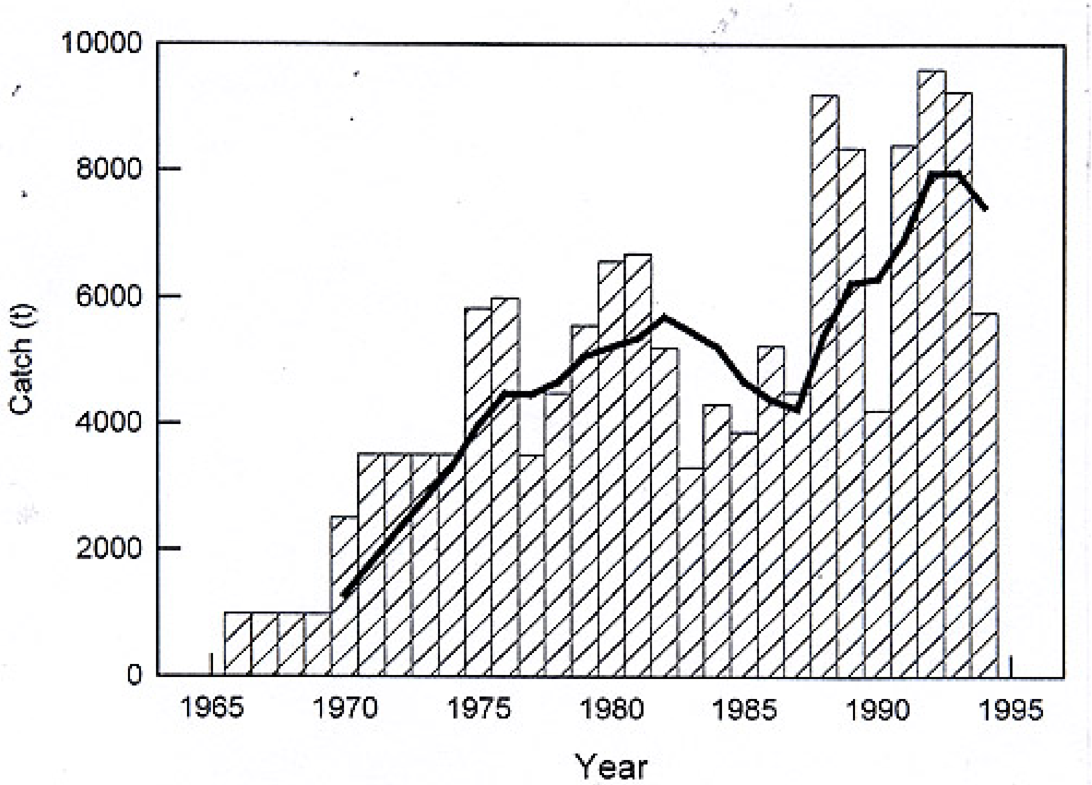
The Central Barotse Floodplain extends from Lukulu in the north to Nangweshi in the south, and is approximately 240 km long and up to 35 km wide (Bell-Cross 1974). In the flood season it covers an area of up to 7500 km^2 (Vanden Bossche & Bernacsek 1990). It is largely covered with grass but with isolated trees or clumps of trees. The dominant semi-aquatic plants along the main channel are the grass *Vossia* sp. and *Potomogeton* spp. Patches of the reed *Phragmites* occur on banks of the main channel and in the numerous lagoons and backwaters that branch off. Water lilies (*Nymphaea* spp. and *Nymphoides* sp.) are abundant in these channels and lagoons, as are dense beds of other aquatic macrophytes like *Utricularia* sp., *Najas* sp. and *Ceratophyllum* sp.

The Southern Barotse floodplain is approximately 100 km in length and is located between Sesheke and Mombova, and the main river channel marks the international boundary between Zambia and Namibia (Bell-Cross 1974). On the Zambian side the floodplain is about 8 km wide and the vegetation is similar to that of the Central Barotse floodplain, although there are more trees along the river. This floodplain is contiguous with the eastern portion of the Chobe-Linyati floodplain system.

In both floodplains, the river flows over belts of Kalahari sands and is constantly changing course owing to the erosion and redeposition of its sandy banks. These sands are very low in nutrients and the river water is therefore nutrient-poor, especially compared to the Kafue, Luangwa or Shire rivers (Table 7.12). The system is therefore unproductive and the fishery yield from the Barotse floodplain is only about half of that from the Kafue floodplain, even though they are of comparable size (Bell-Cross 1974). The catches from the Upper Zambezi vary from year to year but there is a generally increasing trend (Figure 7.15) possibly because of the growth of the human population and perhaps to an improvement in the road network which makes it easier for fishermen to market their catch. The potential yield of this system has been estimated to be around 14,000 t per annum (Vanden Bossche & Bernacsek 1990), which may be an overestimate bearing in mind the low productivity of the system..

Most of the fish species recorded from the Upper Zambezi occur on the floodplains, with the exception of a few that are restricted to its upper reaches – such as *Paramormyrops jacksoni, Barbus neefi*, *B. brevidorsalis*, *Clarias liocephalus* (Bell-Cross lists *C. submarginatus*, a synonym of *C. liocephalus*, as being widespread but this almost certainly refers to *C. stappersii*), *Hypsopanchax jubbi* and *Schilbe yangambianus*. The status of *Serranochromis coulteri* is uncertain as it appears to be limited to the headwaters of the system but it may also occur on the floodplain. The most abundant large species seem to be *Hydrocynus vittatus*, *Oreochromis macrochir*, *O. andersonii* and *Tilapia rendalli*, which together made up 56% of the catch in the gillnet fishery (Table 7.13). Gill nets are highly selective, however, and only 26 species were represented; small one like the barbs, which may be among the most numerous, are not represented in the catch because they are too small.

Figure 7.15 Fish catches from the Upper Zambezi system in Zambia. The bars indicate the catch while the continuous line is the 5-year moving average (data from Department of Fisheries, in Anon. 1995).



Little is known about the biology of the fish on the Zambezi floodplains. Bell-Cross (1974) gives some notes on the biology of each species, while Winemiller (1991) and Winemiller & Kelso-Winemiller (1994, 1996) have made more detailed biological studies of the serranochromines, the tigerfish and African pike and the squeakers. As on all floodplains, there is a distinct pattern of migration with fish moving onto the floodplain and up tributaries to breed as the water level rises and moving back to the main channel as it falls. Bell-Cross (1974) believed that an increase in river velocity was the stimulus to migration and that the depth of the water controlled fish movements. Each species had its own "depth dependency" factor, which meant that the smaller species were among the first to move onto the floodplain. Of the larger species it appeared that the cichlids were the first to migrate and the large characins among the last. He also thought that falling water levels were the stimulus for a reverse migration and he noted that small species, and the young of larger ones, tended to remain in shoals for much of the dry season. The general pattern of migration was summarised by van Gils (1988) in relation to the traditional Maalelo fishery, and the more intensive gillnet fisheries (Table 7.14).

Table 7.13 The relative abundance (% by weight) of fish species in the gillnet catch, central Barotse floodplain, 1967 survey (data from Bell-Cross 1974). Species are listed in order of abundance.

Hydrocynus vittatus	18.4
Oreochromis macrochir	17
Oreochromis andersonii	10.8
Tilapia rendalli	9.9
Hepsetus odoe	6.3
Serranochromis macrocephalus	4.9
*Serranochromis angusticeps**	4.7
Mormyrus lacerda	4.5
Clarias gariepinus	4.3
Clarias ngamensis	3.4
Serranochromis robustus	2.9
Sargochromis carlottae	2.5
Tilapia sparrmanii	1.4
Sargochromis giardi	1.6
Sargochromis codringtonii	1.6
Schilbe intermedius	0.9
Labeo lunatus	0.8
Synodontis woosnami	0.3
Synodontis nigromaculatus	0.2
Parauchenoglanis ngamensis	0.2
Marcusenius macrolepidotus	0.2

*This is presumably a mixture of Serranochromis *angusticeps* and *S. altus* since the latter had not been described at the time these data were collected.

Table 7.14 The seasonal cycle of fish abundance and fishing activity on the Barotse floodplains (from Van Gils 1988).

Jan-Apr	Apr-Jul	Jul-Oct	Oct-Dec
Late rainy season	Early dry season	Late dry season	Early rainy season
fish move up channels	fish dispersed on floodplain	fish move back to channel and lagoons	fish restricted to dry season refuges
production of young by most species	rapid fish growth	heavy losses to man and predators	reduction in fish population
almost no fishing	Maalelo fishery	intensive fishery	fishing in pools, swamps and landlocked lagoons

The Barotse floodplains seem relatively secure from a conservation point of view as the area lacks significant agricultural or mineral potential and the human population density is relatively low. There are no major dam sites that are likely to alter the flow regime and there are unlikely to be any major projects to drain or channelize the floodplains in the foreseeable future (in contrast to the Okavango, for example). At present, the fish stocks are relatively intact and there are no known alien species in the system; every effort should be made to ensure that this remains so. The main factor affecting the fish population is a continuing increase in fishing intensity, which is likely to affect the larger species first, and could change the composition of the population. Fishing could drastically reduce the numbers of some species but is unlikely to drive any to extinction.

7.5.2 **The Chobe-Linyanti system**

This floodplain system begins at the point where the Kwando River, having flowed south through Angola and the Caprivi Strip, Namibia, reaches Botswana. The Chobe flows in an ENE direction to join the Zambezi at the common borders of Botswana, Namibia, Zambia and Zimbabwe. At this point the Chobe floodplain system becomes part of the southern Barotse floodplain. The Linyanti Swamp is about 300 km^2 in extent but its size varies greatly according to the extent of the flood. Water levels in the system depend to a large extent on the height of the Zambezi floods, which causes the water to back up into it.

The only significant fishery in this system was in Lake Liambezi, located on the Chobe in Namibia and Botswana. It was located in a flat region with numerous swamps and slow-flowing rivers in a swamp system covering an area of some 300 km^{2,} of which only 101 km^2 consisted of open water. The lake had an unstable recent history since it is not shown on maps published before 1950, which show only an area of reed swamp. It came into being after a drought when the local inhabitants burnt the accumulated organic matter to clear land for agricultural purposes (Seaman *et al*. 1978).

Fishing activity began in 1959 and, although there are no records from this early period, it is believed that considerable quantities of fish were captured and exported to Zambia. The fishery was investigated between May 1973 and April 1976 and some data on catches and yields are available from this period (Van der Waal 1980). The catch was made up mostly of cichlids (80.4% by weight), of which *Oreochromis andersonii* and *O. macrochir* were the most important (43% and 26%, respectively). The clariids (*Clarias gariepinus* and *C. ngamensis*) were the next most important species (12.6%) with a variety of other species making up the remainder of the catch.

Fish catches fell during this period, from 640 t in 1973-74 to 115 t in 1975-76 (Table 7.15).

Table 7.15 Fish catches and productivity of Lake Liambezi, May 1973 to April 1976 (data from van der Waal 1980).

		Yield(kg/ha)	
	Catch (t)	**Open water**	**Lake + swamp**
1973-74	636.9	63.7	21
1974-75	279.2	27.9	9
1975-76	115.3	11.5	4
Mean	343.8	34.5	11.5

According to Van der Waal (1980) this decline was not a result of excessive fishing because the number of fishermen decreased as well. Instead, he attributed it to a rise in the water level, which decreased the efficiency of the nets because (a) the nets no longer reached to the bottom of the lake, (b) the surface area of the lake doubled in size and the population density of the fish decreased, and (c) the turbidity of the water decreased, making the nets more visible and therefore less efficient. Van der Waal (1980) made various recommendations for managing this fishery, and believed that it could produce as much as 750 t/yr and thus provide a permanent living for one hundred people. Unfortunately the lake dried up during the droughts of the 1980s and no longer supports a fishery. However, recent information suggests that the lake may come into existence once again, following high flows in the Zambezi during the 1997-98 rainy season.

The species composition of the fish is similar to that of the Upper Zambezi and it is likely that the same species occur in both systems. Van der Waal (1996) collected a total of 65 species during a survey in the Caprivi area out of a total of 76 recorded from the whole Caprivi area (Van der Waal & Skelton 1984). Some idea of their relative abundance can be obtained from his data (Table 7.16) but they clearly illustrate the effect of fishing gear on estimates of relative abundance. Little work has been done on the biology of fish in the Chobe/Linyanti system. The general biology, including investigations of growth, feeding and breeding, of the larger species was investigated by Van der Waal (1980), who made some general comments on their migration, which were expanded in a later paper (Van der Waal 1998). The general pattern of migration was similar to that of the Upper Zambezi, with a total of 31 species moving between the rivers and the floodplain, compared to 12 species that remained in the river and 17 that remained on the floodplain (Table 7.17).

The conservation status of this wetland is similar to that of the Zambezi floodplains. The area has very little agricultural potential because it lies over infertile Kalahari sands, and there are no known mineral deposits of any significance. Consequently, there are unlikely to be any major drainage projects, or other developments that will significantly reduce the size of the floodplain, in the immediate future.

7.5.3 **Lower Shire**

Some small, but important, floodplains occur along the Lower Shire in Malawi. The fish species caught in these systems are typically Zambezian with *Clarias gariepinus* and *Oreochromis mossambicus* being the most important of them. The total catch ranged from 4000 to 17,000 t/yr, with a mean around 8000 t (for the period 1970-1982), which is close to the estimated potential yield (Vanden Bossche & Bernacsek 1990). The Elephant Marsh (500 km^2 flooded permanently, up to 1000 km^2 flooded during the rainy season) is the largest and most important flood plain in the system and may support as many as 4000 fishermen. These marshes are densely populated and heavily cultivated, with at least parts of them having been converted into sugar plantations. It is not known what effect this has had on fish productivity.

The fish species in the wetlands are typical of those found in the Lower Zambezi system, although most of the marine species do not penetrate upstream as far as the floodplains. The diversity and abundance of fish is related to the distance from the Shire River. The diversity of fish was greatest at a site on the river, and rheophilic species like *Hippopotamyrus discorhynchus*, *Brycinus imberi*, *Hydrocynus vittatus*, both species of *Distichodus*, *Barbus afrohamiltoni*, both species of *Labeo* and *Synodontis zambezensis* were most abundant there. By contrast, both species of *Clarias*, the cichlids *Astatotilapia calliptera*, *Oreochromis mossambicus* and *O. placidus*, and the climbing perch *Ctenopoma multispine* were more numerous away from the river on the floodplain.

Table 7.16 The relative abundance of fish species (% by numbers) in the Lake Liambezi/Linyanti swamp system, according to different methods of capture (data from Van der Waal 1985, 1998).

	Mulapo traps	Seine net (25 mm)	Seine net (50mm)	Gill nets (25-190 mm)
Petrocephalus catostoma	0.9			11.6
Pollimyrus castelnaui	1.6			
Marcusenius macrolepidotus	4.2		0.01	19.3
Mormyrus lacerda	0.03			0.02
Hydrocynus vittatus			0.02	0.02
Brycinus lateralis	0.01	7.3	0.1	2.1
Rhabdalestes maunensis	0.06			
Hepsetus odoe	0.1	1.4	3.6	2.9
Hemigrammocharax multifasciatus	0.04			
Barbus poechii	1.1	1.8	0.1	0.9
Barbus afrovernayi	4.1			
Barbus barotseensis	0.06			
Barbus bifrenatus	4.9			
Barbus multilineatus	0.07			
Barbus paludinosus	54.2			
Barbus radiatus	0.01			
Barbus thamalakanensis	0.01			
Parauchenoglanis ngamensis	0.02			
Schilbe intermedius	4.7		0.1	32.9
Clarias gariepinus	0.1	0.1	0.1	0.7
Clarias ngamensis	0.5	0.1	0.2	0.8
Clarias stappersii	0.02			
Clarias theodorae	0.4			
Synodontis leopardinus/woosnami	0.5		0.1	13.9
Synodontis macrostigma			0.04	2.6
Synodontis nigromaculatus				1.1
Aplocheilichthys johnstonii	0.2			
Aplocheilichthys katangae	0.05			
Aplocheilichthys hutereaui	0.01			
Hemichromis elongatus	0.01			
Oreochromis macrochir	0.2	16.6	60.6	1.1
Oreochromis andersonii	0.3	3.9	6.6	1.3
Tilapia sparrmanii	5.4	5.9	1.6	0.9
Tilapia rendalli	0.7	15.3	7.1	0.8
Sargochromis giardi		0.6	0.3	0.3
Sargochromis codringtonii		2.2	3.4	0.9
Sargochromis carlottae		2.4	1.1	0.1
Pharyngochromis acuticeps	0.01	35.2	4.8	2.2
Serranochromis robustus	0.06	0.1	0.2	0.02
Serranochromis macrocephalus	0.01	3.1	3.5	2.7
Serranochromis longimanus		1.5	2.9	0.6
Serranochromis angusticeps		1.3	1.8	0.9
Serranochromis thumbergi		1.1	2.2	0.3
Pseudocrenilabrus philander	13.6	0.1		
Aethiomastacembelus frenatus	0.04			
Ctenopoma intermedium	0.4			
Ctenopoma multispine	1			
Number of specimens	24,948	2,157	6,725	15,014

Table 7.17 The migration pattern of fish species in the Chobe/Linyanti and southern Zambezi floodplain system (data from Van der Waal 1998).

Group A: species that remain in the rivers	Group C: species that move between rivers and floodplains
Hippopotamyrus discorhynchus	*Marcusenius macrolepidotus*
Barbus eutaenia	*Mormyrus lacerda*
Barbus lineomaculatus	*Petrocephalus catostoma*
Labeo cylindricus	*Pollimyrus castelnaui*
Opsridium zambezense	*Barbus afrovernayi*
Hemigrammocharax multifasciatus	*Barbus barnardi*
Nannocharax macropterus	*Barbus barotseensis*
Parauchenoglanis ngamensis	*Barbus bifrenatus*
Amphilius uranoscopus	*Barbus multilineatus*
Chiloglanis neumanni	*Barbus paludinosus*
Synodontis macrostigma	*Barbus poechii*
Hemichromis elongatus	*Barbus radiatus*
	Barbus thamalakanensis
Group B: species that remain on the floodplain	*Barbus unitaeniatus*
Barbus fasciolatus	*Labeo lunatus*
Coptostomobarbus wittei	*Brycinus lateralis*
Rhabdalestes maunensis	*Hydrocynus vittatus*
Clarias stappersii	*Micralestes acutidens*
Aplocheilichthys hutereaui	*Hepsetus odoe*
Oreochromis andersonii	*Schilbe intermedius*
Oreochromis macrochir	*Clarias gariepinus*
Sargochromis carlottae	*Clarias ngamensis*
Sargochromis codringtonii	*Clarias theodorae*
Sargochromis giardi	*Synodontis leopardinus*
Serranochromis angusticeps	*Synodontis nigromaculatus*
Serranochromis macrocephalus	*Synodontis woosnami*
Serranochromis robustus	*Aplocheilichthys johnstonii*
Serranochromis thumbergi	*Pharyngochromis acuticeps*
Tilapia ruweti	*Pseudocrenilabrus philander*
Ctenopoma intermedium	*Tilapia rendalli*
Ctenopoma multispine	*Tilapia sparrmanii*

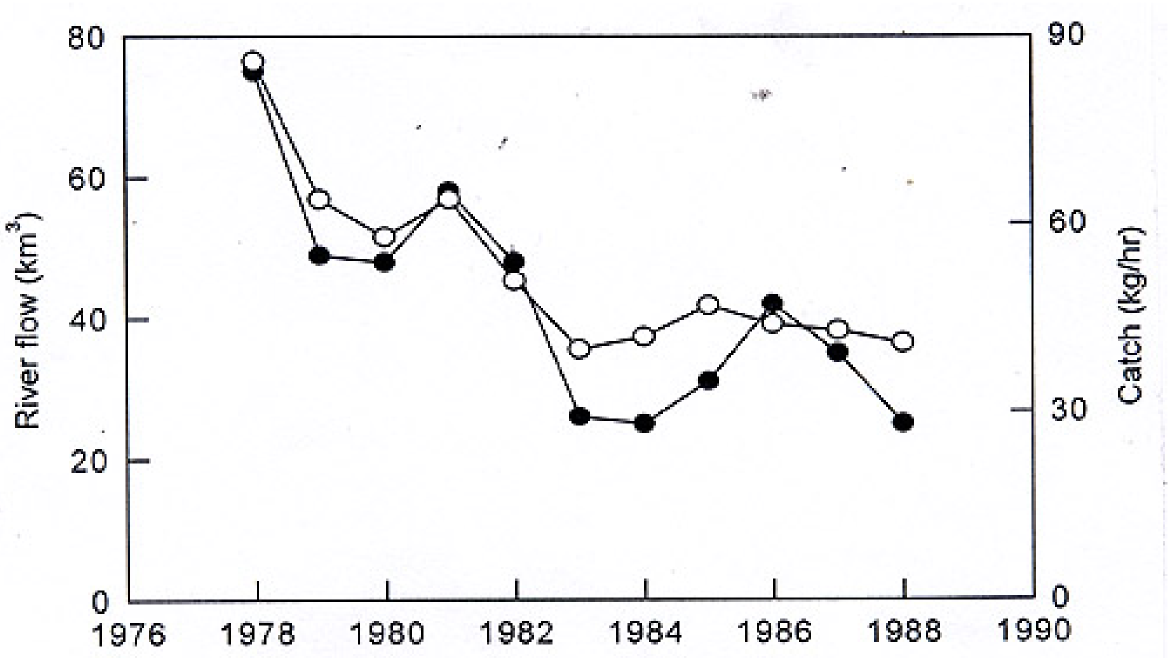
As with the Zambezi Delta, the main threats to diversity in the Lower Shire floodplains come from the possible development of large-scale irrigation farming. Crops like sugar and rice would convert more of the floodplain into agricultural land and require canalization of the river and the consumption of water. Pollution from agro-chemicals is a possibility in such a system. There is a clear need for an investigation of future proposals for development in these floodplains, an assessment of their impact, and measures to rectify some of the problems.

7.5.4 **The Zambezi Delta**

The delta of the Zambezi River is an ecologically important area where there is a transition from fresh to salt water. Its fish fauna reflects this transition by the presence of various marine species that enter freshwater (Table 7.2). The delta is an important area because of its potential for fishery production and as a nursery area for marine species, but its current fish yield is presently unknown. Unfortunately, very little is known about the ecology of the delta or the biology of its fish. There is an urgent need for investigations in view of the threats to the system.

Fears were expressed that the ecology would be severely disrupted by changes in the river flows after construction of the Cabora Bassa dam (Davies 1975, Davies *et al.* 1975). The only published data on this aspect is the evidence that the catch of prawns on the Sofala Bank, off the delta, was positively correlated with the flow of freshwater into the sea (Figure 7.16). The flow of freshwater is, of course, partly controlled by the Kariba and Cabora Bassa dams (but also by the climate). This is similar to the situation in the eastern Mediterranean where catches of fish and shrimps decreased after construction of the Aswan High Dam on the Nile (Ryder & Henderson 1975, Wadie & Abdel Razek 1985).

Figure 7.16 The relationship between the flow of the Zambezi River (●) and prawn catches (○) on the Sofala Bank, Mozambique (redrawn from data in Gammelsrod 1992).



There are few other data on the fish catches from the delta. Some information made available by IUCN indicates that the catch includes a mixture of estuarine and freshwater fish and the proportions of each will depend on the location of the fishery. Among the more important species are the mullets (*Mugil* and *Liza*) that tend to enter freshwater, and the Tarpon (*Megalops cyprinoides*) which is known to penetrate up the Zambezi as far as Tete. The distribution of fish in the delta will be determined by the salinity of the water, with marine and estuarine fish occurring in areas of high salinity, while other species will be restricted to freshwater. These distribution patterns are presently unknown.

The Zambezi Delta is, potentially, one of the most threatened of the Zambezi wetlands. Dam building is one of the threats and several dams have been proposed on the river below Cabora Bassa, e.g. Mepanda Uncua, Boroma and Lupata (Norconsult, undated). They have the potential to further alter the flow regime, already much changed by the existing dams. Another threat is the possibility of large-scale irrigation as the Zambezi Valley below Tete has areas of irrigable soil. Extensive plantations of crops such as sugar have been grown in the past in the Lower Zambezi and further development of irrigation is possible. Irrigation would further reduce the amount of freshwater flowing into the system, while large-scale agriculture brings the risk of pollution from agro-chemicals. Finally, exotic fish species could reach the delta from the Zimbabwean plateau where they are widespread. The River Sardine *Mesobola brevianalis* may have already done so, since the reports of "kapenta-like" fish in the Lower Zambezi (Williams 1998) may refer to it. The impact of exotic fish is uncertain at present, but they could have some impact on the indigenous species.

There is therefore an urgent need for a better understanding of the ecology of the Zambezi Delta. In particular, the distribution and salinity tolerance of its freshwater fishes needs to be known so that the effects of reduced fresh water inflows (and possible increases in salinity can be assessed. While the fish community consists primarily of the Lower Zambezi species listed in Table 7.2, there may be other species present, especially estuarine ones capable of living in both fresh and brackish water, and the community may be more complex than is generally realized (see Appendix 7.1).

7.6 CONSERVATION AND FUTURE DIRECTIONS

7.6.1 Species of special conservation interest

The conservation of fish species, like that of all other animals, requires the protection of entire ecosystems. This is a particular problem in rivers because they are linear systems and can be influenced by events in the catchment areas, often far from the area to be protected. Conservation planning therefore needs to consider if there are (a) species and (b) ecosystems of special interest that need special conservation measures. The discussion so far has clearly identified areas of interest but little has been said of species of special concern.

Species with restricted distributions and small populations are generally considered to be the most vulnerable and require special attention. Most of the fish of the Zambezi Basin, with the obvious exception of those in Lake Malawi, have relatively wide distributions and the degree of endemicity[1]

[1] It is worth defining what is meant here. An *endemic* species is one that is restricted to only one of the sub-basins listed in Table 2. Another useful term is *near-endemic*,which is a species that has a restricted distribution in (a) two sub-basins of the Zambezi system, or (b) in one sub-basin and in another river system. Some species with only a limited distribution in the Zambezi sys tem are not considered near-endemics if they are widespread elsewhere. An example is the Yangambi Butter Catfish, *Schilbe yangambianus,* which has only been collected once in the Zambezi system but is widespread in the Congo Basin.

is generally low (Table 7.18). The greatest level of endemicity is in the Cunene system where 18% of the fish species qualify as endemics or near-endemics, which is about three times that of any other sub-basin. The reasons for this are unclear but it is probably not isolation alone, since the Cunene appears to have been cut off from the main Zambezi system for about as long as the Kafue (Skelton 1994), which has no endemics. It is possible that habitats in the Cunene are more diverse than in the Kafue, or that the river has more frequently been invaded by fish from the Congo or west coast river systems. Whatever the reasons, the Cunene is one of the most important centres of fish diversity in the southern African region and warrants further study and conservation. Unfortunately most of its length lies in Angola and little can be done at present.

The headwaters of the Okavango and Zambezi are also centres of slightly higher endemism with some species that seem to be restricted to fast-flowing streams in forested areas. The Lower Shire is the only other part of the basin with significant endemism, caused by the presence of some species typical of the Lake Malawi system entering it. An exception is *Varicorhinus pungweensis*, which also occurs in the headwaters of the Pungwe in eastern Zimbabwe. The only other endemic species in the basin are two killifish (*Nothobranchius* spp.), one endemic to each of the Kafue and East Caprivi, which are a group that typically occur in small areas. This is because of their specialized habits that enable them to live in temporary waters that are frequently isolated from other systems.

7.6.2 **Future directions**

Much of the work done on fish in the basin over the last fifty years has concentrated on fisheries. The development of fishery resources is obviously given priority because of the growth of the human population and the consequent demand for fish. Much of this work has progressed without an adequate biological base and there is a clear need for further biological investigations. This is especially important now that many fisheries have reached a level of intensity where they may be changing the composition of the fish population. The extent and impact of these changes is largely unknown. These problems have been recognised in Lake Malawi, one of the world's major centres of fish biodiversity, where a major GEF-supported project has been established. But little is being done elsewhere in the basin and this lack needs to addressed. Areas of concern include:

(a) The distribution of fish species. While this aspect is reasonably well known, there remains much to be done and areas that have been poorly investigated need further study. These include the Lower Zambezi and Delta, the Luangwa Valley and the headwaters of the Zambezi, Okavango and Cunene in Angola.
(b) Although some areas have been collected thoroughly, much of the work was done some time ago and little is known about the changes that have taken place since. It is important that some effort is made to determine the extent of change in some of these areas at least.
(c) While much of the interest centres on the larger floodplains, there are more vulnerable areas that deserve attention. They include smaller rivers and streams where changes are much more dramatic and whose fish populations may already have been irrevocably altered.

The Zambezi Basin is an area with a great diversity of fish species, and with some highly productive systems that can provide large quantities of fish for the human populations of the region. These fisheries can be sustainable with proper management, which in turn requires a proper understanding of the ecological processes that drive them. Understanding the composition of the stocks and their biological relationships is an essential first step.

Table 7.18 The number of endemic and near-endemic (see text for explanation) fish species in the major sub-basins of the Zambezi system, excluding Lake Malawi.

	Endemics	**Near-endemics**
Chambeshi/Lake Bangweulu	*Barbus owenae*	
	Labeo simpsoni	
	Tylochromis bangwelensis	
	Aethiomastecembelus signatus	
	N = 4 (5.9%)	
Cunene	*Kneria maydelli*	*Barbus argenteus*
	Barbus dorsolineatus	*Labeo ruddi*
	Orthochromis machadoi	*Labeo ansorgii*
	Thoracochromis albolabris	*Chetia welwitschi*
	Thoracochromis buysi	*Sargochromis gracilis*
	Sargochromis coulteri	*Schwetzochromis machadoi*
	N = 6 (9.0%)	N = 6 (9.0%)
Zambezi headwaters	*Paramormyrops jacksoni*	*Barbus breviceps*
	Barbus bellcrossi	*Hypsopanchax jubbi*
	N =2 (2.3%)	N = 2 (2.3%)
Okavango	*Parakneria fortuita*	*Barbus breviceps*
		Sargochromis gracilis
	N = 1 (1.2%)	N = 2 (2.4%)
Barotse floodplain		
Chobe/Caprivi	*Nothobranchius* sp.	
	N = 1 (1.2%)	
Kafue	*Nothobranchius kafuensis*	
	N = 1 (1.6%)	
Lake Kariba/Middle Zambezi		*Chiloglanis emarginatus*
		N = 1 (1.6%)
Lake Cabora Bassa catchment		*Barbus manicensis*
		N = 1 (2.0%)
Lower Shire		*Barbus choloensis*
		Varicorhinus pungweensis
		Opsaridium tweddlorum
		Oreochromis shiranus
		Aethiomastacembelus shiranus
		N = 5 (6.9%)
Lower Zambezi		

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Back to Contents

Table 7.2. The fishes of the Zambezi River system (excluding Lake Malawi) together with those of the Cunene, Okavango and Pungwe-Buzi systems. Taken from Skelton (1993, 1994) with additions from other sources. The list of fish from the Chambeshi/Bangweulu is based on Jackson (1961a), updated as far as possible from CLOFFA (Daget *et al.* 1984, 1986, 1991) and is probably incomplete. ● = fish with a relatively widespread distribution, ○ = fish with a limited distribution (in some cases, known only from one specimen, numbers refer to the notes that follow at the bottom of the table.

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
PROTOPTERIDAE													
Protopterus annectens	Lungfish	●							●	●	●	●	●
Protopterus amphibius	East African Lungfish											●	
MORMYRIDAE													
Mormyrops anguilloides	Cornish Jack	●							●	●	●	●	●
Mormyrus lacerda	Western Bottlenose		●	●	●	●	●	●	1				
Mormyrus longirostris	Eastern Bottlenose	●							●	●	●	●	●
Mormyrus caballus		●											
Campylomormyrus tamandua		●											
Hippopotamyrus ansorgii	Slender Stone-basher		●	●	●	●	●				●	●	●
Hippopotamyrus discorhynchus	Zambezi Parrotfish	●	●	●	●	●	●		●	●	●	●	●
Marcusenius macrolepidotus	Bulldog	●	●	●	●	●	●	●	●	●	●	●	●
Petrocephalus catostoma	Churchill	●	●	●	●	●	●	●	2		●	●	●
Petrocephalus simus		●											
Pollimyrus castelnaui	Dwarf Stone-basher	●	●	●	●	●	●	●					
Paramormyrops jacksoni	Ghost Stone-basher			○									
MEGALOPIDAE													
Megalops cyprinoides	Oxeye Tarpon										●	●	●

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabóra Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
ANGUILLIDAE													
Anguilla mossambica	Long-finned Eel								•	•	•	•	•
Anguilla bicolor	Short-finned Eel										•	•	•
Anguilla marmorata	Madagascar Mottled Eel										•	•	•
Anguilla bengalensis	African Mottled Eel						3		•	•	•	•	•
KNERIIDAE													
Kneria auriculata	Southern Kneria									4			•
Kneria maydelli	Cunene Kneria		o										
Kneria polli	Northern Kneria		•	•	•	•	•	•					
Parakneria mossambica													•
Parakneria fortuita	Cubango Kneria				o								
CYPRINIDAE													
Mesobola brevianalis	River Sardine		•	•	•	•	•						
Mesobola moeruensis		•											
Opsridium zambezense	Barred Minnow			•	•	•	•		•	•	•	•	•
Opsaridium tweddlorum											•		
Barbus trachypterus		•											
Barbus breviceps	Short-headed Barb		•		•								
Barbus annectens	Broad-striped Barb								•	•	•	•	•
Barbus barotseensis	Barotse Barb	•	•	•	•	•	•	•					
Barbus bellcrossi	Gorgeous Barb			•									
Barbus lineomaculatus	Line-spotted Barb	•	•	•	•	•	•	•	•	•	•	•	•
Barbus neefi	Side-spotted Barb			•				•					

			UPPER ZAMBEZI						MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Barbus pseudognathodon		•											
Barbus unitaeniatus	Long-bearded Barb	•	•	•	•	•	•	•	•	•			
Barbus bifrenatus	Hyphen Barb	•	•	•	•	•	•	•					
Barbus viviparus	Bow-striped Barb										•	•	•
Barbus brevidorsalis	Dwarf Barb	•		•	•			•					
Barbus owenae		•											
Barbus thamalakanensis	Thamalakane barb			•	•	•	•						
Barbus barnardi	Black-backed Barb		•	•	•	•	•	•					
Barbus toppini	East Coast Barb										•	•	•
Barbus macrotaenia	Broad-banded Barb										•	•	
Barbus fasciolatus	Red Barb	•	•	•	•	•	•	•	•	•			
Barbus radiatus	Beira Barb	•	•	•	•	•	•	•	•	•	•	•	•
Barbus haasianus	Sickle-finned barb	•	•	•	•	•	•	•			•	•	•
Barbus trimaculatus	Three-spotted Barb	•	•						•	•	•	•	•
Barbus poechii	Dash-tailed Barb		•	•	•	•	•	•	I				
Barbus eutaenia	Orange-finned Barb	•	•	•	•	•	•	•			•	•	•
Barbus miolepis	Zigzag Barb			•	•	•	•	•					
Barbus multilineatus	Copper-striped Barb	•	•	•	•	•	•	•					
Barbus afrovernayi	Spot-tailed Barb	•	•	•	•	•	•	•	I				
Barbus argenteus	Rose-finned Barb		•										
Barbus choloensis	Silver Barb										o		
Barbus paludinosus	Straight-finned Barb	•	•	•	•	•	•	•	•	•	•	•	•
Barbus afrohamiltoni	Hamilton's Barb	•									•	•	•

			UPPER ZAMBEZI						MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Barbus mattozi	Papermouth		•	o		o			o				
Barbus kerstenii	Red-spotted Barb		•	•	•	•	•	•			•	•	
Barbus manicensis	Yellow Barb									o			
Barbus dorsolineatus	Cunene Barb		o										
Barbus marequensis	Large-scaled Yellowfish								•	•	•	•	•
Barbus codringtonii	Upper Zambezi Yellowfish			•	•	•	•	•					
Coptostomobarbus wittei	Upjaw Barb			•	•	•	•	•					
Varicorhinus pungweensis	Pungwe Chiselmouth										o		•
Varicorhinus nasutus	Short-snouted Chiselmouth								•	•	•	•	•
Labeo altivelis	Manyame Labeo	•							•	•	•	•	•
Labeo simpsoni		•											
Labeo ruddi	Silver Labeo		•										
Labeo congoro	Purple Labeo								•	•	•	•	•
Labeo cylindricus	Red-eyed Labeo			•	•	•	•	•	•	•	•	•	•
Labeo molybdinus	Leaden Labeo								•	•	•	•	•
Labeo lunatus	Upper Zambezi Labeo			•	•	•	•	•	I				
Labeo ansorgii	Cunene Labeo		■										
DISTICHODONTIDAE													
Distichodus mossambicus	Nkupe								•	•	•	•	•
Distichodus schenga	Chessa								•	•	•	•	•
Distichodus maculatus		•											
Hemigrammocharax machadoi	Dwarf Citharine		•	•	•	•	•						
Hemigrammocharax multifasciatus	Multi-barred Citharine		•	•	•	•	•	•					

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Nannocharax macropterus	Broad-barred Citharine			•	•	•	•	•					
CHARACIDAE													
Brycinus imberi	Imberi	•							•	•	•	•	•
Brycinus lateralis	Striped Robber		•	•	•	•	•	•	•	•	•	•	•
Alestes grandisquamis		•											
Alestes macrophthalmus		•											
Micralestes acutidens	Silver Robber		•	•	•	•	•	•	•	•	•	•	•
Micralestes humilis		•											
Bryconaethiops boulengeri		•											
Rhabdalestes maunensis	Slender Robber	•	•	•	•	•	•	•					
Hemigrammopetersius barnardi	Barnard's Robber										•	•	•
Hydrocynus goliath	Goliath Tigerfish	•											
Hydrocynus vittatus	Tigerfish	•		•	•	•	•		•	•	•	•	•
HEPSETIDAE													
Hepsetus odoe	African Pike		•	•	•	•	•	•	1				
CLAROTEIDAE													
Auchenoglanis occidentalis		•											
Chrysichthys sharpii		•											
Amarginops hildae	Hilda's Grunter												•
Parauchenoglanis ngamensis	Zambezi Grunter			•	•	•	•						
AMPHILIIDAE													
Leptoglanis rotundiceps	Spotted Sand Catlet		•	•	•	•	•	•	•	•	•	•	•
Leptoglanis cf dorae	Chobe Sand Catlet			•	•	•	•						

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Doumea allula		•											
Amphilius natalensis	Natal Mountain Catfish									o	o		
Amphilius laticaudatus	Broadtail Mountain Catfish												•
Amphilius uranoscopus	Common Mountain Catfish	•		•	•	•	•		•	•	•	•	•
SCHILBEIDAE													
Schilbe intermedius	Silver Barbel	•	•	•	•	•	•	•	•	•	•	•	•
Schilbe bangwelensis		•											
Schilbe yangambianus	Yangambi Butterbarbel			o									
CLARIIDAE													
Clarias gariepinus	African Catfish	•	•	•	•	•	•	•	•	•	•	•	•
Clarias ngamensis	Blunt-toothed Catfish	•	•	•	•	•	•	•			•	•	
Clarias stappersii	Blotched Catfish	•	•	•	•	•	•	•	5				
Clarias liocephalus	Smooth-headed Catfish	•	•	•	•			•					
Clarias theodorae	Snake Catfish	•	•	•	•	•	•	•			•	•	
Clariallabes platyprosopus	Broad-headed Catfish			•	•	•	•						
Heterobranchus longifilis	Vundu	•							•	•	•	•	
MALAPTERURIDAE													
Malapterurus electricus	Electric Catfish								•	•	•	•	•
MOCHOKIDAE													
Chiloglanis emarginatus	Phongolo Rock Catlet								o				•
Chiloglanis fasciatus	Okavango Rock Catlet			•	•		•						
Chiloglanis neumanni	Neumann's Rock Catlet	•	•	•		•	•	•	•	•	•	•	•
Chiloglanis pretoriae	Short-spined Rock catlet								•	•			•

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Chiloglanis elizabethianus		•											
Euchilichthys guentheri		•											
Euchilichthys royauxi		•											
Synodontis zambezensis	Brown Squeaker								•	•	•	•	•
Synodontis nigromaculatus	Spotted Squeaker	•		•	•	•	•						
Synodontis nebulosus	Cloudy Squeaker								•	•	•	•	•
Synodontis woosnami	Upper Zambezi Squeaker		•	•	•	•	•						
Synodontis macrostigma	Large-spotted Squeaker		•	•	•	•	•	•					
Synodontis macrostoma	Large-mouthed Squeaker		•	•	•	•	•	•					
Synodontis leopardinus	Leopard Squeaker		•	•	•	•	•						
Synodontis thamalakanensis	Bubble-barbed Squeaker			•	•	•	•						
Synodontis vanderwaali	Fine-toothed Squeaker		•	•	•	•	•						
Synodontis ornatipinnis		•											
APLOCHEILIDAE													
Nothobranchius orthonotus	Spotted Killifish										•	•	•
Nothobranchius kuhntae	Beira Killifish												•
Nothobranchius kafuensis	Kafue Killifish							o					
Nothobranchius sp.	Caprivi Killifish						o						
Nothobranchius symoensi		•											
Nothobranchius rachovii	Rainbow Killifish										•	•	•
CYPRINODONTIDAE													
Aplocheilichthys johnstoni	Johnston's Topminnow		•	•	•	•	•	•	•	•	•	•	•
Aplocheilichthys hutereaui	Mesh-scaled Topminnow	•		•	•	•	•	•			•	•	•

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Aplocheilichthys katangae	Striped Topminnow	•	•	•	•	•	•	•	6	6	•	•	•
Aplocheilichthys moeruensis		•											
Hypsopanchax jubbi	Southern Deepbody			o									
CICHLIDAE													
Hemichromis elongatus	Banded Jewelfish			•	•	•	•		1				
Orthochromis machadoi	Cunene Dwarf Bream		•										
Pseudocrenilabrus philander	Pygmy Bream	•	•	•	•	•	•	•	•	•	•	•	
Chetia welwitschi	Angolan Bream		•										
Astatotilapia calliptera	Eastern Bream										•	•	•
Pharyngochromis acuticeps	Zambezi Dwarf Bream			•	•	•	•		•	•	?	?	
Thoracochromis albolabris	Thick-lipped Bream		•										
Thoracochromis buysi	Namib Bream		•										
Sargochromis mellandi		•											
Sargochromis carlottae	Rainbow Bream			•	•	•	•	•	1				
Sargochromis codringtonii	Green Bream			•	•	•	•	•	•	•			
Sargochromis giardi	Pink Bream		•	•	•	•	•	•	1				
Sargochromis greenwoodi	Greenwood's Bream				•	•	•	•					
Sargochromis mortimeri	Mortimer's Bream			•				•					
Sargochromis coulteri	Cunene Bream		•										
Sargochromis gracilis	Slender Bream		o		o								
Serranochromis altus	Hump-backed Largemouth				•	•	•	•					
Serranochromis angusticeps	Thin-faced Largemouth	•	•	•	•	•	•	•					
Serranochromis longimanus	Long-finned Largemouth			•	•	•	•						

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Serranochromis macrocephalus	Purple-faced Largemouth	•	•	•	•	•	•	•	•				
Serranochromis robustus	Nembwe	•		•	•	•	•	•	I				
Serranochromis thumbergi	Brown-spotted Largemouth	•	•	•	•	•	•	•					
Tylochromis bangwelensis		•											
Tilapia sparrmanii	Banded Tilapia	•	•	•	•	•	•	•	•	•			•
Tilapia rendalli	Red-breasted Tilapia	•	•	•	•	•	•	•	•	•	•	•	•
Tilapia ruweti	Okavango Tilapia			•	•	•	•						
Orthochromis machadoi			•										
Oreochromis mossambicus	Mozambique Tilapia										•	•	•
Oreochromis mortimeri	Kariba Tilapia								•	•			
Oreochromis andersonii	Three-spotted Tilapia		•	•	•	•	•	•					
Oreochromis placidus	Black Tilapia										•	•	•
Oreochromis shiranus	Shire Tilapia										•		
Oreochromis macrochir	Green-headed Tilapia	•	•	•	•	•	•	•					
ANABANTIDAE													
Ctenopoma intermedium	Black-spotted Climbing Perch	•		•	•	•	•	•			•	•	•
Ctenopoma multispine	Many-spined Climbing Perch	•		•	•	•	•	•			•	•	•
MASTACEMBELIDAE													
Aethiomastacembelus frenatus	Long-tailed Spiny Eel			•	•	•	•	•					
Aethiomastacembelus shiranus	Shire Spiny Eel										•		
Aethiomastacembelus signatus		•											
Aethiomastacembelus vanderwaali	Ocellated Spiny Eel				•	•	•		I				
AMBASSIDAE													

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabóra Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
Ambassus gymnocephalus	Bald Glassy											•	•
Ambassus productus	Long-spined Glassy											•	•
MUGILIDAE													
Mugil cephalus	Flat-headed Mullet											•	•
Liza macrolepis	Large-scaled Mullet											•	•
SYNGNATHIDAE													
Microphis fluviatilis	Freshwater Pipefish											•	•
Microphis brachyurus	Short-tailed Pipefish											•	•
SPARIDAE													
Acanthopagrus berda	Sea Bream										•	•	•
MONODACTYLIDAE													
Monodactylus argenteus	Natal Moony											•	•
Monodactylus falciformis	Cape Moony											•	•
ELEOTRIDAE													
Eleotris fusca	Dusky Sleeper											•	•
Eleotris melanosoma	Broad-headed Sleeper											•	•
GOBIIDAE													
Awaous aeneofuscus	Freshwater goby								•	•	•	•	•
Glossogobius giuris	Tank Goby								•	•	•	•	•
CARCHARHINIDAE													
Carcharhinus leucas	Bull Shark										•	•	•

				UPPER ZAMBEZI					MIDDLE ZAMBEZI		LOWER ZAMBEZI		
SPECIES	COMMON NAME	Chambeshi/ L. Bangweulu	Cunene	Zambezi headwaters	Okavango	Barotse floodplain	Chobe/Caprivi	Kafue	L.Kariba/ Mid-Zambezi	L.Cabora Bassa catchment	Lower Shire	Lower Zambezi & Delta	Pungwe & Buzi
PRISTIDAE													
Pristis microdon	Small-toothed Sawfish										•	•	•
TOTAL NO. SPECIES		67	67	87	85	81	82	64	59	48	72	77	74
TOTALS PER SECTION				95					61		83		

Notes:

1. These species have been collected in the transitional area between the Upper and Middle Zambezi, i.e. Batoka Gorge and the upper reaches of Lake Kariba. They were considered to be invaders from above the Victoria Falls, but may also be relict populations.
2. Bell-Cross (1972) and Skelton (1993) indicate that *Petrocephalus catostoma* occurs in the middle Zambezi, but there are no records of it from the main river or the Zimbabwean tributaries, but it apparently occurs in the upland sections of the Zambian tributaries (Jackson, 1961).
3. A single Mottled Eel, *Anguilla bengalensis*, has been collected from the Upper Zambezi (Bell-Cross 1975), but as it was taken in the header dam of the Victoria Falls hydroelectric power station, it was probably able to use this man-made structure to surmount the barrier of the falls.
4. Although *Kneria auriculata* is said to occur in the tributaries of the Upper Zambezi in the Eastern Highlands of Zimbabwe, there are none from these rivers in the collection of the Natural History Museum of Zimbabwe and it may be absent from them.
5. Bell-Cross (1972) reports that a specimen of *Clarias submarginatus* (which he used for *C. stappersii*, although it is now a synonym of *Clarias liocephalus*) was collected from Lake Lusiwashi, on a tributary of the Luangwa River. He suggested that this represented a connection with the Bangweulu system, but this record has been mentioned nowhere else in the literature.
6. According to Skelton (1993), *Aplocheilichthys katangae* occurs throughout the Middle Zambezi but it has never been collected in the Zimbabwean section and there are no specimens in the collection of the Natural History Museum of Zimbabwe, so its occurrence there is doubtful.

Back to Contents

CHAPTER 7 : APPENDIX 1
FRESHWATER FISH SURVEY OF THE LOWER ZAMBEZI RIVER, MOZAMBIQUE

Roger Bills

1. INTRODUCTION

This survey, carried out from 27 July to 14 August 1999, forms part of the Zambezi Basin Wetlands Conservation and Resource Utilisation Project. One of the aims of the project is to provide decision makers with accurate information about resources within the Zambezi Delta so that sound management policies can be implemented. The only major fish survey of the Lower Zambezi region was carried out by the German herpetologist Wilhelm Peters in 1844-45. Many of the Lower and Middle Zambezi endemics, and other more widespread Zambezian species, were discovered by Peters during this expedition. Peters published much of the descriptive work from this expedition in *Reise nach Mozambique* (1868), and most of the material was deposited in the Berlin Natural History Museum. Thus the Lower Zambezi is the type locality for large number of Zambezi fishes (Table 1). Unfortunately, Peters' notes are not sufficiently detailed to identify exact localities, with many simply being given as Tete or Quelimane.

Since Peters' expedition only a few scientists have visited the region and briefly reported on the fishes (Guy 1964, Davies 1975). Some Mozambican fisheries reports have also been published but none were of a systematic nature. This present biodiversity survey is the first systematic survey this century and is long overdue.

Two factors should be noted when considering the July 1999 collection:

1. The limits of the Lower Zambezi are rather ill-defined. Many workers have taken the upper limit to be the Cabora Bassa rapids (now the Cabora Bassa dam wall) while some consider the Shire confluence is more appropriate. Which ever is taken, during this July 1999 expedition, the upper section of the Lower Zambezi was not sampled. Only sites around Marromeu town and downstream of this point in the delta and a single site at Inhamitanga were visited. No rocky habitats were sampled and consequently several species were not collected such as *Hippopotamyrus ansorgii*, *Barbus marequensis*, *Varicorhinus* sp., *Chiloglanis* sp. and *Amphilius* spp. The absence of these rocky habitat specialists from our list must be considered simply a reflection of collecting bias.

2. Our survey was conducted in July which is the cool, low flow period. Most of the fishes are not breeding at this time and many are not very active. Probably the best time for sampling would be during the warm, wet summer, from November to January, when most fishes will be breeding. Of course accessibility during the summer would be a different problem. The rarity of some species in our samples e.g. *Protopterus* spp. and *Malapterurus electricus* was according to locals an artefact of sampling time.

Information concerning species distributions and additional biological details are largely taken from Skelton's "A Complete Guide to the Freshwater Fishes of Southern Africa" (1993a) and Smith's Sea Fishes (Smith & Heemstra 1986). Common English names follow Skelton (1993b). Photographs of habitats, fishes and fishing activities referred to in this report and available as picture files on a CD-ROM.

2. METHODS

Fish samples were collected using a variety of gill, seine and hand nets. Samples were also bought from local fishermen who were using seine and gill nets, basket traps and fish poison. Most samples were fixed in 10% formalin in the field and on returning to Grahamstown transferred to 60% propyl alcohol for long term preservation. Small specimens were placed whole into formalin while specimens larger than 20 cm were also injected with formalin. Some specimens were prepared as skeletons and some tissue samples were taken for DNA analyses. All samples were returned to the JLB Smith Institute of Ichthyology for sorting and identification. A representative collection was prepared for lodging in the Maputo Museum while the bulk of the material was held at the JLB Smith Institute of Ichthyology as a voucher collection for this study. Museum accession numbers for this collection are available on request.

All freshwater fish identifications were determined by I.R. Bills and P.H. Skelton and marine species by E.A. Anderson. The numbering of the families in the checklist follows the J.L.B. Smith Collection numbering system (Anderson, unpublished). Table 2 shows sizes, number of localities collected, habitats collected, etc.

Appendix 7.1 Table 1 Fish species whose type localities are in the Lower Zambezi region.
H = holotype, S = syntype, L = lectotype;
ZMHU (or ZMB) = Zoologisches Museum de Humbold-Universitat, Berlin,
BMNH = British Museum (Natural History), London

Species	type locality	type status & no.	museum number
Protopterus amphibius (Peters 1844)	Quelimane, Zambezi R.	lost	-
Anguilla mossambica Peters 1852	Lumbo, Molumbo R.	H	ZMHU 6230
Anguilla bengalensis labiata Peters 1852	Tete, Zambezi R. & Boro, Licuare R	S (4)	ZMHU 6227-8
Hippopotamyrus discorhynchus (Peters 1852)	Tete, Zambezi R.	S (4)	ZMB 3673-6
Marcusenius macrolepidotus (Peters 1852)	Tete, Zambezi R.	S (3)	ZMHU 3630, 3677, 3678
Mormyrus longirostris Peters 1852	Zambezi R.	S (2)	ZMHU 3671-2
Brycinus imberi (Peters 1852)	Zambezi R.	S (2)	ZMHU 3574
Micralestes acutidens (Peters 1852)	Zambezi R.	S (3)	ZMHU 3576
Distichodus mossambicus Peters 1852	Tete, Zambezi R.	S (2)	ZMHU 3564, 6613
Distichodus schenga Peters 1852	Tete, Zambezi R.	H	ZMHU 3565
Barbus paludinosus Peters 1852	Quelimane, Zambezi R.	S	ZMHU & BMNH 1861.3.10:6-7
Barbus radiatus Peters 1853	Tete, Revugo R.	L	ZMHU 4737
Barbus trimaculatus Peters 1852	Tete, Revugo R.	H	ZMHU 4737
Labeo altivelis Peters 1852	Mozambique	S (6)	ZMHU 3283-7
Labeo congoro Peters 1852	Tete, Zambezi R.	S (2)	ZMHU 3279
Labeo cylindricus Peters 1852	Mozambique	S (3)	ZMHU 3280-2
Opsaridium zambezense (Peters 1852)	Tete, Zambezi R.	S	BMNH1861.3.10:8-9
Synodontis nebulosus Peters 1852	Tete, Zambezi R.	H	ZMHU 3.120
Synodontis zambezensis Peters 1852	Tete, Sana & Boror, Zambezi R.	L	ZMHU 3.119
Nothobranchius orthonotus (Peters 1844)	Quelimane, Zambezi R.	S (3)	ZMHU 4754
Nothobranchius rachovii Ahl 1826	Beira, Mozambique	S (2)	ZMHU 21.389
Microphis fluviatilis (Peters 1852)	Tete, Zambezi R.	S (1?)	ZMHU 6233
Oreochromis mossambicus (Peters 1852)	Mozambique	L	ZMB 2.806-2.821
Oreochromis placidus (Trewavas 1941)	lower Buzi R., Mozambique	H	BMNH1907.7.2:19
Awaous aenofuscus (Peters 1852)	Sena, Zambezi	S (2)	ZMB 2105

3. RESULTS

3.1 Survey sites

The Zambezi River begins to split up into what is known as the delta some 20-30 kms upstream of Marromeu. The river at Marromeu and downstream to the lower delta is a large braided sand bank river. There is an extensive floodplain at Marromeu estimated at over 20 km width. The floodplain consists of river channels (which during July were not connected to the main river and so were not flowing), isolated lagoons, swamps and man-made irrigation channels. During the July 1999 expedition the floodplain channels were not flowing and the main river channel consisted of three braids at the Marromeu sugar factory.

We sampled extensively around Marromeu: the main river channel, natural backwaters and irrigation channels. We visited a site near the western edge of the of the delta for a single day and a lower section of the delta (Micelo River) for two days. We also travelled by boat from Marromeu to Malingapansi (on the Micelo River) which afforded us opportunities of collecting at various points down the main channels of the Zambezi and Micelo Rivers and interconnecting mangrove channels. Details of sample sites are given in Table 7.

3.1.2 *Habitats*

Zambezi River - main channel

At Marromeu the Zambezi River consists of two to three channels of approximately 200-300 m wide. These may be separated by islands themselves 200-300 m wide. The banks on both sides of the river were eroded sand, 6-8 m above the river level in July. The river substrate consisted of sand. River channels are more than 10 m deep in many places. In addition to the main channels there were lagoons which were clearly part of the main river at higher water levels. These had been isolated in July, sedimented partially and some were vegetated with aquatic macrophytes such at *Potamogeton pectinatus*, *Ceratophyllum* sp. and *Azolla pinnata*.

There are marginal reeds, grasses and *Polygonum*. The aquatic vegetation is sparse and dominated by floating species: *Ceratophyllum* sp., *Utricularia* sp., *Azolla pinnata*, *Ricciocarpus natans* (all native) and *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia molesta* (all exotic South American species).

Floodplain lagoons and wetlands

Large and small channels and lagoons, which during higher water levels will probably form distinct flowing channels, are present all around Marromeu. They range from large deep and extensive non-flowing river channels with large aquatic and marginal vegetation beds to very small pools with little but ephemeral invertebrate life. Certain pools are affected by rural farming and were turbid, others were fully covered with *Azolla* and some were clear.

Flooded grasslands were sampled at the northwestern edge of the Marromeu floodplain on the main road toward Inhamitanga. Water depths were shallow (<1.5 m), water was usually clear and grass cover was usually close to 100%. Few species were present in these areas possibly indicating that these areas dry out and have to be recolonised from adjacent regions.

Irrigation channels a few metres wide and up to 1 m deep were also present around Marromeu. Some of these were dry or almost so, while others appeared to remain with water for long periods as they had extensive *Azolla* cover.

Isolated pools ranging in size up to a kilometre in diameter are common on the floodplain. We visited one and it was shallow (<2 m deep), stained with humic acid, the substrate consisted of rotting plant and the lake was surrounded by a belt of 200-300 m of grassy swamp.

Appendix 7.1 Table 2 Summary details of fishes collected by the July 1999 expedition to the Zambezi Delta.

Number of sites - fish were sampled at a total of 35 sites. The number of site a species was collected at is given as a % of total sites.
% community composition - these were calculated for species from sites where the species was collected and not using the entire collection. Hopefully this will reflect more accurately abundance of species in preferred habitats. Mean, minimum and maximum % compositions are given
Estimate of abundance - R = rare, F = frequent, C = abundant. This is my opinion taken from the sample data, my knowledge of sampling techniques and fishermen's catches (not included in the data in the table).
Preferred habitats - R = main river channel, RL = lagoons associated with the main river channel, F = floodplain swamps and channels, C = creeks and small streams, V = associated with vegetation, O = open water, S = associated with the substrate.
Salinity preference - FW = freshwater (<1‰), E = estuarine (varying salinities between 1-25‰), M = marine (>25‰).

Species collected	Fish size (mm SL) (min-max)	No. of sites collected (%)	% composition		Abundance	Salinity	Preferred habitats
			mean	min-max			
Carcharinus leucas	-	-	-	-	R	FW-M	R O
Protopterus annectens brieni	197-450	6	2.4	2.4	F	FW	F V
Elops machinata	500	-	-	-	R	FW-M	R O
Megalops cyprinoides	174-322	6	1.2	0.8-1.6	F	FW-M	R O
Brachysomophis crocodilinus	630-850	3	1.9	1.9	R	M	R S
Hippopotamyrus discorhynchus	66-210	3	2.1	2.1	F	FW	R L V
Marcusenius macrolepidotus	51-258	3	22.5	22.5	C	FW	R RL F C V
Mormyrops anguilloides	218-700	6	2.6	0.8-4.3	F	FW	R RL
Mormyrus longirostris	152-240	-	-	-	F	FW	RL
Petrocephalus catostoma	41-66	3	4.2	4.2	R	FW	C V
Brycinus imberi	44-80	26	10.1	0.9-34.0	C	FW	R O
Brycinus lateralis	33-64	6	1.5	0.9-2.0	R	FW	F O
Hemigrammopetersius barnardi	29-35	6	3.2	0.5-5.8	R	FW	R O
Hydrocynus vittatus	57-380	14	2	0.9-3.3	F	FW	R O
Micralestes acutidens	13-57	23	36	6.7-89.5	C	FW	R F C O
Distichodus mossambicus	65-295	14	1.8	0.8-3.7	F	FW	R O V
Distichodus schenga	30-159	23	14.8	1.3-75	C	FW	R O
Barbus afrohamiltoni	30-87	29	11.7	0.3-73.5	F	FW	RL F C S
Barbus annectens	17-30	29	16.7	0.4-67.9	C	FW	RL F C V
Barbus haasianus	10-32	20	19.8	2.4-56.4	C	FW	RL F C V
Barbus kerstenii	24-27	3	1.4	1.4	R	FW	C V
Barbus macrotaenia	11-31	43	11.3	0.4-36.9	C	FW	RL F C V
Barbus paludinosus	10-69	49	31.8	1.6-100	C	FW	RL F C S
Barbus radiatus	20-38	9	13.2	9.5-15.4	F	FW	RL F S
Barbus trimaculatus	54-69	3	37.2	37.2	R	FW	C S
Barbus viviparus	18-34	17	17	0.4-55.6	C	FW	RL F C V
Labeo altivelis	46-195	20	12.5	0.4-33.3	C	FW	R O
Labeo congoro	89-195	17	3.5	0.8-7	F	FW	R O
Opsaridium zambezense	21-45	3	2.2	2.2	R	FW	R O
Schilbe intermedius	160-248	9	1.8	0.8-2.4	F	FW	R RL O V
Clarias gariepinus	114-490	14	5.4	0.5-19	F	FW	R RL F S

Species collected	**Fish size (mm SL) (min-max)**	**No. of sites collected (%)**	**% composition**		**Abundance**	**Salinity**	**Preferred habitats**
			mean	**min-max**			
Clarias ngamensis	303-307	3	1.4	1.4	R	FW	F S
Clarias theodorae	85-132	3	1.1	1.1	R	FW	C S V
Malapterurus electricus	248-318	-	-	-	R	FW	RS
Synodontis zambezensis	45-162	11	9.8	0.8-34.8	C	FW	R S
Synodontis nebulosus	-	-	-	-	R	FW	R S
Nothobranchius orthonotus	40	3	2.2	2.2	R	FW	F V
Aplocheilichthys hutereaui	36452	17	13	1.3-43.7	C	FW	RL F S V
Aplocheilichthys katangae	36492	26	11.4	0.8-63.9	C	FW	RL F S V
Microphis fluviatilis	78-177	11	6.5	2.2-26.7	F	FW-E	R S V
Microphis brachyurus	81-84	3	2.8	2.8	R	M	R S
Ambassis productus	10-96	11	22.7	0.8-40.0	C	FW-M	R O
Ambassis gymnocephalus	49	3	11.1	11.1	R	FW-M	R O
Ambassis natalensis	44-64	3	10.4	10.4	R	FW-M	R O
Leiognathus equula	20-28	3	100	100	R	E	R O
Acanthopagrus berda	16-122	6	22.4	4.7-40.0	F	E	R S O
Astatotilapia calliptera	16-58	9	1.2	0.6-2.2	R	FW	F V
Oreochromis mossambicus	9-85	46	5.5	0.8-23.4	C	FW	RL F V O
Oreochromis placidus	16-260	26	7.3	1.5-17.4	C	FW	R RL V O
Pseudocrenilabrus philander	9-71	43	12.8	1.3-59.3	C	FW	RL F C V
Tilapia rendalli	28-202	9	1.4	0.9-1.8	F	FW	RL V
Liza alata	285-330	-	-	-	F	E	R O
Valamugil seheli	23-58	6	7.4	3.8-11.1	F	E	R O
Epinephalus coiodes	-	-	-	-	F	E	R O
Terapon jarbua	31-100	9	24.5	7.3-46.2	C	E-M	R O
Sillago sihama	19-236	3	2.8	2.8	R	E-M	R S O
Glossogobius callidus	12-59	11	5.8	1.5-13.4	C	FW-E	R S O
Glossogobius giurus	235-280	3	0.8	0.8	F	FW-E	R S O
Yongeichthys nebulosus	58-72	3	3.8	3.8	R	E-M	RL S
Priolepis sp.	10-33	3	98.6	98.6	C	FW	FS
Periophthalmus argentilineatus	25-70	6	39.2	22.8-55.6	C	E-M	R S
Stenogobius kenyae	15-51	17	3.6	0.4-11.1	C	FW	R S O
Ctenopoma multispine	50-76	9	5.9	0.4-9.3	F	FW	F C V
Microctenopoma intermedium	19-33	20	2.8	0.5-10.5	F	FW	RL F C V
Solea bleekeri	12	3	0.9	0.9	R	M	R S O
Chelonodon laticeps	33-119	9	18.3	17.0-29.0	C	E-M	R O

<u>Streams draining the floodplain</u>

Two streams at the western edge of the floodplain were sampled. These were small (5 m width, <1m depth), sand substrate, vegetated streams. Their banks were forested and consequently they had considerable amounts of leaf litter. Water was brown from humic acid.

Mangrove channels

Main river and interconnecting channels in the lower delta. During July these areas were saline and tidal. Substrates were fine, soft mud. In most places vegetation was dominated by the mangrove tree *Avicenna marina*. At each of the sites we sampled there was a distinct vertical change in salinity with lower water being more saline. On exposed mud surfaces there were usually large numbers of the mudskipper *Periophthalmus argentilineatus*.

Marine lagoons near the mouth

A single site was sampled in the lagoon at the southern (marine) end of the Micelo River. Salinity was 30‰, substrates were coarse sand and water visibility was several metres. This area clearly receives little freshwater input and was dominated by marine fish species. The lagoon was estimated at 3 km wide (at its widest point) and 1 km long, its mouth (although not visited) was estimated at 500 m.

3.2 **Water conductivity and salinity**

Water salinity in the lower delta

Two river channels and an interconnecting backwater were sampled and tested for salinity using a salinometer. Where possible both surface and bottom samples were taken using a water bottom sampler. The two channels and backwater appear to have varying freshwater inputs indicated by both salinity and water clarity. Results are given in Table 3.

The large lagoon at the marine end of the Micelo River was dominated by salt water at the surface and on the bottom, the water clarity was high and at site ZD99/27 the substrate was coarse sand – all tending to indicate low freshwater input. This would seem to be confirmed by fishermen who informed us that the upstream connection with Zambezi main channel was either blocked or very shallow and not accessible by boat. Fishermen also informed us that at site ZD99/27 there were no crocodiles but sharks were common.

In the interconnecting mangrove channels there was salt-brackish water on the bottom but the surface water was predominantly fresh and very turbid indicating freshwater through flows even at high tide. Presumably these flows are coming from the main Zambezi channel to the north east. When the tide was out, exposed mud banks were 2-3m high and the dominant vegetation was the mangrove tree *Avicenna marina*.

The Zambezi main channel has a greater freshwater flow compared to the Micelo River, reflected in lower salinities at all levels and more turbid water in its estuary. Once we entered the Zambezi main channel at site ZD99/27 the mangroves disappeared within 2 km.

Water conductivities at freshwater sites around Marromeu and Malingapansi

Conductivity readings taken around the Marromeu area during July 1999 were high. From 14 sites around Marromeu and Malingapansi (both considered freshwater areas) we recorded a mean conductivity of 3.15 mS and a range from 1370 µS to 14.22 mS (Table 4). These data are an order of magnitude greater (i.e. more saline and conductive) than those given by Hall *et al*. (1977), who recorded water conductivity at Chinde as 140 µS.

Appendix 7.1 Table 3 Salinity of water samples in the Lower Zambezi River.

Site coordinates	Date	Site number	Time	Surface sample	Bottom sample
				parts per thousand (ppt)	
18 48'57"S 36 14'46"E	8/8/99	1	06:15	0	-
18 53'19"S 36 09'04"E	5/8/99	2	11:30	30	-
18 51'36"S 36 07'57"E	5/8/99	3	12:15	26	30
18 47'54"S 36 08'52"E	5/8/99	4	13:15	8	15
18 46'08"S 36 10'42"E	8/8/99	5	14:15	0	0
18 48'12"S 36 15'10"E	8/8/99	6	11:10	0	5
18 49'14"S 36 12'56"E	8/8/99	7	10:30	1	14
18 43'16"S 36 13'37"E	8/8/99	8	12:40	0	0
18 50'30"S 35 14'17"E	8/8/99	9	08:30	4	22

Appendix 7.1 Table 4 Conductivity and temperature of water at certain fish collection sites in the Lower Zambezi River (July 1999).

Site	Date/time	Conductivity (µS or Ms/cm)	Total dissolved solids (mg or g/l)	Temperature (ºC)
ZD99/5 river	28/7/99 09.00	2.01 mS	1.01 g/l	22.6
ZD99/6 lagoon	28/7/99 10.30	2.81 mS	1.46 g/l	24.5
ZD99/6 river	28/7/99 11.00	2.00 mS	1.00 g/l	23.0
ZD99/7 pool	28/7/99 12.00	3.29 mS	1.65 g/l	27.6
ZD99/8 backwater	30/7/99 09.00	1574 µS	788 mg/l	22.3
ZD99/10 backwater	30/7/99 12.00	1370 µS	675 mg/l	22.2
ZD99/14 stream	01/8/99 10.00	1440 µS	727 mg/l	22.3
ZD99/15 stream	01/8/99 14.45	1698 µS	861 mg/l	24.6
ZD99/22 mangrove	05/8/99 06.15	7.40 mS	3.8 g/l	23.7
ZD99/25 swamp	06/8/99 12.00	2.89 mS	1.49 g/l	22.7
ZD99/25 swamp	07/8/99 09.30	2.68 mS	1.34 g/l	20.5
ZD99/33 furrow	10/8/99 07.00	4.4 mS	2.19 g/l	18.2
ZD99/34 furrow	10/8/99 09.00	14.22 mS	7.14 g/l	20.3
ZD99/35 furrow	10/8/99 10.00	1716 µS	858 g/l	22.1
ZD99/36 swamp	10/8/99 11.00	1978 µS	992 mg/l	23.4

4. LOWER ZAMBEZI CHECKLIST

The following is a complete list of fishes recorded from the Lower Zambezi region. The families are arranged in phylogenetic order which follows the arrangement of the J.L.B. Smith Institute of Ichthyology collection (RUSI).

* refers to numbered comments in notes below.
\# species collected during the July 1999 expedition.

Note	Scientific name	Class, Order & Family	English, Sena name
		CLASS: CHONDRICHTHYES	
		ORDER: CARCHARHINIFORMES	
		Carcharhinidae – requiem sharks	
*1#	*Carcharinus leucas* (Valenciennes 1839)		bull shark, madjibundi
		ORDER: RAJIFORMES	
		Pristidae – sawfishes	
	Pristis microdon Latham 1794		smalltooth sawfish, caixaô
		CLASS: OSTEICHTHYES	
		ORDER: LEPIDOSIRENIFORMES	
		Protopteridae – African lungfishes	
*2#	*Protopterus annectens* brieni Poll 1961		lungfish, dóe
*3	*Protopterus amphibius* (Peters 1844)		east coast lungfish, dóe
		ORDER: ELOPIFORMES	
		Elopidae – springers	
*4#	*Elops machinata* (Forsskål 1775)		springer
		Megalopidae – tarpons	
*5#	*Megalops cyprinoides* (Broussonet 1782)		oxeye tarpon, uláwa
		ORDER: ANGUILLIFORMES	
		Anguillidae – freshwater eels	kopokopo
	Anguilla bicolor bicolor McClelland 1844		shortfin eel
	Anguilla marmorata Qouy & Gaimard 1824		giant mottled eel
	Anguilla mossambica Peters 1852		longfin eel
	Anguilla bengalensis labiata Peters 1852		African mottled eel
		Ophichthidae – snake- & worm-eels	
*6#	*Brachysomophis crocodilinus* (Bennett 1833)		crocodile snake-eel
		ORDER: CLUPEIFORMES	
		Clupeidae – herrings	
*7#	*Hilsa kelee* (Cuvier 1829)		kelee shad, malola
		Engraulidae – anchovies	
*8#	*Thryssa vitrirostris* (Gilchrist & Thompson 1908)		orangemouth glassnose
		ORDER: OSTEOGLOSSIFORMES	
		Mormyridae – snoutfishes	
*9	*Hippopotamyrus ansorgii* (Boulenger 1905)		slender stonebasher
*10#	*Hippopotamyrus discorhynchus* (Peters 1852)		Zambezi parrotfish, mputa

*11#	*Marcusenius macrolepidotus* (Peters 1852)	bulldog, ndagumka
*12#	*Mormyrops anguilloides* (Linnaeus 1758)	Cornish jack, nentche
*13#	*Mormyrus longirostris* Peters 1852	eastern bottlenose, nkupe
*14#	*Petrocephalus catostoma* (Günther 1866)	Churchill, mputa

ORDER: GONORYNCHIFORMES

Kneriidae – knerias

	Kneria auriculata (Pellegrin 1905)	southern kneria
	Parakneria mossambica Jubb & Bell-Cross 1974	Gorongosa kneria

ORDER: CHARACIFORMES

Characidae – characins

#	*Brycinus imberi* (Peters 1852)	imberi, mberi
*15#	*Brycinus lateralis* (Boulenger 1900)	striped robber
#	*Hemigrammopetersius barnardi* (Herre 1936)	sootfin robber
#	*Hydrocynus vittatus* Castelnau 1861	tigerfish, ncheni
#	*Micralestes acutidens* (Peters 1852)	silver robber

Distichodontidae – citharines

*16#	*Distichodus mossambicus* Peters 1852	nkupe, xeréwa
*17#	*Distichodus schenga* Peters 1852	chessa, chenga

ORDER: CYPRINIFORMES

Cyprinidae – barbs & labeos — simbo

#	*Barbus afrohamiltoni* Crass 1960	plump barb
#	*Barbus annectens* Gilchrist & Thompson 1917	broadstriped barb
*18#	*Barbus haasianus* David 1936	sicklefin barb
*19#	*Barbus kerstenii* Peters 1868	redspot barb
*18#	*Barbus macrotaenia* Worthington 1933	broadband barb
	Barbus marequensis Smith 1841	largescale yellowfish
#	*Barbus paludinosus* Peters 1852	straightfin barb
#	*Barbus radiatus* Peters 1853	Beira barb
	Barbus toppini Boulenger 1916	east coast barb
*20#	*Barbus trimaculatus* Peters 1852	threespot barb
#	*Barbus viviparus* Weber 1897	bowstripe barb
*21#	*Labeo altivelis* Peters 1852	manyame labeo
*21#	*Labeo congoro* Peters 1852	purple labeo
	Labeo cylindricus Peters 1852	redeye labeo
	Labeo molybdinus du Plessis 1963	leaden labeo
*22#	*Opsaridium zambezense* (Peters 1852)	barred minnow
	Opsaridium tweddlorum	dwarf sanjika
	Varicorhinus nasutus Gilchrist & Thompson 1911	shortsnout chiselmouth
	Varicorhinus pungweensis Jubb 1959	Pungwe chiselmouth

ORDER: SILURIFORMES

Schilbeidae – butter catfishes

#	*Schilbe intermedius* Rüppell 1832	silver catfish, dambe

Amphiliidae – mountain catfishes — all mpombwe?

	Amphilius uranoscopus (Pfeffer 1889)	stargazer mountain catfish
	Amphilius natalensis Boulenger 1917	Natal mountain catfish
	Leptoglanis rotundiceps (Hilgendorf 1905)	spotted sand catlet

	Clariidae – airbreathing catfishes	
*23#	*Clarias gariepinus* (Burchell 1822)	sharptooth catfish, nsomba
*24#	*Clarias ngamensis* Castelnau 1861	blunttooth catfish, nsomba
*25#	*Clarias theodorae* Weber 1897	snake catfish, ngola
*26	*Heterobranchus longifilis* Valenciennes 1840	vundu, nhumi
	Malapteruridae – electric catfishes	
*27#	*Malapterurus electricus* (Gmelin 1789)	electric catfish, tinhesse (Ndau - dinda)
	Mochokidae – squeakers & suckermouths	
	Chiloglanis neumanni Boulenger 1911	prickleback suckermouth
*28#	*Synodontis nebulosus* Peters 1852	cloudy squeaker, nkonokono
*29#	*Synodontis zambezensis* Peters 1852	brown squeaker, nkonokono (Ndau - gorokoro)
	Ariidae – sea catfishes	
*30#	*Ariodes dussumieri* (Valenciennes 1840)	tropical seacatfish, bagré, mpombwe
	ORDER: CYPRINIDONTIFORMES	peribanchi
	Aplocheilidae – annual killifishes	
*31#	*Nothobranchius orthonotus* (Peters 1844)	spotted killifish
*32#	*Nothobranchius rachovii* Ahl 1826	rainbow killifish
	Cyprinidontidae – topminnows	
#	*Aplocheilichthys hutereaui* (Boulenger 1913)	meshscaled topminnow
	Aplocheilichthys johnstoni (Günther 1893)	slender topminnow
#	*Aplocheilichthys katangae* (Boulenger 1912)	striped topminnow
	ORDER: SYNGNATHIFORMES	
	Syngnathidae – pipefishes	
*33#	*Microphis fluviatilis* (Peters 1852)	freshwater pipefish
#	*M. brachyurus* (Bleeker 1853)	opossum pipefish
	ORDER: SYNBRANCHIFORMES	
	Mastacembelidae – spiny eels	
	Aethiomastacembelus shiranus (Günther 1896)	Malawi spinyeel, kopokopo
	ORDER: PERCIFORMES	
*34	Ambassidae – glassies	
#	*Ambassis productus* Guichenot 1866	longspine glassy
#	*Ambassis gymnocephalus* (Lacepéde 1801)	bald glassy
#	*Ambassis natalensis* Gilchrist & Thompson 1908	slender glassy
	Leiognathidae – soapies	
*35#	*Leiognathus equula* (Forsskål 1775)	slimy
	Sparidae – sea breams	
#	*Acanthopagrus berda* (Forsskål 1775)	riverbream, chesi
	Cichlidae – cichlids	
*36#	*Astatotilapia calliptera* (Günther 1893)	eastern bream, suli
*37#	*Oreochromis mossambicus* (Peters 1852)	Mozambique tilapia, nkobue
*37#	*Oreochromis placidus* (Trewavas 1941)	black tilapia, nkobue
*38#	*Pseudocrenilabrus philander* (Weber 1897)	southern mouthbrooder, suli
#	*Tilapia rendalli* (Boulenger 1896)	redbreast tilapia, ngondue

	Mugilidae – mullets	ngalazi/mangalazi
*39#	*Liza alata* (Steindachner 1892)	diamond mullet
#	*Valamugil seheli* (Forsskål 1775)	bluespot mullet
	Serranidae – rockcods & groupers	
#	*Epinephalus coiodes* (Hamilton 1822)	orangespotted rockcod, garopa
	Teraponidae – thornfishes	
#	*Terapon jarbua* Forsskål 1775	thornfish
	Sillaganidae – sillagos	
#	*Sillago sihama* (Forsskål 1775)	silver sillago
	Gobiidae – gobies	
	Awaous aeneofuscus (Peters 1852)	freshwater goby
*40#	*Glossogobius callidus* (Smith 1937)	river goby
#	*Glossogobius giurus* (Hamilton-Buchanan 1822)	tank goby
*41#	*Yongeichthys nebulosus* (Forsskål 1775)	shadow goby
*42#	*Mugilogobius mertoni (*Weber 1911*)*	
*43#	*Periophthalmus argentilineatus* Valenciennes 1837	bigfin mudhopper
*44#	*Stenogobius kenyae* Smith 1959	Africa rivergoby
	Anabantidae – labyrinth fishes	dambru
*45#	*Ctenopoma multispine* Peters 1844	manyspined climbing perch
*46#	*Microctenopoma intermedium* (Pellegrin 1920)	blackspot climbing perch
	ORDER: PLEURONECTIFORMES	
	Soleidae – soles	
*47#	*Solea bleekeri* Boulenger 1898	blackhand sole
	ORDER: TETRAODONTIFORMES	
	Tetraodontidae – pufferfishes	
#	*Chelonodon laticeps* Smith 1848	bluespotted blaasop

Notes on species

1. *Carcharinus leucas*. Several recent sightings ranging from the mouth of the Micelo River to up stream of Marromeu were reported to me during the expedition. Although not positively identified as *C. leucas* (Zambezi or bull shark) this is the most likely species to enter estuarine and riverine environments. From discussions with local fishermen it would appear to be relatively common in the lagoons and channels around the river mouth.

2. *Protopterus annectens*. Lungfish are well known by local people. We were informed that July was the wrong time to collect these and that the rainy season (late October to December) would be better. Three specimens were obtained: two from local fishermen who trapped the fish in a small backwater near Malingapansi, while a third was collected by sugar estate workers near Marromeu who dug a cocooned specimen up during ploughing operations. Local people eat this fish which was a contributing factor to why we received so few specimens.

3. *Protopterus amphibius*. Specimens collected by Peters during the 1844 expedition were identified by Trewavas (1953) as *P. amphibius*. Wier (1962) challenged the validity of Trewavas' identification while Skelton (1993b) tentatively chose to include the species in the southern African checklist. Although no specimens of this species were collected on this expedition local residents reported two types of lungfish present in the Marromeu region, both referred to as *dóe* (B. Chande, pers. comm.).

4. *Elops machinata*. A single fresh specimen, bought in Marromeu market, was apparently caught close to the town in the main channel with gill-seine nets. Skelton (1993b) removed this species from the southern African freshwater checklist. The water conductivity of the river at Marromeu around 2.0mS/cm and it was not tidal.

5. *Megalops cyprinoides*. Widespread in the main river channels up to Marromeu and in the Micelo River up to Malingapansi. Nowhere common.

6. *Brachysomophis crocodilinus*. Two specimens collected in shallow water (<20 cm) in the marine lagoon in the lower Micelo River channel. This species is characterised by oral papillae on upper and lower lips and has no caudal fin. The tail is a hardened bony tip clearly well adapted to reversing into soft sediments. Both specimens were buried in the coarse sand substrate and were presumably feeding on small fishes by ambushing them. The only two species collected with a large seine at the site were juvenile *T. jarbua* and the puffer fish *C. laticeps*.

7. *Hilsa kelee*. Caught in the lagoons and estuary of the Zambezi delta. Large fishing camps occur in the delta where this and a few other species are collected. Most fish are split or cut and sun-dried while some are smoked. They are then transported considerable distances in land. Recorded by Jackson (1975) as present in the delta but we found no indications of it moving upstream in to freshwaters. It is the most commonly seen marine-estuarine species in the Marromeu market.

8. *Thryssa vitrirostris*. No samples collected, but it was positively identified at several camps in the lower Zambezi delta. Caught by local fishermen with *H. kelee*. Not seen in Marromeu market so it appears to get sorted out of traded fish.

9. *Hippopotamyrus ansorgii*. This is species prefers rocky habitats. No habitats typical for this species were sampled and we collected no specimens. Likely to be in upper reaches of small streams in the region where suitable complex rocky habitat occurs.

10. *Hippopotamyrus discorhynchus*. A major component of the local fishery and commonly seen in the Marromeu market. Found in marginal vegetation of the main channel and lagoons along the main channel. Local fishermen were catching large numbers of this species by seine netting under grass mats. Thus it would appear to be a shoaling species.

11. *Marcusenius macrolepidotus*. Abundant in many areas, it is the most widespread mormyrid in the delta region. Habitats varied from small acidic streams draining the edges of the delta, swamps in the delta, the main channel to small pools along the Pungwe-Zambezi divide near Inhamitanga. There is a considerable amount of variation in body form within populations which we are still examining as they may represent two species. A second species, *Marcusenius livingstonii* (Boulenger 1898), occurs in parts of the Lake Malawi-Shire system (Tweddle & Willoughby 1982).

12. *Mormyrops anguilloides*. Frequently caught by local hook and line fishermen and regularly seen in the local fish market. Does not appear as common as *M. macrolepidotus*, *H. discorhynchus* or *M. longirostris,* although varying habitat requirements may account for this. It is the largest mormyrid in the Zambezi and specimens up to 75 cm seen during this trip. Good angling sites seem to be deeper “holes” in the main channel.

13. *Mormyrus longirostris*. Common in the main channel and marginal lagoons around Marromeu. A major component of the local fishery.

14. *Petrocephalus catostoma*. Only collected at one site near Camp 1 where local fisherwomen had poisoned a small stream. One of two mormyrids present there and it accounted for less than 4% of the population. The habitat was a medium sized stream, sand substrate with lots of leaf litter and marginal grasses.

15. *Brycinus lateralis*. Rare. Collected at two sites in the same backwater river channel near Marromeu. Mature adults collected together with *M. acutidens*. This species exhibits a split distribution within the Zambezi system, being abundant in the upper part of the system. The taxonomic status of the Lower Zambezi and South African stocks require examination.

16. *Distichodus mossambicus*. This and the next species are Middle and Lower Zambezi endemics described by Peters in 1852. Caught in mainstream habitats only. A component of the local fishery but not as common as the next species. On a few occasions we and fishermen caught higher numbers of *D. mossambicus,* which may indicate habitat preferences between the two *Distichodus* species. Highest numbers of both juveniles and adults of *D. mossambicus* were collected in slower flowing sections of main channels, heavily vegetated and mud substrates. Largest specimens in our samples were collected at Malingapansi in gill nets and measured 252 mm SL.

17. *Distichodus schenga*. The dominant *Distichodus* species and a major component of the local fishery. Abundant in the main river channel at Marromeu over sand substrates in fast flows. Slightly smaller than *D. mossambicus* with the typical specimens in the Marromeu market ranging from 70 to 160 mm SL.

18. *Barbus haasianus* and *B. macrotaenia*. Both species abundant around Marromeu. Found in the main river channel to seasonal swamps on the floodplain providing aquatic vegetation cover is present. Mature males of *B. haasianus* show the characteristic concave "hooked" anal fin and those in breeding condition were pink to bronze in colour. Most specimens collected were juveniles.

19. *Barbus kerstenii*. Common in drainages along the Inhamitanga-Dondo road. Habitats are well vegetated pools and streams. Two juveniles were also collected in a small stream near camp one (site ZD99/14) in vegetated habitats.

20. *Barbus trimaculatus*. Collected at a single site near Inhamitanga in pools of a perennial stream.

21. *Labeo altivelis* and *Labeo congoro*. Both species are Middle and Lower Zambezi endemics, and occur in the same habitats. *Labeo altivelis* is usually the more abundant species and forms the bulk of the artisanal fisheries catch at Marromeu. The two species can be distinguished by the shape of the dorsal fin and overall coloration. *Labeo altivelis* has a concave posterior edge to the dorsal fin, which is pointed and the body is olive with pink spots in the centres of scales. *Labeo congoro* has a rounded dorsal fin, a faint spot on the caudal peduncle and an overall dark colour to the body and fins.

22. *Opsaridium zambezense*. Collected in the Zambezi main channel at Marromeu in shallow water (<30cm) channels on one of the islands. Surprisingly only a few (5) juveniles were collected. Presumably this is a result of not collecting in the species' preferred habitats or the wrong season as they should be common in the river channel. In contrast sampling in the Buzi River on our return trip this species was one of the dominant species at most sites (also noted by Bell-Cross 1972).

23. *Clarias gariepinus*. This and the next species known locally as *nsomba* (Sena). Smaller specimens most frequently caught by us in floodplain lagoons and backwater channels. A few large adults were collected in the main channel but it does not appear to be common. Collected by local people by nets, traps, baskets, spears and hook and line. Possibly one of the few species capable of surviving under *Azolla* mats in backwaters as it is an airbreathing species.

24. *Clarias ngamensis*. Rare. Collected from several localities but always only one or two specimens. Local people do not distinguish this and the previous species.

25. *Clarias theodorae*. Collected in small streams draining the delta at camp one where it was rare. Also in small pools and streams along the Dondo-Inhamitanga road. Local fishermen clearly recognise this species as different with the name *ngola* (Sena).

26. *Heterobranchus longifilis*. Not seen during our trip although all fishermen questioned knew the fish. Clearly not very common although widespread.

27. *Malapterurus electricus*. The genus is presently being revised by Dr. Steven Norris. The species in the Middle and Lower Zambezi is likely to be renamed. Only two specimens collected, these were bought from a local fisherman who had been fishing in deep channels of the main river with a large seine net. We were told that these fish are more frequently caught during the summer.

28. *Synodontis nebulosus*. Rare. Only a few badly damaged specimens seen in fishermen's boats at the start of the trip. None were sampled by ourselves and no more were seen in the Marromeu market despite concerted searches during the last week.

29. *Synodontis zambezensis*. Only collected in the main channel and marginal lagoons. Reasonably common. Best methods were throw nets at night and gill nets.

30. *Ariodes dussumieri*. A large species attaining 50 cm. Recorded from the western Indian Ocean. A major component of the estuarine fishery. No specimens collected as only examples seen were split and dried or smoked.

31. *Nothobranchius orthonotus*. A single specimen was collected in a deep (1 m) pool at Site 13. Approximately double the size of *N. rachovii*, yellow-beige with rust red spots all over the body.

32. *Nothobranchius rachovii*. Found in a few irrigation channels and flooded grasslands around Marromeu. At these sites they were the dominant species and could be observed jumping at the surface when approached. Only adults were collected. Specimens from our collections differ slightly in colour pattern from those at the type locality, in Beira (B. Watters, pers. comm.). Male specimens from Marromeu populations tend to have spots rather than bands on the unpaired fins.

33. *Microphis fluviatilis*. Collected and described by Peters from Tete. Common in the main channel at Marromeu and Luabo. Collected over open sand substrates and in small patches of marginal grass and flotsam.

34. Ambassidae. Three species are recorded from Southern Africa. All three species are present in the Zambezi Delta. *Ambassis productus* appears to be the most widespread being present at freshwater sites at Malingapansi, mangrove channels and the Zambezi River estuary. Uncommon in the upper river sites. One of the dominant species close to the mouths together with *T. jarbua* and *C. laticeps*. The other two species were collected at single sites. Some specimens of *A. natalensis* have interrupted lateral lines which alters the keys presented in Smith's Sea Fishes and Skelton (M.E.Anderson, pers. comm.). The rostral spine and preopercular groove serration pattern enable separation of these three species.

35. *Leiognathus equula*. A few juvenile specimens collected in mangrove channels connecting the main Zambezi and the Micelo River. All specimens were collected by otter trawls with the net running at about 5-6 m deep. Salinities at these depths were 5-14‰.

36. *Astatotilapia calliptera*. Rare but widespread in backwaters, only one or two specimens caught at any site. Clearly distinguishable from *Pseudocrenilabrus philander* by the presence of several prominent bright orange egg dummies on the anal fin which were even present in non-mature specimens. In preservative these egg spots become clear and colour pattern differences are more difficult to discern. The emarginate tail is another feature helping to distinguish it from *P. philander*.

36. *Oreochromis mossambicus* and *O. placidus* are widespread in the Zambezi Delta region. Although they were found together on a few occasions they seem to exhibit habitat preferences. *Oreochromis placidus* was caught most frequently in the main channel and in lagoons associated with the main channel. We caught three

large adults at night in the fastest flowing section of main channel along the edge of a deep eroding bank. This contradicts observations by Bell-Cross (1973, 1976) that *O. placidus* prefers quiet vegetated pools.

There has been some debate about distinguishing these two species apart, particularly in juveniles (see Trewavas 1983, p. 337). We found small juveniles with three and four anal fin spines which we could also separate on colour patterns. Four anal spines were found consistently in juveniles down to 15 mm SL. This refutes the assertion by Junor (reported in Jubb & Skelton 1974) that the forth spine develops as the fishes mature.

Specimens were examined from the Moebase region of Mozambique (1997). All had three anal fin spines and exhibited typical *O. mossambicus* colour patterns. The Moebase specimens were collected from a wide variety of habitats from coastal dune lakes and swamps, large river channels to small streams. It may therefore be that the Zambezi Delta does indeed form the northern limit for *O. placidus* as suggested by Trewavas (1983).

38. *Pseudocrenilabrus philander*. Common in backwaters and marginal habitats of the main stream Zambezi. Characterised by a rounded caudal fin, the anal fin has a series of red spots.

39. *Liza alata*. Bought from local fishermen using gill-seines just above the estuary head in the main Zambezi channel. Water was less than 1‰ salinity.

40. *Glossogobius callidus* A new record for the system. It is widespread throughout rivers of the south-east coast. It has been recorded at far inland at Molopo Oog in the Upper Limpopo. Common at Marromeu and Malingapansi over sand and mud substrates of the main channel. It may be missed if large mesh nets are used or if bottom ropes of nets are not held close to the substrate on retrieval.

41. *Yongeichthys nebulosus* Collected at a single site close to the mouth of the Micelo River. Habitat was a muddy mangrove creek draining into a large lagoon (almost full sea salinity). Water was shallow (<30 cm) and clear. Appeared to be territorial as fish were seen chasing and fighting in a shallow pool. A widespread species in the Indo-Pacific region. Poisonous, with higher concentrations of the toxin tetrodotoxin in the organs.

42. *Mugilogobius mertoni* Gobies present in a side channel at Malingapansi and in shallow (10-20 cm deep) muddy pools. The pools were at the top of the tidal ebb, completely freshwater and covered with *Azolla* fern. High numbers were present; I estimate several hundred in two small pools. Identified by Helen Larson. This is a new record for the Zambezi and a northern range extension for the species. Previously known range (Smith's Sea Fishes) was southern Mozambique to Coffe Bay, South Africa.

43. *Periophthalmus argentilineatus*. We have followed Murdy (1989) as Smith's Sea Fishes is incorrect for the two southern African *Periophthalmus*. Little habitat information is available for this species in Murdy. The species was on firm mud slopes and flats where holes could be dug into the substrate. Most frequently typical mud habitats were in mangroves but at a few sites in the main Zambezi channel, where the fresh-salt boundary must have been close by, the mud was covered with an aquatic rush. Holes could be up to 3-4 m from the waters edge at high tide. Usually as holes were approached fishes left holes, skipping across the mud to the waters edge. No other species were noted as being commensal in holes.

44. *Stenogobius kenyae*. Present in main channel habitats of both the Zambezi above Marromeu and the Micelo River at Malingapansi. Not commonly caught but appears widespread. Probably our sampling method is not catching high numbers as small bottom dwellers may be passed over by seine nets being pulled too fast and slightly off the bottom.

45. *Ctenopoma multispine*. Widespread but rare. The site where greatest numbers were collected was the acidic stream near Camp 1. Preferred habitats appear to be small streams and cut off back waters where there is aquatic weed and root cover. Often caught in local fish traps.

46. *Microctenopoma intermedium*. Widespread on the floodplain and in marginal vegetation of the main channel. Appears to prefer shallow waters and extensive vegetation. Rarely caught in more than ones and twos.

47. *Solea bleekeri*. Two (11.8 mm) juveniles collected over coarse sand substrate in the estuarine lagoon of the Micelo River, salinity was 30 ‰. Previously known distribution was False Bay, South Africa to Maputo, Mozambique. This record is a considerable range extension for the species.

5. NEW RECORDS

The Zambezi checklist above is derived from Skelton (1993b), Marshall (pers. comm.) and the present survey and contains 94 species. Twenty one new records were collected during this survey and these are entirely comprised of secondary freshwater fishes such as gobies (e.g. *Glossogobius callidus*, *Stenogobius kenyae*) and estuarine and marine species (e.g. *Solea bleekeri*, *Chelonodon laticeps*) (Table 5).

Several other species were seen in fishermen's catches but not collected. These are not added to the above list as either their place of collection was not determined or they were not identified to species. Some of these species include: a juvenile kob (possibly *Johnius* sp., local name is pula), *Trichiurus* eels (possibly caught at sea, local name is *tapia*), a carangid (local name is *carapau*) and juvenile mullet (collectively called *ngalazi*).

Appendix 7.1 Table 5 New records for the Zambezi Delta collected during the July 1999 expedition.

Enter freshwater	Estuary only
Elops machinata	*Brachysomophis crocodilinus*
Ambassis productus	*Thryssa vitrirostris*
A. gymnocephalus	*Ariodes dussumieri*
A. natalensis	*Leiognathus equula*
Liza alata	*Acanthopagrus berda*
Valamugil seheli	*Epinephalus coiodes*
Glossogobius callidus	*Terapon jarbua*
Mugilogobius mertoni	*Sillago sihama*
Stenogobius kenyae	*Youngeichthys nebulosus*
	Periophthalmus argentilineatus
	Solea bleekeri
	Chelonodon laticeps

6. LOCAL FISHING METHODS

6.1 Monofilament gill nets

Monofilament gill nets are the most commonly used nets in the fishery around Marromeu. We were told that these are bought in Beira, mesh sizes ranged from 30-50 mm and the nets were very strong. We observed them being used in two distinct ways: as seine nets and as drift nets.

Seine netting. Nets were usually dragged from the canoes by hand and pulled out into deep water (<3 m) by the fishermen. They were apparently not concerned about crocodiles. The net was pulled in an arc and then the two fishermen pulled the net into the bank. Areas netted were usually shallow, slower flowing sections of the main channel. These areas are not that common and my impression was that the favoured areas were being regularly netted. These areas are also open water habitats as the fishermen are avoiding snagging the nets and because of low cover have lower numbers of fishes.

Drift netting. Nets were thrown out from a drifting canoe in the middle of the river channel. The net was usually put in at 45-90 to the flow. Once the net was fully deployed the net and boat was left to float downstream for 10-15 minutes or until the net snagged. Sometimes nets were set drifting parallel to and close to the river bank. The fishermen would thump the vegetation along the bank as they drifted downstream frightening fish into the net. Usually this operation was shorter than those in mid-channel with the net being retrieved when it reached the bottom of a vegetated section of bank.

6.2 Fish trapping

Traps are probably the most widespread type of fishing method in the Lower Zambezi. They are most frequently set in fences and usually where waters are receding and constrict into a channel, thus concentrating the fish. In extensive swamps which were bisected by roads, fences were set at culverts and at the head of the receding section. Fences may also be constructed in the centre of swamps with deeper holes being made by digging to attract larger fish. Here traps were baited with a variety of foods and plants.

The design of these traps is different from other regions I have visited. The traps of the area are characterised by double entrances which reduce the chance of a caught fish escaping through the mouth. This is important as traps are often left in the water for extended periods of time before being checked. With a double mouth in a trap the chances of fish escaping is reduced considerably.

6.3 Thrust baskets

Although not seen in operation thrust baskets are used widely in the Lower Zambezi to Buzi region. Baskets are used in groups with people walking in a line through shallow water. The basket is pushed down into the water and any fish trapped inside the basket are removed by hand. Fish are usually held on strings or bags and thrusting continues until the line reaches the bank. Thrust basket fishing is a seasonal activity. Waters are fished when they start receding and fishes are beginning to concentrate. This occurs at different times throughout the region but is usually after the summer. Thrust baskets of the area were of a different design to those seen further south in the Phongolo floodplain as they have handles built into the structure of the basket. This may be due simply to different fashions in different regions, or it could reflect differences in techniques, e.g. handles used for scooping of the basket.

6.4 Hook and line

Fishermen in canoes tended to use lines of several metres, large hooks and fish in deep channels and holes. Consequently, their catches usually comprised large specimens of larger species such as *Mormyrus anguilloides*, *Oreochromis* spp., *Tilapia rendalli* and, *Hydrocynus vittatus*. Women and children fishing from the banks were observed using short lines (less than two meters), small hooks and were fishing at the margins of the main channel or lagoons. Their catches were usually dominated by juveniles of *Distichodus schenga*, *Labeo* spp., *Oreochromis* spp. or adult *Brycinus imberi*. Hand made hooks were available in the Marromeu market.

6.5 Seine netting

None seen in operation but several large multi-filament seine nets were seen in transit and catches from these examined. Only one was observed in the Marromeu area. The catch indicated that deeper lagoons and channels of the main river had been fished as it was dominated by large specimens of mormyrids and cichlids. Seines were more common in the in the delta area and may be used more at night. A single daytime catch was almost entirely small mullet (Mugilidae spp.). Night time catches may be dominated by *Hilsa kelee*, certainly sorted catches in the process of drying are dominated by this species.

6.6 Gill netting – multifilament nets

Multifilament gill nets which were set in the main channel and marginal lagoons appeared to be uncommon and poorly maintained. The few nets we observed were left in the river all day and night for long periods. Nets were simply raised, checked for fish and put back in. Consequently, nets are in poor condition with many holes and probably rotting more quickly. Catches comprised large cichlids, mormyrids, labeos and *Clarias gariepinus*.

6.7 **Spearing**

We did not observe fishermen using spears but we did see one man returning from fishing. He said he had speared the *Clarias gariepinus* catfish in a shallow swamp by randomly spearing the water ahead of him as he walked through the water.

6.8 **Draining swamps**

Evidence of this activity was seen all over the region with mud walls and dried sections of swamps. We observed this activity in a swampy area close to Dondo in the Lower Pungwe system. Three women had cut off a section of swamp by the constructing a mud wall. Water was then simply poured out of the enclosure using plastic buckets and bowls. The swamp is completely drained and fish are collected by hand and held in a woven baskets. At Dondo, the most abundant large fish present was the mormyrid *Marcusenius macrolepidotus,* while the smaller fishes were a variety of *Barbus* and juvenile cichlids. We bought some of these fish and the prices was three times that in the Marromeu fish market, apparently on account of the difficulty in catching fish using this method.

6.9 **Fish poisoning**

One of the streams we visited, near camp one (ZD99/14, 01/08/99, 18 33'45"S / 35 39'46"E), had been poisoned by local women. The procedure was not observed but was described to us. Leaves and stems of the plant *Synaptolepis kirkii* were pulped and then poured into the stream as a liquid. This was apparently left for an hour or so when the women then returned to collect dead and dying fishes. The list of species found is given in Table 6.

The poison selectively killed fishes. Small fish, dominated by cyprinids, were killed first, then mormyrids (only two species present were *Marcusenius macrolepidotus* and *Petrocephalus catostoma*). Excepting the mormyrids almost no large fish were killed. Large cichlids and cyprinids were seen swimming in the area that was poisoned. The behaviour of fishes appears similar to that described for rotenone, an ichthyocide commonly used by scientists. Fishes swim in a distressed manner (on their sides and in circles) and move towards the shallows. Here they often jump out of the water onto vegetation or the bank.

At a first glance the poison had had little effect as few dead fish were visible. However, the women retrieved fishes by hauling the marginal vegetation onto the bank exposing the shallow water region and collecting fishes into small woven grass baskets. When their baskets were full fish were placed in depressions in the sand bank which were lined with leaves and then covered with damp sand.

6.10 **Catching fish by hand**

Five fishermen were observed catching fish by hand. The procedure was to drive their dugout canoe onto the edge of a vegetation mat in the main channel or in a lagoon. All the men jumped out onto the vegetation mat and walked towards the shore, splashing and thrusting their hands down into the vegetation. They have strings woven out of grass for their catches. On the two attempts we witnessed almost all members of the group caught one fish while some caught up to three. All specimens caught were large *Oreochromis* spp.

6.11 **Fish trading**

Fresh fish

Fresh fish are sold outside the Marromeu market building on grass stalls. Fish are sold unsorted and come into the market at all times of the day. The species which dominate are *Labeo altivelis*, all the mormyrids (barring *Petrocephalus catostoma*), *Hydrocyanus vittatus*, *Schilbe intermedius*, *Synodontis zambezensis*, *Clarias gariepinus* and medium sized (10-15 cm SL) cichlids of various genera, in that order of abundance. Fishermen are frequently the people doing the vending as the same people were seen on the river fishing. Sales are typically quick with the fresh catches being sold in under one hour.

Dried and smoked fish

Fish which have been split and dried and, or smoked are sold inside the Marromeu market building. Dry fish salesmen set up stalls early in the morning and remain there all day. The fish have already been sorted into sizes at least and often into species before transportation. The most common dried species is the clupeid *Hilsa kelee*. Split and smoked species commonly present are *Clarias gariepinus*, *Oreochromis* spp., *Acanthopagras berda* and small Mugilidae. The bulk of dry fish come from fishing camps in the delta and are transported up river by boat.

Appendix 7.1 Table 6. A collection of fishes from a stream near Camp 1 (Site 14, 01/08/99) poisoned by local fisherwomen.

Species	number	Size (mm SL)	
	(%)	minimum	maximum
Marcusenius macrolepidotus	81 (22.4)	50.9	172
Barbus paludinosus	66 (18.2)	25	56.1
Barbus macrotaenia	42 (11.6)	14.5	20.8
Aplocheilichthys hutereaui	33 (9.1)	11.8	20
Ctenopoma multispine	33 (9.1)	49.5	75.7
Barbus annectens	31 (8.6)	18.2	26.9
Barbus haasianus	21 (5.8)	14.6	16.5
Petrocephalus catostoma	14 (3.9)	41.2	65.6
Pseudocrenilabrus philander	11 (3.0)	18	70.8
Aplocheilichthys katangae	10 (2.8)	15.3	25.5
Barbus sp.	6 (1.7)	18.4	27.6
Microctenopoma intermedium	3 (0.8)	22.7	35.7
Oreochromis spp.	3 (0.8)	60.3	93
Clarias theodorae	3 (0.8)	85.1	132
Clarias gariepinus	2 (0.6)	129.5	142
Micralestes acutidens	2 (0.6)	32.6	35.1
Barbus afrohamiltoni	1 (0.3)	87.3	-
Total	362 (100)	-	-

7. DISCUSSION AND CONCERNS

7.1 Fishes

The size of the delta, coupled with the variety of habitats and changing seasons, make it likely that the number of recorded estuarine and marine vagrants will increase considerably with more thorough surveys. As these species form a complex and major fishery it is desirable that more thorough understanding of the fishery diversity, estuarine functioning and socio-economics of the fishery are obtained in the near future. Further surveys with these aims are recommended. If future trips are possible then a greater range of habitat types need to be surveyed, with rocky areas in upper catchments and the estuarine lower delta being the main targets. Early summer would be a better sampling period for fishes as they will be more active in warmer conditions and will be preparing to breed.

When trying to identify species of concern I am faced with several problems. The survey that has been conducted was of short duration, in the cold season, and did not survey the entire delta. The lower delta (estuary) was sampled as we travelled through it during two days, which is obviously inadequate for a proper assessment. Consequently, any comments of species presence, absence or abundance have to be viewed bearing these points in mind.

Certain tentative points can be made:

1. As there are no Lower Zambezi endemics, and habitats are widespread over a considerable area, it would appear that no species are presently threatened by extinction.

2. The riverine fauna is dominated by labeos (2), distichodids (2), characins (3) and mormyrids (4).

3. Certain species do appear to be naturally rare, e.g. *Protopterus* spp., *H. longifilis*, *Malapterurus electricus*, while others appear to have sporadic distribution patterns e.g. *Nothobranchius* spp., *Ctenopoma multispine*, *Micraoctenopoma intermedium*.

4. The fauna in the mouth area was clearly dominated during July by estuarine and marine species. It is probable that this situation will change during the summer, with increased freshwater flows pushing the estuary head closer to the mouth or even out into the sea.

7.2 **Fishing surveys**

Artisanal fishing activities in the Zambezi Delta are diverse ranging from catching fish by hand, spears, rod and line, various traditional basket traps, various seine and gill nets to poisoning. Areas fished cover most habitats from the floodplains, the main river channel to the estuary. Few areas are un-fished. Fishing pressure appeared to be high while the resource conversely appeared to be rather sparse in the main river channel during July. Catches brought into the Marromeu market were dominated by juvenile fishes ranging in size from 5-20 cm SL. Accurate assessment of the numbers of people fishing, number of boats present, the days fishing, the quantities of fish in transit through the Marromeu market and price structures could be achieved fairly easily by resident ichthyologists. This kind of simple data could provide valuable insights in to the socio-economics of the fishery and fishery dynamics throughout the seasons. Assistance with establishing such programs could be obtained from many institutions, e.g. JLB Smith Institute of Ichthyology/Department of Ichthyology, Rhodes University.

There is no regulation of the fishery, e.g. size of mesh in nets, number and size of nets, methods of setting nets. If the fishery is to remain sustainable it is likely that some sort of regulation will be necessary and that for this to be effective it must go hand-in-hand with education of local fishermen. Additional benefits to fishermen in such an education programme could be teaching of equipment maintenance, e.g. boat and net repairs. Certain activities, e.g. poisoning, although traditional are probably not sustainable with increasing populations and should be stopped. For accurate decisions in this regard assessments of the fishery must be made first.

7.3 **Concerns**

There are concerns for freshwater fishes in the Zambezi Delta and these are as follows.

1. <u>Over-exploitation of the riverine and estuarine fisheries</u>

The sugar estate at Marromeu has already attracted a considerable population within a year. With further developments the indirect effects of this needs to be considered. The use of natural resources by staff of the sugar company and the associated population, in particular fishes, mammals and trees, needs urgent attention if it is to be preserved.

In terms of fisheries, an alternative to simply increasing fishing pressure would be to establish fish farms. These could be organised in two ways:

a) as part of the sugar estates operations (large scale) and sold for commercial purposes; or

b) as rural projects (a few ponds per village) and run along subsistence lines.

In addition, areas of no development and no fishing would be desirable. These should encompass multiple habitats in the same block. Almost certainly these would require local residents' help in their maintenance. This would require an education of local residents to explain why these are necessary and what benefits local people would gain from them.

2. Effects of damming

The Zambezi is already heavily impounded and further plans to dam the river near Tete are likely to go ahead. The effects on seasonal floods and therefore on fish breeding patterns and fecundity needs to be examined. It is possible that mis-timed floods could significantly reduce fisheries catches. Projects examining fish catches over long periods of time and breeding patterns in several species, and relating this to environmental parameters, will be required to establish dam effects. These sorts of projects could be PhD programmes for young Mozambican scientists and could be supervised from numerous universities, e.g. Rhodes, Department of Ichthyology, Grahamstown.

3. Exotic plants

Effects of exotic aquatic plants such as *Salvinia* and *Azolla* can be devastating to aquatic animals: blocking out light, reducing current flows and depositing large quantities of organic material on substrates. All these cause reduced oxygenation of waters and so reduce animal productivity and alter the environment considerably. Three species of exotic aquatic plants were present in the main river channel: the water cabbage (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*) and Kariba weed (*Salvinia molesta*).

Another plant, the aquatic fern *Azolla*, was present in large quantities in most backwaters around the Marromeu area during July 1999. Small samples were taken and these have been identified as *Azolla pinnata* a native species. It should be verified that there is no exotic *Azolla filiculoides* present in the delta.

The abundance of exotic weeds needs to be monitored seasonally and their effects studied. Control measures should be considered. *Azolla filiculoides*, for example, can be eradicated effectively using the weevil *Stenopelmus rufinasus*.

4. Eutrophication

In a summary of eutrophication in freshwater, Mason (1991) notes six effects:

- species diversity decreases;
- dominant biota change;
- plant and animal biomass increases;
- turbidity increases;
- sedimentation rates increase; and
- anoxic conditions may develop.

The abundance of *Azolla* in backwater channels may well be due to eutrophication and is potentially disastrous for aquatic floodplain specialists, which include many of the smaller fishes. Covering of water surfaces by *Azolla* will reduce light penetration, oxygen levels, and submerged aquatic plants. Certainly, fish biodiversity at sites where there was complete *Azolla* cover was lower than at "open" water sites in the same region of the floodplain. Whether our measurements are a reflection of sampling during different seasons, or represent real changes over the two decades, needs to be examined.

8. RECOMMENDATIONS

- Further surveys to determine biodiversity are suggested
    - in the Marromeu area during different seasons,
    - in upper regions around Caia to Tete, and
    - in the lower delta (estuary and mouth).

- A regular fisheries monitoring programme should be established (at least a 2-3 year programme).

- Fish farming enterprises to be considered to reduce pressure on fish stocks. Native tilapiine cichlids and not exotic species should be used for this.
- Local farmers should be trained in fish farming techniques.
- Monitoring of, and an eradication programme for, exotic aquatic weeds should be established.
- Regions of little or no development within the delta need to be identified for their long term protection of distinct habitat types, breeding and refuge areas for fishes.
- A programme to alleviate general habitat degradation in the delta needs to be considered in conjunction with the main industries and local people.

9. ACKNOWLEDGMENTS

Many persons have helped with this project, in particular Narcisa Loureiro (Instituto Nacional de Investigação Pesqueira, Maputo) and Punky Yose (JLB Smith Institute) who were both fully involved with the fieldwork. At the JLB Smith Institute, Sally Terry and Jane Stockwell sorted and catalogued all the fishes collected. Sally Terry, Charles de Vos, Linda Coetzee and Wendy Sweetman are thanked for their help in organising the expedition. Eric Anderson identified all marine species we collected and Paul Skelton assisted with freshwater identifications. Tony Dodd and Estelle Brink (Albany Museum, Grahamstown) are thanked for identifying aquatic plants. Jonathan Timberlake is thanked for arranging our participation in the project and Baldeu Chande for organising logistics in Marromeu. All the staff of the project in Marromeu are thanked for much assistance during our stay there. Dr Augusto Cabral of the Maputo Natural History Museum is thanked for permission to collect fish samples.

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Appendix 7.1 Table 7 Collection sites during the Zambezi Delta expedition (July 1999).

Site code	Date	Site description	Coordinates	Capture methods
ZD99/1	27/07/99	Zambezi R. main channel at Marromeu	18 17'23"S / 35 57'25"E	T
ZD99/2	27/07/99	Nyarugwe village near Marromeu	18 15'51"S / 35 51'40"E	T & S
ZD99/3	28/07/99	Zambezi R., main channel, upstream from Marromeu	18 15'26"S / 35 55'48"E	-
ZD99/4	29/07/99	Zambezi R., main channel, upstream from Marromeu	18 17'09"S / 35 36'53"E	S, D & fishermen
ZD99/5	29/07/99	Zambezi R., main channel, upstream from Marromeu	18 16'51"S / 35 56'38"E	S & D
ZD99/6	28/07/99	Zambezi R., main channel, upstream from Marromeu	18 16'43"S / 35 56'31"E	S, D & fishermen
ZD99/7	29/07/99	Zambezi R., main channel, upstream from Marromeu	18 16'14"S / 35 56'29"E	D net
ZD99/8	30/07/99	Floodplain channel, now chain of pools S of Marromeu	18 19'04"S / 35 54'42"E	S & D
ZD99/9	30/07/99	Irrigation channel, covered with *Azolla* fern	18 18'21"S / 35 55'09"E	S
ZD99/10	30/07/99	Same floodplain channel as ZD99/8 - further downstream	18 20'31"S / 35 54'10"E	S
ZD99/11	30/07/99	Swamp on road just N of Marromeu	18 16'11"S / 35 52'02"E	-
ZD99/12	30/07/99	Bridge on main road leaving Marromeu	18 12'39"S / 35 45'29"E	-
ZD99/13	30/07/99	Nyamisundu village - flooded grassland	18 13'42"S / 35 47'44"E	S & D
ZD99/14	36167	Stream near Camp 1	18 33'45"S / 35 39'46"E	P
ZD99/15	36167	Stream near Camp 1	18 30'00"S / 35 39' 03"E	S
ZD99/16	36167	Lake near Camp 1	18 32'50"S / 35 38'40"E	S
ZD99/17	36198	Pools along dyke near Marromeu	18 19'53"S / 35 54'54"E	-
ZD99/18	36198	Pools 20 km out from Marromeu airstrip on main road.	18 15'19"S / 35 51'19"E	S & D
ZD99/19	36226	Zambezi R., main channel, upstream from Marromeu	18 16'01"S / 35 56'19"E	S
ZD99/20	36257	Zambezi R., just downstream from Luabo	18 25'03"S / 36 06'02"E	S & T
ZD99/21	36257	Zambezi R., downstream from Luabo (mid channel)	18 34'49"S / 36 14'40"E	O
ZD99/22	36287	Mangrove fishing camp	18 48'57"S / 36 14'46"E	T, S, D & R
ZD99/23	36318	Malingapansi (Camp 2), main channel of Micelo R. (opposite bank - vegetated)	18 40'32"S / 36 06'12"E	G
ZD99/24	36318	Malingapansi (Camp 2), main channel of Micelo R. - village bank (mud)	18 40'32"S / 36 06'12"E	S & T
ZD99/25	36318	Backwater channel and muddy pools behind Malingapansi village	18 40'38"S / 36 06'07"E	S
ZD99/26	36348	Naminazi village near Malingapansi	18 39'44"S / 36 06'03"E	D & AT
ZD99/27	36379	Fishing camp on sand dune close to the mouth of the Micelo R.	18 53'36"S / 36 09'00"E	S, D & H

ZD99/28	36379	Rio Inhangurue - mangrove channel connecting Zambezi and Micelo	18 50'30"S / 36 14'17"E	T
ZD99/29	36379	Rio Inhangurue - mangrove channel connecting Zambezi and Micelo	18 49'14"S / 36 12'56"E	O
ZD99/30	36379	Zambezi main channel	18 46'20"S / 36 14'21"E	S, D & T
ZD99/31	36379	Zambezi main channel - Luabo	18 23'36"S / 36 05'26"E	T, H & LL
ZD99/32	36410	Drainage channels in sugar fields near Marromeu	18 22'56"S / 35 52'53"E	D
ZD99/33	36440	Drainage channels in sugar fields near Marromeu	18 22'54"S / 35 52'45"E	D
ZD99/34	36440	Drainage channels in sugar fields near Marromeu	18 22'39"S / 35 52'43"E	D
ZD99/35	36440	Drainage channels in sugar fields near Marromeu	18 21'35"S / 35 53'18"E	D
ZD99/36	36440	Swamp bisected by sugar plantation road	18 21'39"S / 35 53'57"E	S, D & H
ZD99/37	36471	Zambezi main channel - muddy out of current area in sugar factory harbour	18 17'09"S / 35 56'53"E	S & T
ZD99/38	36410	Sugar fields outside Marromeu (lungfish collection site)	18 19'01"S / 35 54'49"E	BD
ZD99/39	14/08/99	Tributary of the Rio Zongue near Inhamitanga (Inhamitanga-Dondo road)	18 13'33"S / 35 09'00"E	S & D
ZD99/40	14/08/99	Rio Chissadze, tributary of Rio Zongue on the Inhamitanga-Dondo road	18 16'57"S / 35 06'59"E	S & D