Potential of *Metriaclima lanisticola* (Teleostei: Cichlidae) for biological control of schistosome intermediate host snails

Mary Lundeba[1‡], Jeremy S. Likongwe[1], Henry Madsen[2*] & Jay R. Stauffer, Jr[3]

[1]*Aquaculture and Fisheries Science Department, University of Malawi, Bunda College of Agriculture, Box 219, Lilongwe, Malawi*

[2]*DBL Center for Health Research and Development, Jaegersborg Allé 1D, DK-2920 Charlottenlund, Denmark*

[3]*School of Forest Resources, Penn State University, 420 Forest Resources Building, University Park, PA 16802-4302, U.S.A.*

Received 5 December 2005. Accepted 4 July 2006

Metriaclima lanisticola, a native cichlid of Lake Malawi, was studied under laboratory conditions to evaluate its possible role as a predator of snails (_Bulinus_ spp.). _Bulinus globosus, B. nyassanus_ and _B. tropicus_ were used as prey. _B. globosus and B. nyassanus_ are intermediate hosts of human schistosomes in Lake Malawi. _M. lanisticola_ orally shelled snails of all three species. Even when small snail sizes were offered, the fish shelled them. This suggests that _M. lanisticola_ is entirely an oral sheller. Opercula of _Melanoides_ species were commonly found in the stomach contents of wild-caught _M. lanisticola,_ while whole snail shells or shell fragments were never observed, further suggesting that the fish is an oral sheller. _M. lanisticola_ consumed more _B. nyassanus_ in aquaria without substratum than in aquaria with a sandy substratum and apparently the fish is dependent on visual perception for prey detection.

Key words: **schistosomiasis, Lake Malawi, _Bulinus,_ biological control, _Metriaclima lanisticola_.**

INTRODUCTION

Urinary schistosomiasis, caused by *Schistosoma haematobium* (Bilharz 1852), has long been recognized as a major public health problem in lakeshore communities of Lake Malawi (World Health Organization 1993), although the open waters of Lake Malawi were believed to be free of schistosome transmission prior to about 1988 (Stauffer *et al.* 1997). Transmission only occurred within relatively protected areas of the lake, where the intermediate host snail, *Bulinus globosus,* is primarily found.

During mid-1980s, reports indicated that transmission had increased and also occurred along open shorelines (Cetron *et al.* 1996; Stauffer *et al.* 1997). It is now evident that in the southern part of the lake, especially Cape Maclear (see Fig. 1 in Stauffer *et al.* 2006) on Nankumba Peninsula, transmission also occurs along exposed shorelines with sandy sediment devoid of aquatic plants, via another intermediate host, *Bulinus nyassanus,* which is endemic to Lake Malawi (Madsen *et al.* 2001, 2004).

Stauffer *et al.* (1997) suggested that this increased transmission was caused by an increase in density of intermediate host snails associated with the decline in the density of the shallow-water molluscivorous cichlid fishes. Densities of, for example, *Trematocranus placodon,* an important snail predator (Evers *et al.* 2006), has declined greatly in shallow water, most likely as a consequence of seine net fishing from the beach (Stauffer *et al.* 2006). Although biological control theoretically would be more likely if foreign control agents were introduced, this option is, however, out of the question due to the unforeseeable effect such introductions might have on the unique fauna of Lake Malawi. Therefore, the only obvious possibility of biological control is to protect existing fish predators so that they may attain previous population densities where they can affect the snail population density. Previous studies have shown that better results would be achieved if several molluscivores were used in any control attempt (Chiotha 1990) and therefore as many native species as possible should be protected in order to control schistosomiasis. In this paper, we test the suitability of *Metriaclima lanisticola,* a native cichlid of Lake Malawi, for possible use in

‡Present address: Department of Fisheries, P.O. Box 350100, Chilanga, Lusaka, Zambia

*Author for correspondence. E-mail: hmadsen@dblnet.dk

the control of three *Bulinus* species, *B. globosus* and *B. nyassanus,* which are intermediate hosts for *Schistosoma haematobium* and *B. tropicus*.

Metriaclima lanisticola (Burgess, 1976)

Metriaclima lanisticola is indigenous to the Cape Maclear area of Lake Malawi. Most other members of the genus *Metriaclima* are rock-dwelling cichlids (Stauffer *et al.* 1997). *M. lanisticola,* however, inhabits the sandy habitat (Konings 1990). The fish hides in empty snail shells of *Lanistes nyassanus,* and breeds in the sand just in front of the snail shell (Stauffer *et al.* 1997). Turner (1996) reported that this fish attains a maximum size of 8.5 cm (total length).

MATERIALS & METHODS

Laboratory studies

Metriaclima lanisticola were collected at Chembe village and kept in the laboratory at Bunda College, University of Malawi, located near Lilongwe, Malawi. Water temperature ranged between 23 and 27°C. Each fish was used only once in a feeding trial. The fish were acclimated for two weeks and were fed with a locally formulated diet consisting of 30% crude protein of fish origin. The snails used in the feeding trials were field-collected *Bulinus nyassanus* from Chembe village, field-collected *B. globosus* from a stream at Msaka, and from different swamps along Nankumba Peninsula, Lake Malawi (Stauffer *et al.* 2006: Fig. 1), and field-collected *B. tropicus* from a pond at Bunda College. Snails were kept in the laboratory for two weeks before being used in the experiments and were fed fish food (Lundeba *et al.* 2006).

Preliminary experiments were conducted prior to this study to determine the number of fish to be used in each aquarium. In preliminary observations, single fish placed in aquaria did not consume any snails, but multiple fish in aquaria fed on snails. In order to have a reasonable level of snail consumption, we conducted all experiments with 10 fish in each aquarium.

Glass aquaria measuring 0.8 × 0.4 × 0.4 m filled with 60 l of water were partitioned into two equal parts by a removable vertical glass plate. Ten fish with an average standard length (SL) of 6.0 cm (range 5.0 to 7.0 cm) were placed in one part of the aquarium and 15 snails of one species in the other partition (five specimens of each of three shell height classes, 3–6, 7–10 and >10 mm). Fish were starved for 72 hours, after which access to the snails was permitted by removing the vertical plate. Routine observations of fish behaviour were made every two hours during daylight for three days. These observations were repeated five times for each snail species.

In a second trial, using the same aquaria as above, *M. lanisticola* was allowed to prey on *B. nyassanus* in aquaria with or without a 2–3 cm layer of sand as a substratum. Fish and snails were introduced as described above and observations were made as above. The total number of snails eaten in each aquarium within three days was noted. The remaining snails were then recovered from the aquaria. Empty and half-empty shells were scored as orally shelled (Slootweg 1987). The Mann-Whitney *U*-test was used to compare results of prey detection with and without substratum on aquaria bottoms.

Stomach contents of wild-caught fish

Stomachs and intestines of 114 fish collected during the period March–June 2004 at Cape Maclear, Lake Malawi, were examined for snail remnants, such as shell fragments or opercula. Fish examined ranged from 3.4–7.9 cm standard length (SL). Fish were anaesthetized using clove oil and preserved in 10% formalin as soon as they were collected. The preserved fish were washed under running tap water for three days, after which standard length (SL) in cm of each fish was measured. Fish were then preserved in 70% ethanol after which fish were dissected and stomach contents preserved in 70% ethanol for later examination. Stomach contents were examined for any snail remains that could help identify species, i.e. shell fragments, radulae, or opercula.

RESULTS

Laboratory studies

Metriaclima lanisticola started feeding almost immediately after access to the snails was given. Prey capture involved observing a snail for some time, approaching it and biting the foot of the snail. The fish targeted the fleshy part of the snail. Some of the snails were injured in the process of biting and haemolymph was seen coming out. At times the fish failed to bite or extract the snail tissue because the snail withdrew into its shell. The fish also attempted to push small snails into the mouth, but attempts to crush snails failed and fish ejected whole snails with shells in a few seconds. In certain instances, more than one fish tried to attack one snail. On a few occasions the

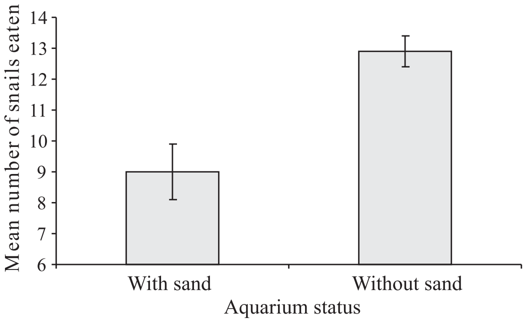

Fig. 1. Mean numbers of snails eaten by *Metriaclima lanisticola* in aquaria with and without a sandy substratum.

fish would flip the snail in order to gain access to the snail's foot when stretched out to regain its foothold.

No snail was observed to be crushed in the mouth or the pharyngeal mill, as observed in *Trematocranus placodon* (Evers *et al.* 2006), but the extraction of the snail tissue from all size classes was observed. The fish were able to rip the whole snail tissue or just part of it from its shell. The shell apertures of some *B. globosus* and *B. tropicus* or any part of the shells could be damaged in the oral shelling process. The shells of *B. nyassanus* remained intact. Empty or half-empty shells were mostly found on the second and third days. Among the three species of snails, *B. globosus* and *B. tropicus* were observed to stick more on the aquaria walls within the water or above the waterline than *B. nyassanus*. Out of 225 snails that were offered in total, 128 snails (56.9%) were consumed (orally shelled) and 97 snails were not eaten. The proportion eaten did not differ significantly among species, i.e. 64% for *B. nyassanus* and 53.3% for both *B. globosus* and *B. tropicus*.

In the experiment with sediment, almost all *B. nyassanus* exposed on top of the substratum were killed (in the field *B. nyassanus* usually descends into the top sediment). There were no crushed or empty shells, only half-empty shells were found. All snails that were recovered from the substratum were alive. The mean number of snails eaten in aquaria (Fig. 1) with a sandy substratum was significantly lower than that in aquaria without substratum ($P < 0.05$).

Stomach content of wild-caught fish

A total of 46 *Melanoides* opercula was found in 21 stomachs/intestines of the 114 wild-caught *M. lanisticola,* but snail shells or shell fragments were not found. Also, radulae from snails were not recorded. Other items that were found in stomach contents included sand, detritus, insect parts, and one stomach contained flaccid material (possibly animal tissue), which could not be identified.

In order to obtain a rough estimate of shell size, opercula were removed from field-collected specimens of *Melanoides tuberculata,* the morph that according to Genner *et* al. (2004) is invasive, and related to shell height. The estimated shell sizes found in the 21 fish ranged from 3.4–13.2 mm in fish that ranged from 3.4–7.9 cm. The average of the estimated shell sizes by individual fish increased linearly with fish size (linear regression, $P < 0.05$).

DISCUSSION

Metriaclima lanisticola feeds on snails by orally shelling them. This is in contrast to another common snail predator in the lake, *Trematocranus placodon,* which crush snails in their pharyngeal mills or swallow them whole (Evers *et al.* 2006). While the amount of food obtained by crushing snails is constant and can be predicted from snail size, the amount of food obtained by shelling can vary from nothing to half the snail (Slootweg 1987). This may be attributed to the escape response that the snail displays by retracting its foot before the fish can get hold of it or crawling above the waterline. Makoni *et al.* (2004) demonstrated that *B. globosus* and *B. tropicus* crawl above the waterline when exposed to predation risk, and that the snails actively seek refuge in the presence of a fish molluscivore, *Sargochromis codringtonii*. Physical examination of the jaw apparatus of a few *M. lanisticola* did not show the characteristics (i.e. molariform teeth) of pharyngeal crushers. It was also observed in the laboratory that *M. lanisticola* fed only when they were in a group, but not as individuals. In the field, females are reported to gather in small foraging groups (Konings 1990).

Metriaclima lanisticola shelled both small and large snails. With its jaws, the fish grasps a large snail by its foot and rips the snail from its shell. This is in agreement with Slootweg (1987) who demonstrated that shellers could feed on larger snails than crushers. Shelling of large snails is an advantage for biological control of intermediate host snails because studies have shown that the majority of infected snails tend to be large ones (Chiotha 1990; Coulibaly & Madsen 1990). Schistosome-infected *B. nyassanus* were in the shell height classes of 6.0–10.9 mm and schistosome-infected

B. globosus in the 9.0 to >15 mm shell height class (Phiri 2002).

Shelled snails permit easy passage through the intestines, and also make digestion easier than when snails with shells are ingested. Additionally, energy cost is minimal when snails are shelled compared to when snails are crushed. The process of crushing snails results in some shell fragments being ingested and small snails may be swallowed whole. Thus, *S. codringtonii* swallowed snails of ≤3 mm in shell height (Chimbari *et al.* 1996). While thick-shelled snails may escape predation by pharyngeal crushers, *M. lanisticola* is able to consume such snails.

The results of prey detection in the substratum revealed that only half-empty shells were observed. It could be that there was no tight grip on the loose substratum to support fish to pull the snail tissue completely. Most likely as fish tried to bite the flesh, the snails were slowly sinking into the loose sediment, which resulted in them just being injured. The limited prey detection in sediment might be a disadvantage for the control of host snails.

The failure of *M. lanisticola* to detect prey in sediment could be due to the fact that this fish does not have a morphological adaptation capable of detecting snail movement beneath the sediment, such as the hypertrophied canals (sensory pits on the lower jaw) of *T. placodon* (Konings 1990); thus, *M. lanisticola* most likely depends on visual perception to detect its prey. Oral shelling requires an accurate, visually guided predation technique (Keenleyside 1991). *Bulinus nyassanus,* an intermediate host for *S. haematobium* lives on coarse sediment, and digs into the sediment where it feeds on detritus (Madsen *et al.* 2001).

This study has also revealed for the first time that *M. lanisticola* feeds on *Melanoides* species, which dominate the mollusc fauna in Lake Malawi. Unpublished work by Grant and Turner did not report the presence of snail shells or opercula in stomach contents of *M. lanisticola*. As the fish shelled the snails, the snail tissues were ingested together with the opercula that are indigestible, hence easy to identify. *Bulinus* species do not have opercula and since this fish species shells snails, and the soft tissues digest quickly, it could not be determined if they preyed on *Bulinus* species in the field.

The implication for biological control of schistosome intermediate host snails is that *M. lanisticola* is capable of consuming intermediate host snails by shelling them, but field trials are required to assess to what extent this would affect density of the intermediate host snails. The fish lives on sandy sediment at depths from at least 2 m and in this habitat the snail fauna is dominated by *Melanoides* spp. and *B. nyassanus* and the density of *Melanoides* spp. is much higher than that of *B. nyassanus* (Genner *et al.* 2004; Evers *et al.* 2006). Usually, *B. nyassanus* is found in the top sediment and if *M. lanisticola* detects prey visually, it may not be likely to consume large numbers of the schistosome intermediate host, *B. nyassanus*. *Melanoides tuberculata* has been suggested for biological control of schistosome intermediate hosts (Pointier 2001). This introduced morph attains very high densities in the southern part of the lake (Genner *et al.* 2004) and one could envisage that it would exert some competition on *B. nyassanus* and the predation by *M. lanisticola* on *M. tuberculata* might counteract on this. Density of *B. nyassanus* in the shallow water in the southern part of the lake, however, is greater than in other parts of the lake (Madsen & Stauffer, unpubl. data). Manipulative field experiments are required to address these aspects.

The results of this study are considered preliminary, awaiting further trials to confirm the results and answer broader practical questions on biological and ecological aspects, including the preference of *M. lanisticola* to feed on snails in the presence of other foodstuffs, and their ability to feed on snails under natural or semi-natural conditions. These further investigations will determine the full potential of *M. lanisticola* as a biological control agent for snails.

ACKNOWLEDGEMENTS

This project was funded by the NSF (U.S. National Science Foundation)/NIH (U.S. National Institutes of Health) joint program in Ecology of Infectious Diseases (DEB 0224958) and the Beth Bowers Memorial Fund.

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Responsible Editor: K. Prochazka