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The distribution and relative abundance of stream fishes in the upper Manyame River, Zimbabwe, in relation to land use, pollution and exotic predators

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A survey of the upper Manyame River catchment, middle Zambezi system, Zimbabwe, yielded a total of 22 fish species from 48 stations. The most widespread species (present at >20 stations) were *Marcusenius macrolepidotus*, *Barbus paludinosus*, *Labeo cylindricus*, *Clarias gariepinus* and *Tilapia sparrmanii*. The most numerous species (>10% of the total) were *B. paludinosus, B. lineomaculatus* and *T. sparrmanii*. A number of species that occurred, or formerly occurred, in the catchment were not collected and the possible reasons for their absence are discussed. Some distinctive patterns of distribution could be discerned, with the presence of exotic predators (*Micropterus salmoides* and *Serranochromis robustus*) and pollution being the most important determinants. Although the species richness of indigenous fishes was relatively high when the predators were present, their relative abundance was low. Pollution from sewage, in contrast, brought about a reduction in both species richness and biomass. Land use also influenced both species richness and abundance, which were lower on commercial farms where most streams were regulated by dams and where exotic predators were present. In contrast, both variables were highest on communal lands where subsistence farmers had not built dams, leaving the streams unregulated, and where exotic predators were generally absent.

Keywords: Zimbabwe, stream fish, distribution, land use, impacts, exotic predators, conservation, species richness

Introduction

Stream fishes throughout the world are threatened by various human activities that include physical changes to their environment, alteration of flow regimes, pollution, and alien species (Moyle and Leidy 1992, Whittier *et al*. 1997, Davies and Day 1998). In southern Africa about 24 species of freshwater fishes (or c.11% of the total) are now considered to be rare or endangered because of dam-building and water abstraction, among other things (Skelton 1990). In Zimbabwe little is known about stream fish populations although they are believed to have been adversely affected by various developments over the last hundred years (Minshull 1993, Marshall 1999). One species typically found in running waters, the southern barred minnow, *Opsaridium peringueyi* (Gilchrist and Thompson), might now be extinct in the country since no specimens have been collected in the past forty years (Marshall and Gratwicke 1998/1999). The possible extinction of a fluvial species highlights the need for more information on Zimbabwean stream fishes. This paper describes a survey of fishes in the upper Manyame catchment, which was chosen because most of the human activities that influence stream fishes are evident in it, providing an opportunity to determine the response of fish populations to these activities.

Study site

The upper Manyame catchment, part of the middle Zambezi system, is situated on the central plateau of Zimbabwe at an altitude ranging from 1 300m to 1 600m. The topography is mostly gentle with only a few scattered granite hills and some ironstone ridges, which provide suitable sites for dams. Four major reservoirs have been constructed on the Manyame River, namely Lake Manyame (8 100ha), Lake Chivero (2 364ha), Seke Dam (109ha) and Harava Dam (215ha) to provide water for the city of Harare and its satellite towns (Figure 1). The city, with a population of about 1.5 million, lies in the centre of the catchment and affects aquatic habitats through the discharge of sewage effluent into Lake Chivero via the Mukuvisi and Marimba Rivers. Consequently, the lake has been eutrophic since the 1960's with serious water quality problems that have led to fish kills in recent years (Marshall 1994, 1997). These rivers themselves are severely polluted by poorly treated sewage effluent, and elevated levels of heavy metals and other inorganic compounds have also been noted (Mathuthu *et al*. 1997, Zaranyika 1997). The Nyatsime and Manyame Rivers above Lake Chivero are also severely polluted by sewage effluent from the town of Chitungwiza.

The climate is seasonal, with rains falling between November and April. The rivers therefore flow strongly during the rainy season, but their flow decreases once the rains end. By October the smaller streams have ceased to flow, while the larger ones are reduced to pools up to 3m wide and 1–2m deep connected to each other by shallow riffles. The Mukuvisi and Marimba Rivers flow throughout the year because of the sewage effluent discharged into them, this making up their entire flow by the end of the dry season.

Most of the farmland in the catchment is under commercial mixed farming, producing maize, wheat, tobacco, vegetables and horticultural crops, as well as dairy and livestock. These farmers use fertilisers and other agricultural chemicals that are believed to affect the streams (Magadza 1997) although no data are available to support this view. More importantly, they have constructed numerous reservoirs of various sizes that provide suitable habitat for exotic predators like largemouth bass, *Micropterus salmoides,* and nembwe, *Serranochromis robustus,* which have severely reduced populations of some native species (Gratwicke and Marshall 2001a). Regulation of these streams by dams has also allowed the water fern, *Azolla filiculoides* Lamarck, to spread, with adverse effects on fish diversity (Gratwicke and Marshall 2001b). The southeastern part of the catchment includes an area of communal land with a relatively dense population of subsistence farmers who cultivate the land intensively but use little fertiliser or chemicals. Few dams have been constructed in this part of the catchment and uncultivated areas are intensively grazed by livestock leading to serious soil erosion in places.

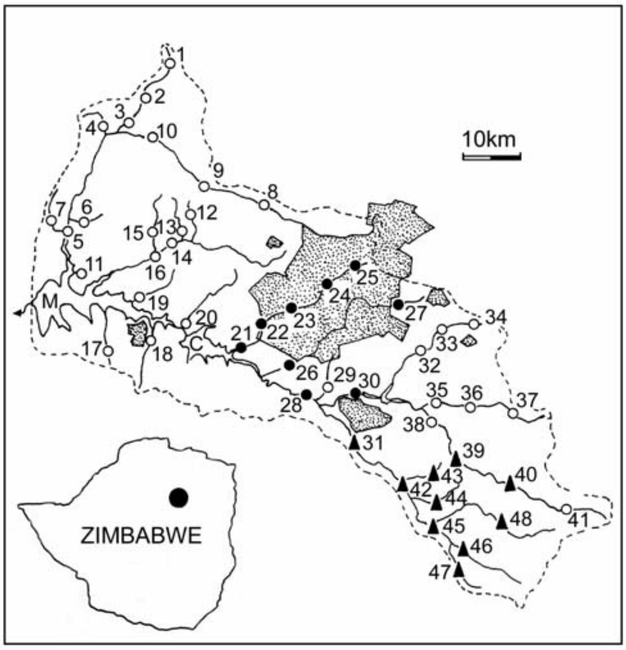

Figure 1: The upper Manyame catchment, Zimbabwe, showing the location of the major rivers and sampling stations in the commercial farming area (○), in communal land (▲) and. urban and polluted stations (●). M = Lake Manyame, C = Lake Chivero. The stippling indicates the approximate extent of urban areas, the largest being the city of Harare. The inset shows the location of the study area in Zimbabwe

Methods

Samples were taken from 48 stations located at accessible sites, usually near bridges, on rivers throughout the catchment (Figure 1) during the dry season (August to November) of 1999. Each station extended for about 30m along the river and included a variety of habitats such as pools with sandy bottoms, rocky riffles, and vegetated areas, although most were either predominantly rocky or predominantly sandy. Because of the numerous dams and weirs in the commercial farming area, the streams there had more water in them and larger and deeper pools. In the communal lands the rivers had less water and consisted of pools connected by shallow sections of flowing water. Streams into which sewage effluent is discharged were regarded as polluted if the dissolved oxygen content was less than 4.0mg l^{-1} and conductivity above 400µS cm^{-1}. They were also characterised by visual evidence of contamination such as sewage fungus, excessive algal growth, the visible presence of tubificid worms, detergent foam, and abnormal odours.

Fish were collected at each station with a Smith-Root VI-A electrofisher powered by a Honda EZ 4500 generator. The voltage was set at 750V DC (60pps) but the current varied depending on the conductivity of the water, which ranged from 35–647µS cm^{-1}. A collecting net (5mm mesh) was sewn onto the 40cm diameter aluminium anode attached to a 1.5m wooden handle. A timer fitted to the electrofisher enabled the electrofishing time to be accurately measured. Each site was fished for about ten minutes and relative abundance was expressed as catch per unit effort (No. min^{-1}). Conductivity, dissolved oxygen and pH were measured at each station at the time of sampling. All the habitats present were sampled and the collected fish were identified and counted. Voucher specimens from each site were retained and deposited in the Natural History Museum of Zimbabwe, Bulawayo.

The data were subjected to multivariate factor analysis, using the MINITAB programme that groups variables according to their associations with each other. The purpose was to see which species were mutually most closely associated and what characteristic features distinguished them. Species collected at fewer than four stations were excluded from the analysis.

Results

Patterns of species distribution

A total of 8 361 fish were caught during the survey (Table 1). The most widespread species was the sharptooth catfish, *Clarias gariepinus*, which occurred at 38 stations, followed by the bulldog, *Marcusenius macrolepidotus*, the straightfin barb, *Barbus paludinosus*, the redeye labeo, *Labeo cylindricus* and the banded tilapia, *Tilapia sparrmanii* (>20 stations each). The most abundant species was the line-spotted barb, *Barbus lineomaculatus*, which made up almost 25% of the total number caught, followed by *B. paludinosus*, and *T. sparrmanii* (each >10% of the total).

Several distinct patterns of distribution were evident, determined to a considerable extent by the distribution of

Table 1: Fish species collected in the upper Manyame system, August–November 1999. The columns indicate the number of stations (out of 48) at which they occurred, the total number of each species collected, and the proportion (%) of each in the total
* = exotic species

Family	Species	No. of Stations	No. of Fish	%
Mormyridae	*Cyphomyrus discorhynchus* (Peters)	2	67	0.8
	Marcusenius macrolepidotus (Peters)	25	225	2.6
Cyprinidae	*Opsaridium zambezense* (Peters)	9	291	3.4
	Barbus paludinosus Peters	28	1 155	13.3
	Barbus lineomaculatus Boulenger	17	2 122	24.5
	Barbus trimaculatus Peters	17	988	11.4
	Barbus radiatus Peters	3	6	0.1
	Labeobarbus marequensis A. Smith	3	61	0.7
	Labeo cylindricus Peters	22	441	5.1
Characidae	*Micralestes acutidens* (Peters)	2	51	0.6
Amphiliidae	*Leptoglanis rotundiceps* (Hilgendorf)	11	544	6.3
Clariidae	*Clarias gariepinus* (Burchell)	38	314	3.6
Mochokidae	*Chiloglanis neumanni* Boulenger	10	293	3.4
Centrarchidae	*Micropterus salmoides* Lacèpede*	13	49	0.6
Cichlidae	*Pseudocrenilabrus philander* (Weber)	16	230	2.7
	Pharyngochromis acuticeps (Steindachner)	5	69	0.8
	Tilapia rendalli Boulenger	8	37	0.4
	Tilapia sparrmanii A. Smith	29	1 290	14.9
	Serranochromis robustus (Boulenger)*	19	239	2.8
	Oreochromis mossambicus (Peters)[1]	8	37	0.4
	Oreochromis niloticus (L.)*	4	23	0.3
	Unidentified, possibly *O. mossambicus/O. niloticus* hybrids	2	68	0.8

[1] Specimens collected during this survey were kept in aquaria and brought into breeding colours, which indicated that they were *O. mossambicus*. *O. mortimeri* (Trewavas) is generally thought to replace it in the middle Zambezi drainage basin (Trewavas 1983, Bell-Cross and Minshull 1988, Skelton 1993), but the situation on the Zimbabwean plateau is confused, owing to the widespread translocation of *O. mossambicus* from the Save-Runde and Limpopo catchments (Toots 1970). The two species are genetically close (Feresu-Shoniwa and Howard 1998) and extensive hybridisation may have taken place

exotic predators and pollution. The two exotic predators, *Micropterus salmoides* and *Serranochromis robustus*, were largely absent from streams in the communal lands, but widely distributed in those in the commercial farmland (Figure 2). *Micropterus* were primarily restricted to the Manyame and Gwebi Rivers and some of their tributaries, while *Serranochromis* were more widespread in the western part of the catchment. Both species were absent from polluted stations.

Four almost ubiquitous species occurred throughout the catchment, except at the most severely polluted sites. *Marcusenius macrolepidotus* was widespread, being found in small numbers in quiet waters in both large and small streams where some aquatic macrophytes were present. It was present at station 25, an unpolluted section of the Mukuvisi River, but was otherwise absent from the polluted streams draining the city of Harare (Figure 3a). *Labeo cylindricus* was widespread, although never abundant, but absent from polluted sites (Figure 3b). It was generally restricted to areas with large rocks, either in pools or riffles, and was therefore absent from sites on the Muzururu River where this habitat was very limited. *Clarias gariepinus* was the most widely distributed species and the only one found in almost all the polluted sites, although usually in relatively small numbers (Figure 3c). An exception was station 21 on the Marimba River where a thick deposit of organic matter had accumulated behind a weir and no fish of any kind were present. *Tilapia sparrmanii* was the most abundant cichlid

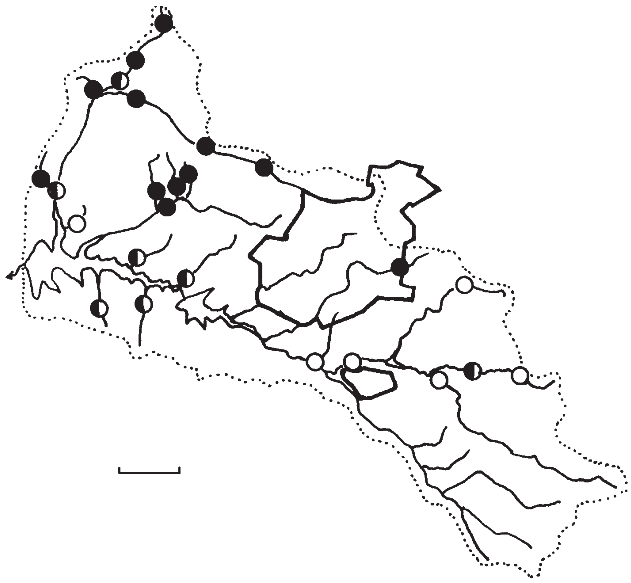

Figure 2: The distribution of two exotic predators in the upper Manyame catchment: ○ = *Micropterus salmoides*, ● = *Serranochromis robustus*, bicoloured points = both species. In this and the next four figures the city of Harare and the dormitory town of Chitungwiza are outlined by a thick line, while the scale bar is 10km

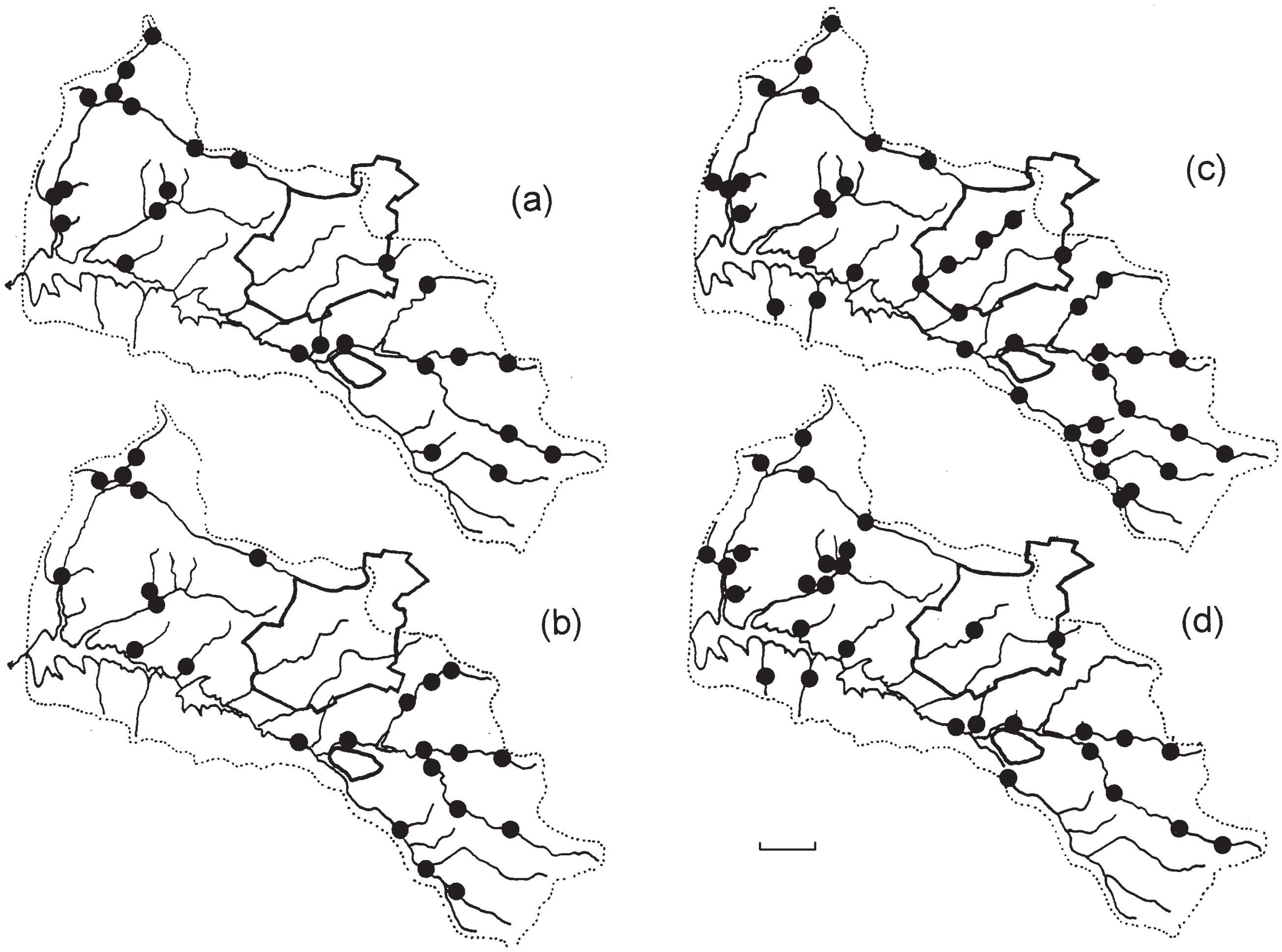

Figure 3: The distribution of four ubiquitous species in the upper Manyame catchment: (a) *Marcusenius macrolepidotus*, (b) *Labeo cylindricus*, (c) *Clarias gariepinus* and (d) *Tilapia sparrmanii*

and was widely distributed throughout the catchment, being especially numerous in streams affected by dams where quiet pools and marginal vegetation occurred, habitats also favoured by the exotic predators (Figure 3d). Unlike the other cichlid species, it was largely absent from the communal lands in the southeast, probably because the streams in this area were largely free of dams and therefore with more severe floods during the rains and more extreme low flows in the dry season.

Two of the most abundant species, *Barbus paludinosus* and *B. lineomaculatus*, were widely distributed and abundant throughout the catchment (Figures 4a and 4b), except at the polluted sites and those where *M. salmoides* and *S. robustus* were present. A third species, the three-spotted barb, *B. trimaculatus,* was relatively numerous but restricted to the south-east and north-west parts, being absent from the polluted streams in the central parts of the catchment (Figure 4c).

Three species that favour running water, the barred minnow, *Opsaridium zambezense*, the spotted sand catlet, *Leptoglanis rotundiceps* and Neumann's rock catlet, *Chiloglanis neumanni*, were found mostly in the south-eastern part of the catchment, where streams were predominantly unregulated and where exotic predators were absent (Figure 5). The distributions of two small cichlid species were mutually exclusive. The southern mouthbrooder, *Pseudocrenilabrus philander,* was widely distributed in the western part of the catchment, while the Zambezi bream, *Pharyngochromis acuticeps*, was confined to the Manyame River and some of its tributaries in the eastern part (Figure 6a). The indigenous Mozambique tilapia, *Oreochromis mossambicus*, was widely distributed but nowhere abundant, whilst the exotic Nile tilapia, *O. niloticus,* was more restricted (Figure 6c). This species is well established in both Lakes Manyame and Chivero, but the stations at which it was caught were on one of the larger tributaries of L. Manyame and were probably influenced by the lake. Some fishes that were difficult to identify may have been hybrids between the two species.

The remaining species were either scarce or had much more restricted distributions. The Zambezi parrotfish, *Cyphomyrus discorhynchus,* was recorded at only two stations (3 and 38) in deep, quiet pools with large rocks. Two cyprinids, the Beira barb, *B. radiatus,* and the largescale yel-

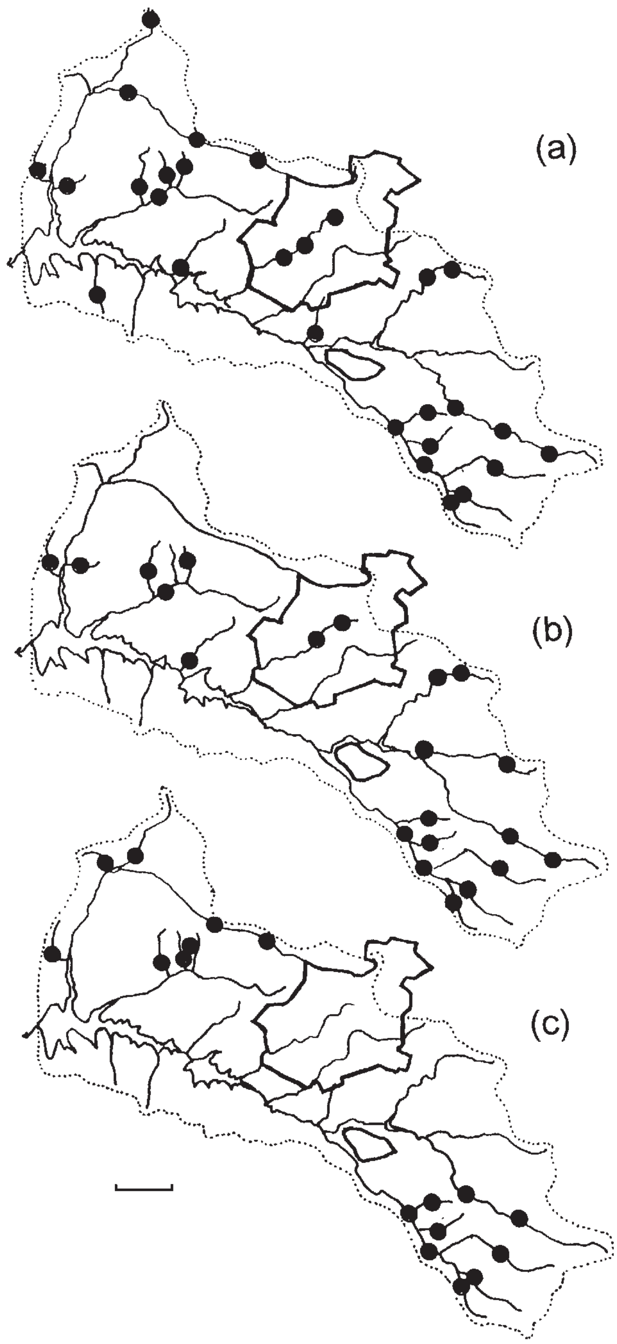

Figure 4: The distribution of three widespread barbs in the upper Manyame catchment: (a) *Barbus paludinosus*, (b) *B. lineomaculatus* and (c) *B. trimaculatus*

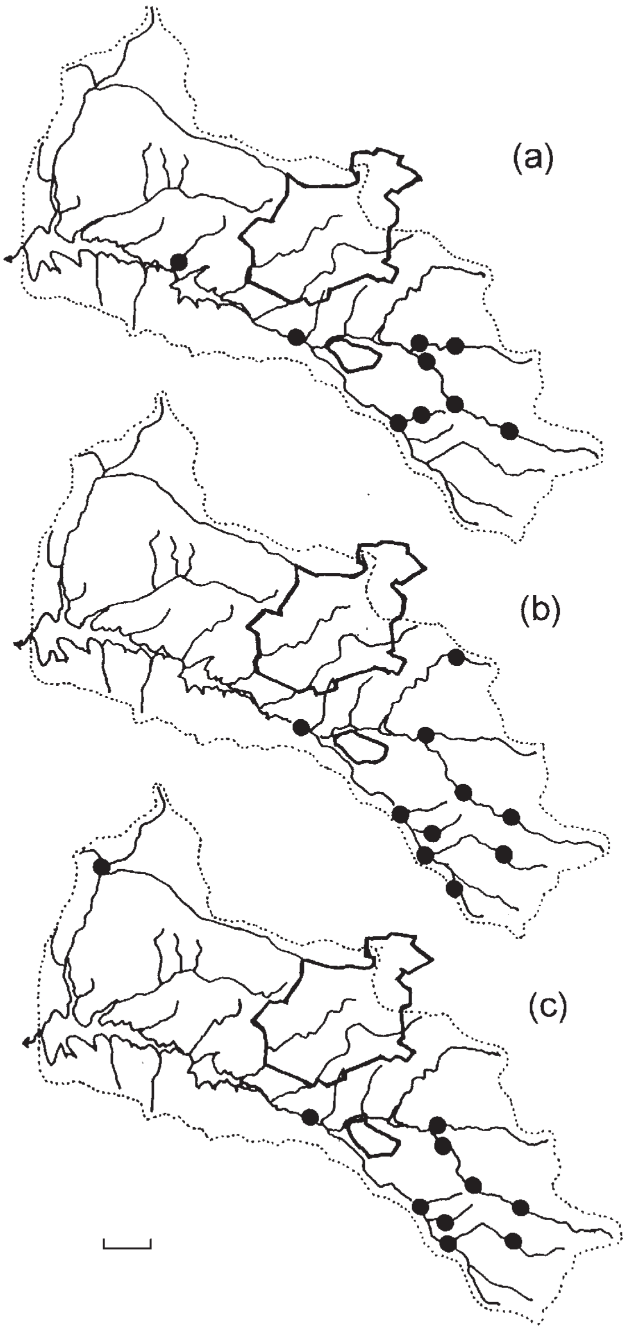

Figure 5: The distribution of three species largely restricted to the south-east of the upper Manyame catchment: (a) *Opsaridium zambezense*, (b) *Leptoglanis rotundiceps* and (c) *Chiloglanis neumanni*

lowfish, *Labeobarbus marequensis*, were taken in small numbers at a few sites. The former occurred in small, well-vegetated headwater streams (stations 1, 3 and 41) while the latter was taken in rapids on the Nyatsime and Manyame Rivers (stations 28, 42 and 45). The only characid in the samples, the silver robber, *Micralestes acutidens*, was taken at two stations on the Manyame River where it was relatively abundant at station 36 but less so at station 35 (cpue = 0.4min^{-1} and 2.5min^{-1}, respectively). The redbreast tilapia, *Tilapia rendalli,* was found in standing water with aquatic macrophytes, but occurred at only 7 stations (1, 3, 14, 27, 34, 37 and 40) and was much less numerous than *T. sparrmanii*.

Influence of abiotic and biotic factors

Land-use influenced the species richness and abundance of fish (Table 2). Both variables were greatest at stations in the communal lands (mean = 7 species), compared to those on

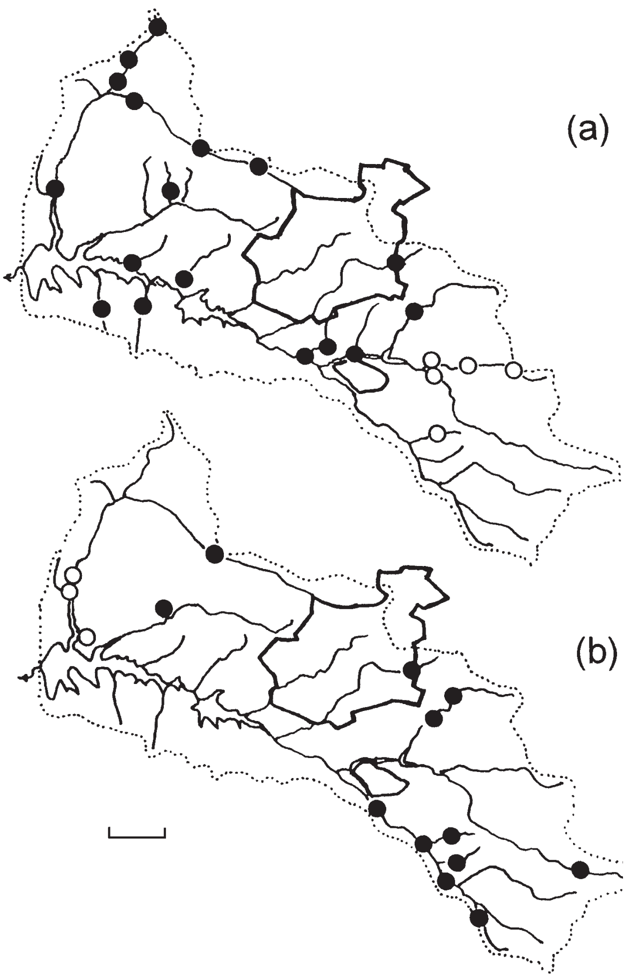

Figure 6: The distribution of some cichlid species in the upper Manyame catchment: (a) *Pseudocrenilabrus philander* (●) and *Pharyngochromis acuticeps* (○) and (b) *Oreochromis mossambicus* (●) and *O. niloticus* (○)

commercial farms and in polluted situations (five and two species, respectively). Relative abundance followed a similar trend, with the mean at communal land stations being 1.5 times and 6.7 times greater than it was on commercial farms or at polluted stations respectively. The Simpson and Shannon diversity indices also reflected this pattern. A striking difference between stations on communal land and those on commercial farms was the incidence of the exotic predators *M. salmoides* and *S. robustus*, which were absent from the former but present at 83% of the latter (Table 2). This suggests that exotic predators are a factor controlling the community structure of indigenous species. Although their influence on the diversity of indigenous species was relatively small, their effect on relative abundance was considerable, although not as great as the impact of pollution (Figure 7).

The major source of pollution in the catchment is sewage effluent and its effect was usually seen in reduced levels of dissolved oxygen and elevated conductivity in the water. There was a correlation between dissolved oxygen in the range 0–4.5mg l^{-1} ($r = 0.733$, $P < 0.05$) but not when the dissolved oxygen concentration was greater than 4.5mg l^{-1} (Figure 8a). The species richness and abundance of fish was also low at three stations which had unusually high concentrations of dissolved oxygen. These stations were shallow and supported dense growths of green algae, which were avoided by most fish. *Clarias gariepinus* and *B. paludinosus* were the only species that were consistently found in the most polluted sites, although station 28 was unusual in having numerous fish of several species in spite of being severely polluted. They were concentrated below a small waterfall where the dissolved oxygen concentration was 2.5mg l^{-1}, compared to 0.04mg l^{-1} in the river above the fall. There was no correlation between dissolved oxygen and the relative abundance of fish, although this was always low when oxygen fell below 4mg l^{-1} (Figure 8b).

Similar relationships were obtained with conductivity, except that the number of species declined with high conductivity, especially above 400µS cm^{-1} (Figure 9a). There was no correlation between conductivity and relative abundance except that the relative abundance was always low once the threshold of 400µS cm^{-1} was reached (Figure 9b).

A loading plot from the multivariate factor analysis revealed three main groupings among the commoner (i.e. present at more than four stations) species (Figure 10). The first cluster (group 1) consisted of species most commonly found in riffles and which were most common in unregulated streams. They also tended to be vulnerable to predation by the exotic predators. *Opsaridium zambezense*, *C. neumanni* and *L. rotundiceps* were strongly associated, whilst *L. cylindricus*, which requires a stony habitat regardless of current, had a weaker association with the riffle habitat.

The second cluster (group 2) included ubiquitous species with no specific habitat preferences and the *Barbus* species were particularly vulnerable to the exotic predators. *Clarias gariepinus*, *B. trimaculatus, B. lineomaculatus* and *B. paludinosus* were strongly associated, whilst *O. mossambi-*

Table 2: The influence of land use on the species diversity and relative abundance of stream fishes. Values are means, with SD in brackets. Three anomalous stations with very high dissolved oxygen and two unpolluted urban stations have not been included. Predatory species were *Micropterus salmoides* and/or *Serranochromis robustus*

Land use/water quality	Communal Land	Commercial Farms	Polluted (DO <4.0mg l^{-1})
No. of species	7.00 (1.55)	5.20 (1.49)	1.60 (1.36)
Relative abundance (No. min^{-1})	14.52 (9.73)	9.20 (10.10)	2.18 (2.03)
% of stations with alien predators	0	83	40
Simpson's diversity index (D)	4.21 (1.14)	2.91 (1.14)	1.59 (1.16)
Shannon's diversity index (H)	1.54 (0.32)	1.25 (0.34)	0.91 (0.94)

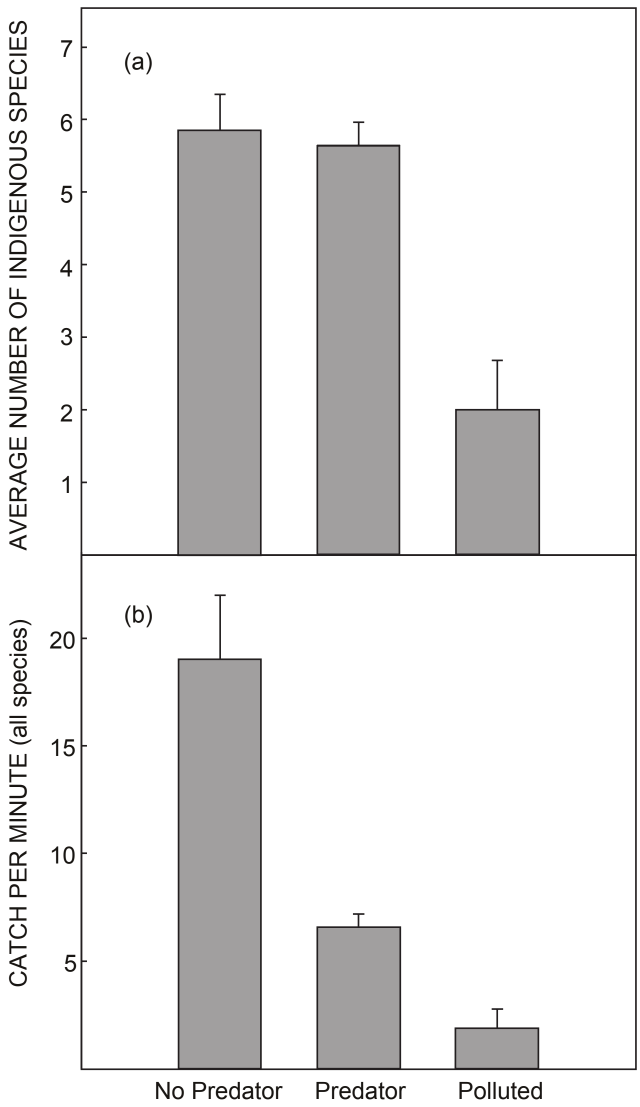

Figure 7: The impact of exotic predators and pollution on (a) the diversity of indigenous species and (b) their relative abundance in the upper Manyame system. Values are means plus standard error

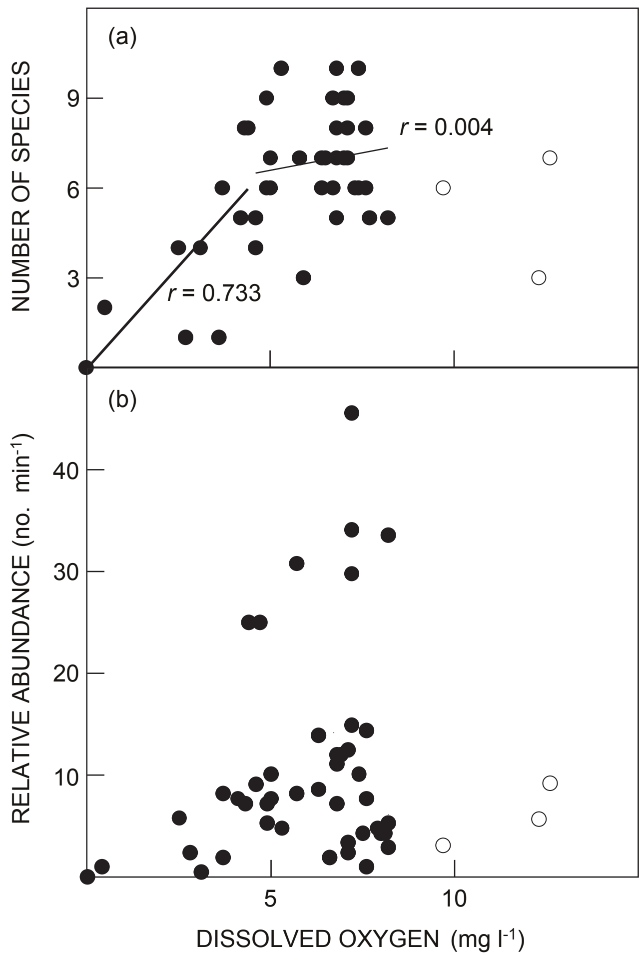

Figure 8: The relation between dissolved oxygen concentration and (a) species diversity, and (b) relative abundance of stream fishes in the upper Manyame system. ○ = stations with unusually high dissolved oxygen (see text)

cus was weakly linked to this group. If more specimens of *O. mossambicus* had been collected it would most probably have been placed in group 3. The final cluster (group 3) consisted of species commonly associated with pools, having adapted to regulated streams, and which are generally able to coexist with *M. salmoides* and *S. robustus*. This group was dominated by the commonest cichlids, *P. acuticeps, P. philander, T. rendalli* and *T. sparrmani*, but also included *M. macrolepidotus*, a cryptic species that occurs amongst rocks in pools.

Discussion

Patterns of species distribution

At the beginning of the survey it was not known with certainty how many fish species occurred in the Manyame River system. Marshall (1982) listed 26 species from Lake Chivero and since then two exotic cichlids, *Serranochromis robustus* and *O. niloticus,* have become well established here, bringing the total to 28 species. Nineteen of these were recorded during this survey, together with two others, *L. rotundiceps* and *C. neumanni*, which do not occur in the lake.

Species that were known to occur in the system, but which were not collected, fall into two main categories. The first category comprises species that are rare and therefore unlikely to be encountered. It includes three exotics; the common carp, *Cyprinus carpio* L., and the green bream, *Sargochromis codringtonii* (Boulenger), which are both present in small numbers in Lake Chivero and some other reservoirs, and the spotted bass, *M. punctulatus* (Rafinesque), which is known to occur only in Cleveland dam, a small reservoir at the head of the Mukuvisi River (Anonymous 1999). Two indigenous species, the butter catfish, *Schilbe intermedius* Rüppell, and the brown squeaker, *Synodontis zambezensis* Peters, are known from single specimens only from Lakes Chivero and Manyame, respectively. Both these

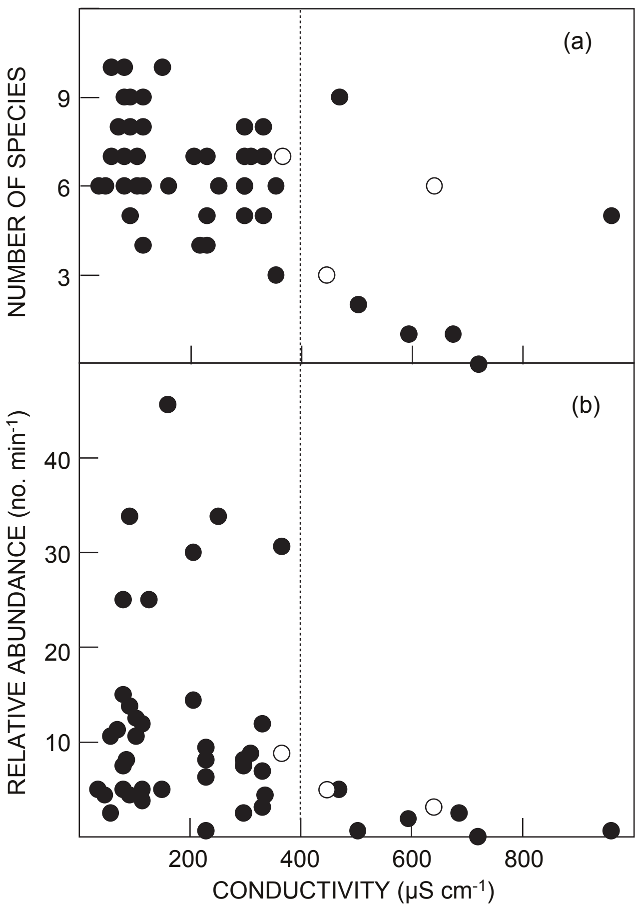

Figure 9: The relation between conductivity and (a) species diversity, and (b) relative abundance of stream fishes in the upper Manyame system. ○ = stations with unusually high dissolved oxygen (see text). The vertical dotted line indicates the apparent threshold of 400μS cm^{-1}

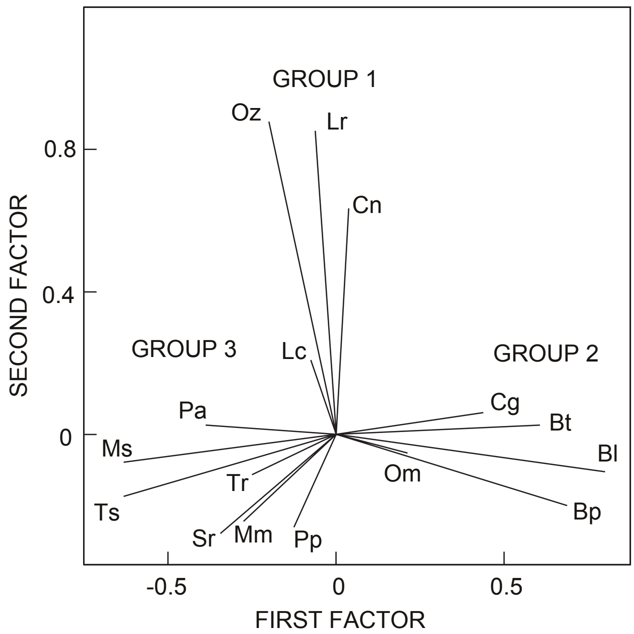

Figure 10: A loading plot from a multivariate factor analysis showing the three principal groupings of fish species. Bl = *Barbus lineomaculatus*, Bp = *Barbus paludinosus*, Bt = *Barbus trimaculatus,* Cg = *Clarias gariepinus,* Cn = *Chiloglanis neumanni,* Lc = *Labeo cylindricus*, Lr = *Leptoglanis rotundiceps*, Mm = *Marcusenius macrolepidotus,* Ms = *Micropterus salmoides*, Om = *Oreochromis mossambicus,* Oz = *Opsaridium zambezense*, Pa = *Pharyngochromis acuticeps*, Pp = *Pseudocrenilabrus philander,* Sr = *Serranochromis robustus,* Tr = *Tilapia rendalli*, Ts = *T. sparrmanii*

species are abundant in the Zambezi River, but their numbers decrease as they penetrate the tributaries and in the upper Manyame they are likely to be at the limit of their distribution.

The second category comprises species that were formerly more numerous but which have not been collected or caught recently, and may therefore have declined or even disappeared from the system. The African mottled eel, *Anguilla bengalensis labiata* Peters, has probably declined because of dams that prevent their upstream migration from the Indian Ocean. The most important of these is the 138m high Cahora Bassa Dam on the Zambezi River in Mozambique, although the smaller dams that form Lakes Manyame and Chivero (23m and 31m high respectively) are probably high enough to prewvent eels from ascending them. There is some evidence that small eels have been able to overcome the Kariba Dam (Balon 1975), but this is countered by Donnelly (1980), who speculated that the absence of *A. mossambica* Peters from the Mtsheleli Dam near Bulawayo reflected their inability to surmount a 2m high spillway.

Eastern bottlenose, *Mormyrus longirostris* Peters, imberi, *Brycinus imberi* (Peters) and Manyame labeo, *L. altivelis* Peters, were once abundant in Lake Chivero and the Manyame River (Munro 1967, Marshall and Lockett 1976, Marshall and Van der Heiden 1977, Marshall 1982), but are now scarce and were not recorded in this survey. All of these fishes are strongly potamodrometic (Bowmaker 1973) and thus weirs and dams on the rivers have probably disrupted their breeding migrations. They may also have been affected by pollution of the rivers flowing out of Harare. Until the 1970’s *Mormyrus longirostris* and *L. altivelis* were common in the Manyame River upstream of Lake Chivero at sites that are now heavily polluted, e.g. station 28 (BE Marshall unpublished observations). The tigerfish, *Hydrocynus vittatus* Castelnau, was not taken from any of the streams and was considered to have disappeared from Lakes Chivero and Manyame, although its numbers seem to have increased recently (Williams 2001). It is not certain that they will be able to recolonise any of the streams flowing into these lakes because of pollution and weirs which will affect their upstream movements.

The greenhead tilapia, *O. macrochir* (Boulenger), fits into neither of the above categories. It was introduced into Lake Chivero in 1956 and subsequently became the most important species in the local fishery (Marshall 1982). It was widely distributed in the catchment and also invaded the river below the lake, becoming important in Lake Manyame further downstream. It is a strongly invasive species (de Moor 1996) and its absence from all the sampling stations cannot be explained.

The impact of abiotic and biotic factors

The finding that fish diversity and abundance was generally greatest in streams in the communal lands was contrary to the conventional view that aquatic habitats in these areas are degraded (Magadza 1997). Streams on the commercial farms are said to be polluted with fertilisers and chemicals (Magadza 1997) but there is no evidence to support this view and it does not explain the lower diversity on the commercial farms. The most likely explanation is the impact of exotic predators, widespread on the commercial farms but absent from the communal lands, which have reduced the numbers of native fishes, especially *Barbus* species (Gratwicke and Marshall 2001a). A species of particular concern is *L. marequensis*, which was recorded at only a few stations. This is one of the most abundant species in rivers on the Zimbabwean plateau, where it can make up to 25% (by numbers) of all fish in unregulated streams (BE Marshall unpublished data). It was formerly numerous in the Manyame and its decline here reflects the changes that have taken place in this river system

The impact of pollution was considerable. Most species were unable to tolerate low levels (<4mg l^{-1}) of dissolved oxygen and species richness decreased as the concentrations fell below this level until the air-breathing species *C. gariepinus* was the only one remaining at the most polluted sites. There was no trend in species richness above the 4mg l^{-1} threshold and the species richness was very variable. This suggests that oxygen was not the primary influence on species richness and other factors were more important. Similarly, the lack of a correlation between relative abundance and dissolved oxygen suggests that other abiotic or biotic factors also have an effect. The impact of exotic predators is one such factor, and variations in water chemistry, such as the ammonia concentrations at polluted sites may be another. Variations in habitat and the different ecological requirements of various fish species probably also affect their numbers but, in Zimbabwe, data on these aspects are not yet available.

The relation between species richness and relative abundance, and conductivity were similar to those with dissolved oxygen except that both variables tended to decrease as conductivity increased. There was no trend below a threshold of 400µS cm^{-1} but relative abundance, in particular, was very low at stations where conductivity was higher than 400µS cm^{-1}. It is unlikely that conductivity alone is the cause of this decrease in abundance; instead it seems to be an indicator of poor water quality since all the stations with such elevated levels of conductivity also had low dissolved oxygen and were judged to be polluted.

The loading plot (Figure 10), which groups species into categories defined by habitat, suggests the importance of these factors. The fish species collected tended to be associated with each other into three groups, which generally reflect the major habitat types in the system, i.e. species of running water, generalists unable to withstand the predators and generalists capable of living with them. Although this programme was unable to investigate diurnal changes, or to characterise habitats in much detail it is unlikely that these groups would change much if this information had been available.

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References

Anonymous (1999) First spotted bass recorded on rod and line. Zimbabwe Fisherman **11**(1): 22.

Balon EK (1975) The eels of Lake Kariba: distribution, taxonomic status, age, growth and density. Journal of Fish Biology **7**: 797–815.

Bell-Cross G and Minshull JL (1988) The Fishes of Zimbabwe. National Museums and Monuments of Zimbabwe, Harare, 294pp.

Bowmaker AP (1973) Potamodromesis in the Mwenda River, Lake Kariba. In: Ackermann WC, White GF and Worthington EB (eds) Man-made Lakes: Their Problems and Environmental Effects. American Geophysical Union, Washington DC, pp 159–164.

Davies BR and Day JA (1998) Vanishing Waters. University of Cape Town Press, Cape Town, South Africa.

de Moor IJ (1996) Case studies of the invasion by four alien species (*Cyprinus carpio*, *Micropterus salmoides*, *Oreochromis macrochir* and *O. mossambicus*) of freshwater ecosystems of southern Africa. Transactions of the Royal Society of South Africa **51**: 233–255.

Donnelly BG (1980) The Energetics of a Population of *Barbus mattozi* Guimaraes, 1884 (Pisces: Cyprinidae). PhD Thesis, University of Zimbabwe, Harare, Zimbabwe, 177pp.

Gratwicke B and Marshall BE (2001a) The relationship between the exotic predators *Micropterus salmoides* and *Serranochromis robustus* and native stream fishes in Zimbabwe. Journal of Fish Biology **58**: 68–75.

Gratwicke B and Marshall BE (2001b) The impact of *Azolla filiculoides* Lam. on animal biodiversity in streams in Zimbabwe. African Journal of Ecology **39**: 216–218.

Magadza CHD (1997) Water pollution and catchment management in Lake Chivero. In: Moyo NAG (ed) Lake Chivero: A Polluted Lake. University of Zimbabwe Publications, Harare, Zimbabwe, pp 13–26.

Marshall BE (1982) The fish of Lake McIlwaine. In: JA Thornton (ed) Lake McIlwaine the Eutrophication and Recovery of a Tropical African Man-Made Lake. W Junk Publishers, The Hague, pp 156–188.

Marshall BE (1994) Ecology and management of the Manyame lakes. In: Matiza T and Crafter SA (eds). Wetlands Ecology and Priorities for Conservation in Zimbabwe. International Union for the Conservation of Nature, Gland, Switzerland, pp 55–68.

Marshall BE (1997) Lake Chivero after forty years: the impact of eutrophication. In: Moyo NAG (ed) Lake Chivero: A Polluted Lake. University of Zimbabwe Publications, Harare, Zimbabwe, pp 1–12.

Marshall BE (1999) The fishes of Zimbabwe: a century of change. Zimbabwe Science News **33**: 45–52.

Marshall BE and Lockett CA (1976) Juvenile fish populations in the marginal areas of Lake McIlwaine, Rhodesia. Journal of the Limnological Society of Southern Africa **2**: 37–42.

Marshall BE and Van der Heiden JT (1977) The biology of *Alestes* *imberi* Peters (Pisces: Characidae) in Lake McIlwaine, Rhodesia. Zoologica Africana **12**: 329–346.

Marshall BE and B Gratwicke (1998/1999) The barred minnows (Teleostei: Cyprinidae) of Zimbabwe: is there cause for concern? Southern African Journal of Aquatic Sciences **24**: 157–161.

Minshull JL (1993) How do we conserve the fishes of Zimbabwe? Zimbabwe Science News **27**: 90–94.

Mathuthu AS, Mwanga K and Simoro A (1997) Impact assessment of industrial and sewage effluents on water quality of the receiving Marimba River in Harare. In: Moyo NAG (ed) Lake Chivero: A Polluted Lake. University of Zimbabwe Publications, Harare, Zimbabwe, pp 43–52.

Moyle B. and Leidy RA (1992) Loss of biodiversity in aquatic ecosystems: evidence from fish faunas. In: Feidler PL and Jain SK (eds) Conservation Biology: The Theory and Practice of Nature Preservation and Management, Chapman and Hall, London, pp 127–169.

Munro JL (1967) The food of a community of east African freshwater fishes. Journal of Zoology, London **151**: 389–415.

Skelton PH (1990) The conservation and status of threatened fishes in southern Africa. Journal of Fish Biology **37** (Supplement A): 87–95.

Skelton PH (1993) A Complete Guide to the Freshwater Fishes of Southern Africa. Southern Book Publishers, Halfway House, South Africa, 388pp.

Whittier TR, Halliwell DB and Paulsen SG (1997) Cyprinid distributions in northeast U.S.A. lakes; evidence of regional-scale minnow biodiversity losses. Canadian Journal of Fisheries and Aquatic Sciences **54**: 1593–1607.

Williams A (2001) Manyame system supporting tigerfish again. African Fisherman **13**(3): 13–15.

Zaranyika MF (1997) Sources and levels of pollution along [the] Mukuvisi River: a review. In: Moyo NAG (ed) Lake Chivero: A Polluted Lake. University of Zimbabwe Publications, Harare, Zimbabwe, pp 35–42.