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The relationship between the exotic predators *Micropterus salmoides* and *Serranochromis robustus* and native stream fishes in Zimbabwe

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Samples of fish were collected from 42 stations in streams around Harare, Zimbabwe. The total abundance of fish was lower by 50% or more at stations where the exotic predators *Micropterus salmoides* and *Serranochromis robustus* were present compared with stations where they were absent. The greatest differences in density occurred among small *Barbus* species, whose populations were 86% lower (*S. robustus* alone) and 99% lower (*M. salmoides* alone). Populations of small rock and sand catlets were less dense when *S. robustus*, but not *M. salmoides*, was present probably because the latter did not enter the riffles where the catlets live. These predators apparently did not affect densities of certain other species in the system that were either cryptic, bottom-dwelling forms or too large. Low *Barbus* diversity and abundance in streams containing exotic predators is of concern because this group of fluvial fishes is threatened throughout southern Africa by dam-building, pollution, and other factors.

Key words: *Micropterus salmoides*; *Serranochromis robustus*; *Barbus*; predation; diversity; abundance; Zimbabwe.

INTRODUCTION

The impact of the Nile perch *Lates niloticus* (L.) on the haplochromine cichlids of Lake Victoria has drawn attention in Africa to the problems that can follow the introduction of exotic predatory fishes (Ogutu-Ohwayo & Hecky, 1991). In southern Africa, concern has been expressed about the impacts of introduced trout (Salmonidae) and bass (Centrarchidae) on the populations of indigenous fish (de Moor & Bruton, 1988), and in South Africa about 14 freshwater fish species are believed to be threatened by exotics (Skelton, 1990). North American bass *Micropterus* spp., in particular, have reduced the abundance of small cyprinid minnows *Barbus* spp., to the extent that some populations have become locally extinct (Cambray & Stuart, 1985). In Zimbabwe, the impact of these introduced predators is generally ignored or overlooked. This point is illustrated by the omission of this topic from an otherwise comprehensive review by Minshull (1993) of the threats facing Zimbabwean fishes.

Largemouth bass *Micropterus salmoides* Lacépède were introduced into Zimbabwe in 1932 (Toots, 1970) and they are now widespread throughout the country. In 1981 the Florida subspecies *M. s. floridianus* was imported from the

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United States (Bell-Cross & Minshull, 1988). Because this subspecies grows rapidly and can reach 9·5 kg in weight it has been propagated and distributed aggressively by Zimbabwean bass anglers. This has been a success from their point of view as the angling record, which had risen by only 0·51 kg in 34 years (from 3·78 kg in 1953 to 4·29 kg in 1987), increased by 3·01 kg to 7·30 kg in the following 11 years (Anon., 1998).

The other introduced predator is the cichlid *Serranochromis robustus* (Boulenger), referred to as nembwe, which was introduced from the Upper Zambezi in the early 1960s (Toots, 1970). This species is also widely distributed throughout the country (Bell-Cross & Minshull, 1988). It does not grow as large as *M. salmoides* and the angling record is only 3·24 kg, but it can become very numerous in small reservoirs where stunted populations may develop (Toots & Bowmaker, 1979).

Neither species has been studied in much detail in Zimbabwe. A general account of the biology and propagation of largemouth bass was given by Toots (1972), while Junor (1969) described aspects of its growth and recruitment and Ludbrook (1974) its feeding habits. The only published work on nembwe was that of Toots & Bowmaker (1976) who described the growth, breeding biology, and feeding habits of a stunted population in a small reservoir. The impact of these predators on communities of indigenous species is unknown. It may be especially severe in rivers, which are already threatened by activities like dam construction, pollution, siltation, invasive alien weeds and habitat degradation (Jubb, 1972; Skelton, 1993).

METHODS

An extensive survey of stream fishes was conducted in the upper Manyame River (Fig. 1). This 3792 km^2 drainage basin is located on the central plateau of Zimbabwe at altitudes ranging from 1300 to 1600 m. The rivers are highly seasonal, and by the end of each dry season (October–November) all but the largest have dried up. The work reported here was done between August and October 1999, i.e. in the latter half of the dry season, when the perennial streams consisted of pools a few metres wide and up to 2 m deep connected by shallower stretches of flowing water. Harare, the country's capital city, with a population of about 1·5 million people is located more or less in the centre of the catchment (17°50′ S; 31°04′ E), and some other smaller satellite towns are also present. Some of the streams that flow through the city are severely polluted, and data from them have been excluded because few fishes occur there.

Samples were taken from 42 stations in streams throughout the catchment (Fig. 1). Fishes were collected with a Smith-Root VI-A electrofisher powered by a Honda EZ 4500 generator. Voltage was set at 750 V DC (60 pps), but the current varied depending on the conductivity of the water, which ranged from 35 to 647 μS cm^{-1}. The electrofisher was fitted with a timer and each site was electrofished for *c.* 10 min. Fish relative abundance was expressed as a catch per unit effort (no. min^{-1}). Voucher specimens were retained from each station and deposited in the Natural History Museum of Zimbabwe in Bulawayo.

RESULTS

Twenty-one fish species were collected during the survey. Also, some cichlids were collected that were difficult to identify and may have been hybrids between *Oreochromis mossambicus* (Peters) and *O. niloticus* (L.) (Table I). The most

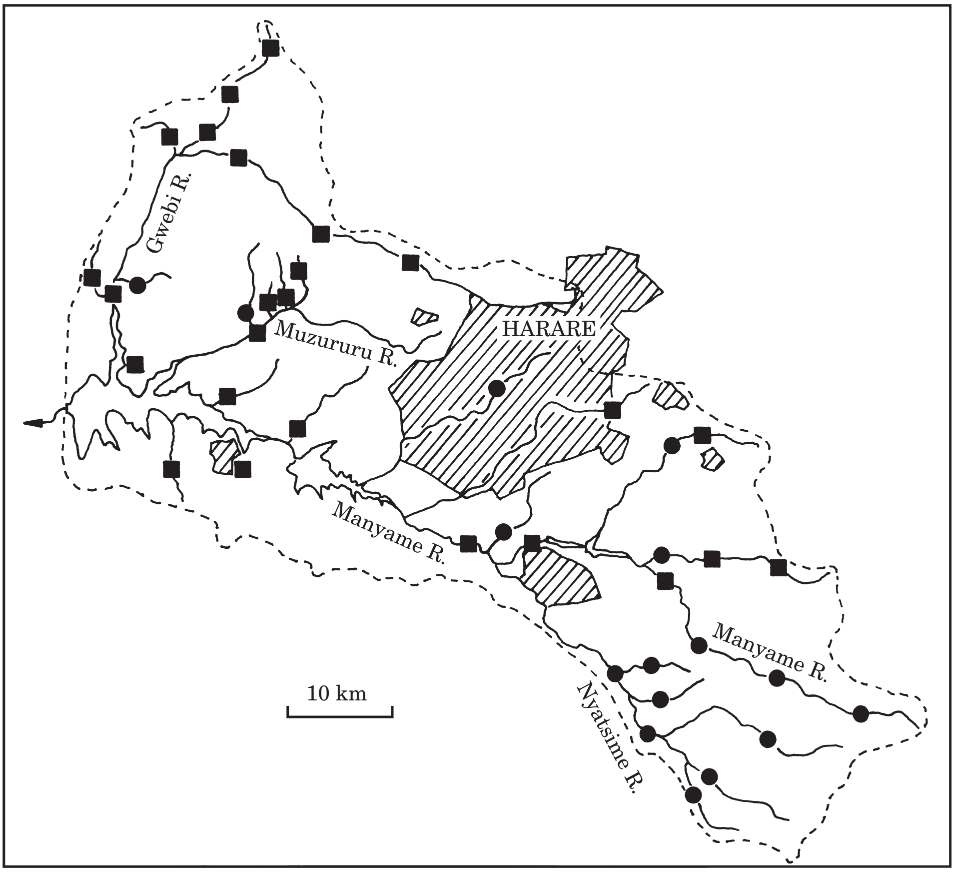

FIG. 1. The upper Manyame catchment area in Zimbabwe showing the sampling stations. ●, Stations without exotic predators; ■, stations with exotic predators; ▨, extent of urban areas in the catchment.

widespread species (present at ≥20 stations) were *Marcusenius macrolepidotus* (Peters), *Barbus paludinosus* Peters, *Labeo cylindricus* Peters, *Clarias gariepinus* (Burchell) and *Tilapia sparrmanii* A. Smith. The most numerous species, each constituting >10% of the total, were *Barbus lineomaculatus* Peters, *B. trimaculatus* Peters, and *T. sparrmanii*. The two introduced predators, *S. robustus* and *M. salmoides*, were found in relatively small numbers but the former was always more numerous (2·76 and 0·57% of the total, respectively). *Micropterus salmoides* were significantly larger (mean weight=80·6 g) than *S. robustus* (mean weight=13·5 g) (*t*-test; $P=0{\cdot}006$). There were 16 stations where neither predator occurred, 12 stations with only *S. robustus*, seven stations with both predators, and six stations with *M. salmoides* only (Fig. 1). The introduced predators were restricted to streams influenced by small dams into which they had been introduced.

The composition of fish communities was associated significantly with presence of exotic predators (Table II). Overall fish abundance was significantly lower (Kruskal–Wallis test, $P<0{\cdot}001$) when the predators were present, but this

TABLE I. Fish species collected and the number of stations where they occurred (out of 42) in the upper Manyame River, August–October, 1999. Species marked * are exotics

Family	Species	Number of stations	Number of fish	%
Mormyridae	*Hippopotamyrus discorhynchus* (Peters)	2	67	0·77
	Marcusenius macrolepidotus (Peters)	25	225	2·60
Cyprinidae	*Opsaridium zambezense* (Peters)	9	291	3·36
	Barbus lineomaculatus Boulenger	19	1155	13·30
	Barbus paludinosus Peters	28	2122	24·50
	Barbus trimaculatus Peters	17	988	11·40
	Barbus radiatus Peters	3	6	0·07
	Barbus marequensis A. Smith	3	61	0·70
	Labeo cylindricus Peters	22	441	5·09
Characidae	*Micralestes acutidens* (Peters)	2	51	0·59
Amphiliidae	*Leptoglanis rotundiceps* (Hilgendorf)	11	544	6·28
Clariidae	*Clarias gariepinus* (Burchell)	38	314	3·63
Mochokidae	*Chiloglanis neumanni* Boulenger	10	293	3·38
Centrarchidae	*Micropterus salmoides* Lacépede*	13	49	0·57
Cichlidae	*Pseudocrenilabrus philander* (Weber)	16	230	2·66
	Pharyngochromis acuticeps (Steindachner)	5	69	0·80
	Tilapia rendalli Boulenger	8	37	0·43
	Tilapia sparrmanii A. Smith	29	1290	14·90
	Serranochromis robustus (Boulenger)*	19	239	2·76
	Oreochromis mossambicus (Peters)	8	37	0·43
	Oreochromis niloticus (L.)*	4	23	0·27
	Unidentified cichlids, possibly *O. mossambicus*/*O. niloticus* hybrids	2	68	0·79

was largely accounted for by a low abundance and diversity of barbs (*Barbus* spp.) (Fig. 2). Barb abundance was not as low when *S. robustus* was present alone compared with when *M. salmoides* was the only exotic. Barb diversity was slightly higher when *S. robustus* was the only predator, but these differences were not significant. Barbs were completely absent from eight of the 13 stations where the bass occurred (either alone or with *S. robustus*) while they were absent from only two of the 12 stations where *S. robustus* was the only introduced predator. Barbs were present at all of the 13 stations where introduced predators were absent.

Small catlets were the only other species to be significantly lower in numbers when *S. robustus* was present (Kruskal–Wallis test, adjusted for ties, $P<0{\cdot}02$). Only one specimen of the sand catlet *Leptoglanis rotundiceps* (Hilgendorf), and no rock catlets *Chiloglanis neumanni* Boulenger were collected at the 19 stations where this predator occurred. The relative abundance of the catfish *Clarias gariepinus* appeared to be lower at stations with *M. salmoides* and/or *S. robustus*, but the differences were not significant (Kruskal–Wallis test, $P>0{\cdot}05$). This catfish was absent from only four stations and *S. robustus* was found at all of them. The relative abundance of *Tilapia sparrmanii* was significantly higher (Kruskal–Wallis test, $P<0{\cdot}05$ adjusted for ties) at sites with exotic predators (Table II).

TABLE II. The structure of the fish communities, with the numbers of each group expressed as relative abundance (no. min^{-1}), in relation to the type of predator present. The symbol + indicates that a species was present, but with a relative abundance of <0·01 fish min^{-1}

	None	*S. robustus*	*S. robustus* and *M. salmoides*	*M. salmoides*
Mormyrids	0·37	0·38	0·53	0·65
Barbus	12·12	1·72	0·63	0·16
Labeo	0·33	0·66	0·37	1·11
Opsaridium	0·63	0	0·44	0·19
Characids	+	0	0·32	0
Catlets	2·27	+	0	0·99
Clarias	0·53	0·25	0·32	0·34
Micropterus	0	0	0·26	0·07
Serranochromis	0	0·78	0·43	0
Tilapia sparrmanii	0·46	1·40	4·18	1·96
Other cichlids	1·02	0·91	0·47	0·42
Total	17·73	6·10	7·95	5·89

DISCUSSION

These data suggest that exotic predators prey selectively on the barbs thus reducing their diversity and abundance. When the predators were absent, the barbs were usually the most numerous forms in all stream habitats and there were no factors other than predation to explain their decrease when bass or nembwe were present. Similar effects have been noted with other predatory species elsewhere in Zimbabwe. For example, barbs were rare in the middle Zambezi River where a lack of cover exposed them to tigerfish *Hydrocynus vittatus* Castelnau, but they were abundant and diverse in the upper Zambezi where submerged macrophytes provided shelter (Jackson, 1961*a*, *b*). Elsewhere on the middle Zambezi, they were present in grassy areas that had been newly flooded but were scarce or absent from the main river (Kenmuir, 1976).

The barbs would be vulnerable to diurnal sight predators because they are shiny, silvery fish that live in midwater and are therefore more conspicuous than other species. Except for *Barbus marequensis* A. Smith, adult barbs are all <10 cm long and are therefore vulnerable to bass and nembwe predation throughout their lives. Also, largemouth bass prefer the elongate shape of these fish over the more rounded form of cichlids as the former are swallowed more easily (Ludbrook, 1974). The only other species that may have been affected adversely by the predators were the small catlets, which were significantly less abundant in the presence of *S. robustus* but not *M. salmoides*. This is probably because *S. robustus* tended to live in riffles where the catlets tend to be most numerous. Catlets are very small benthic fishes (maximum length=4–6·5 cm) and therefore vulnerable even to small *S. robustus*, which are predominantly benthic feeders in Zimbabwean waters (Toots & Bowmaker, 1976). The catlets have sharp dorsal and pectoral spines but these would give little protection

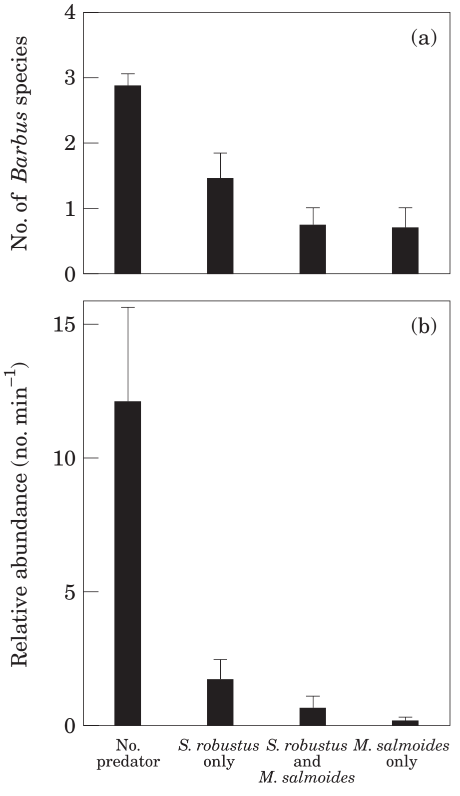

FIG. 2. (a) The diversity and (b) the relative abundance of *Barbus* species in the presence or absence of alien predators. The values are the mean plus the standard error. The difference between stations with and without predators is highly significant (Kruskal–Wallis test, $P<0{\cdot}001$) but the differences between stations where predators were present are not.

against *S. robustus* that are adapted to feeding on fish with protective spines, such as *Synodontis* spp. which make up about 50% of their diet in their natural habitat (Winemiller, 1991).

Other cyprinids have an elongated body shape favoured by bass, but might avoid predation by behavioural means and habitat preferences. *Labeo cylindricus* is a cryptic benthic species that lives among rocks. *Opsaridium zambezense* (Peters) lives in riffles with a strong current, a habitat avoided by largemouth bass. Mormyrids are cryptic, nocturnal species that live among rocks and vegetation where they can avoid diurnal predators, and most *Clarias gariepinus* were too large to be eaten by either predatory species. The same applies to the cichlids, the dominant family at sites with exotic predators. Cichlids also guard their fry and are further protected by their deep bodies and numerous dorsal spines. It was not obvious why the relative abundance of *T. sparrmanii* should have been higher at the stations where the predators were present. Both *T. sparrmanii* and the exotic predators were found mostly in streams influenced by small farm dams with altered flow characteristics making them favourable for cichlids.

The presence of exotic predators was associated with fish community structure in rivers on the Zimbabwean plateau, probably because they reduce populations of the usually dominant forms (*Barbus* spp.). While these species are not threatened at present, functionally they are extinct where the predators occur. These effects might cascade throughout the food web (Power *et al.*, 1985; Carpenter & Kitchell, 1993), but this possibility has not been investigated in Zimbabwe.

Populations of barbs in southern Africa, like those of small cyprinid minnows elsewhere (Whittier *et al.*, 1997), are threatened by land-use changes, siltation, pollution and dam-building (Skelton, 1990). The addition of exotic predators is another threat to fish abundance and biodiversity, and further introductions of *S. robustus* and *M. salmoides* in Zimbabwe should be discouraged to protect these species.

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References

Anon (1998). Zimbabwe bass record falls. *Zimbabwe Fisherman* **10,** 24.

Bell-Cross, G. & Minshull, J. L. (1988). *The Fishes of Zimbabwe*. Harare: Trustees of the National Museums and Monuments of Zimbabwe.

Cambray, J. A. & Stuart, C. T. (1985). Aspects of the biology of the rare redfin minnow *Barbus burchelli* (Pisces, Cyprinidae), from South Africa. *South African Journal of Zoology* **20,** 155–165.

Carpenter, S. R. & Kitchell, J. F. (Eds) (1993). *The Trophic Cascade in Lakes*. Cambridge: Cambridge University Press.

Jackson, P. B. N. (1961*a*). The impact of predation, especially by the tiger-fish (*Hydrocyon vittatus* Cast.) on African freshwater fishes. *Proceedings of the Zoological Society of London* **136,** 603–622.

Jackson, P. B. N. (1961*b*). Ichthyology: the fishes of the middle Zambezi. *Kariba Studies* **1,** 1–36.

Jubb, R. A. (1972). Disappearing river fishes. *African Wild Life* **26,** 48–52.

Junor, F. J. R. (1969). *Tilapia melanopleura* Dum. in artificial lakes and dams in Rhodesia with special reference to its undesirable effects. *Rhodesian Journal of Agricultural Research* **7,** 61–69.

Kenmuir, D. H. S. (1976). Fish spawning under artificial flood conditions on the Mana flood-plain, Zambezi River. *Kariba Studies* **6,** 86–97.

Ludbrook, J. V. (1974). Feeding habits of the largemouth bass *Micropterus salmoides* (Lacépède 1802) in Lake Kyle, Rhodesia. *Arnoldia (Rhodesia)* **6,** 1–21.

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

de Moor, I. J. & Bruton, M. N. (1988). *Atlas of Alien and Translocated Indigenous Aquatic Animals in Southern Africa*. Pretoria: South African National Scientific Programmes Report no. **144**.

Ogutu-Ohwayo, R. & Hecky, R. E. (1991). Fish introductions in Africa and some of their implications. *Canadian Journal of Fisheries and Aquatic Sciences* **48** (Suppl.), 8–12.

Power, M. E., Matthews, W. J. & Stewart, A. J. (1985). Grazing minnows, piscivorous bass, and stream algae: dynamics of a strong interaction. *Ecology* **66,** 1448–1456.

Skelton, P. H. (1990). The conservation and status of threatened fishes in southern Africa. *Journal of Fish Biology* **37** (Suppl. A), 87–95.

Skelton, P. H. (1993). *A Complete Guide to the Freshwater Fishes of Southern Africa*. Harare: Tutorial Press.

Toots, H. (1970). Exotic fishes in Rhodesia. *Rhodesia Agricultural Journal* **67,** 83–88.

Toots, H. (1972). Largemouth Black Bass *Micropterus salmoides* (Lacépede) 1902. *Rhodesia Agricultural Journal* **69,** 27–34.

Toots, H. & Bowmaker, A. P. (1976). *Serranochromis robustus jallae* (Boulenger, 1896) (Pisces: Cichlidae) in a Rhodesian Highveld dam. *Arnoldia (Rhodesia)* **7,** 1–16.

Whittier, T. R., Halliwell, D. B. & Paulsen, S. G. (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.

Winemiller, K. O. (1991). Comparative ecology of *Serranochromis* species (Teleostei: Cichlidae) in the upper Zambezi River floodplain. *Journal of Fish Biology* **39,** 617–639.