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Oral shelling of *Bulinus* spp. (Mollusca: Planorbidae) by the Lake Malaŵi cichlid, *Metriaclima lanisticola* (Pisces: Cichlidae)

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Metriaclima lanisticola (a native cichlid of Lake Malaŵi) was studied under laboratory conditions to evaluate its potential as an agent for the biological control of schistosome intermediate host snails (i.e., *Bulinus globosus*, *Bulinus nyassanus*, and *Bulinus tropicus*). Crushing resistance of the three snail species was evaluated. *M. lanisticola* orally shelled snails of all species. Although there was no preference among species, fish preferred small to large snails. Crushing resistance of snails revealed that *B. nyassanus* had the highest resistance.

Keywords: *Bulinus spp.*; Lake Malawi; oral shelling

Introduction

Metriaclima lanisticola is a rock-dwelling haplochromine cichlid endemic to Lake Malaŵi (Konings 1990) that has reinvaded the shallow-water sand habitat. This species preys on freshwater snails by orally shelling them (Lundeba et al. 2007). *M. lanisticola* hides in empty snail shells of *Lanistes nyassanus* and breeds in the sand just in front of the snail shell. Turner (1996) reported that this fish attains a maximum size of 8.5 cm (total length). Stomachs of wild-caught *M. lanisticola* contained *Melanoides* spp. opercula, sand, detritus, insect parts, and unidentifiable animal tissue (Lundeba et al. 2007). No snail shells or shell fragments were found in the stomachs, which support the conclusion that *M. lanisticola* removes the snail from the shell rather than ingesting and crushing the snail, as does *Trematocranus placodon* (Madsen et al. 2010).

Materials and methods

M. lanisticola were captured at Cape Maclear, Lake Malaŵi by divers and transported to Bunda College of Agriculture (University of Malaŵi) where they were maintained until used in the experiments. *Bulinus nyassanus* were collected from Lake Malaŵi along sandy shores at Cape Maclear at depths from 1 to 2 m using

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standard snail scoops. *Bulinus globosus* were collected from swamps or streams near Lake Malawi, while *Bulinus tropicus* were collected from a dam at Bunda College of Agriculture's field station near Lilongwe, Malaŵi. The snails were then maintained in the laboratory in large aquaria until used in experiments. Both fish and snails were fed a 30% crude protein fish diet (Lundeba et al. 2007).

Ten experimental aquaria, which measured $0.8 \times 0.4 \times 0.4\,m^3$ (length $\times$ width $\times$ height) were filled with 60 L of water. The aquaria were partitioned into two equal parts by a movable glass plate ($40 \times 40\,cm^2$) placed vertically in the middle of the aquarium. Both compartments were aerated. Ten specimens of *M. lanisticola* measuring 5.0–7.0 mm in standard length were introduced into one compartment, and 10 snails of each *Bulinus* spp. were introduced simultaneously into the other compartment. Fish were starved for 72 h in all experiments before use. Each fish was used only once in an experiment. Before the barrier was removed, any dead snails were removed and replaced with live ones. The barrier was removed, and the feeding experiment lasted for 72 h. Crushed, empty, and partially empty shells were classified as eaten. The snails that were not eaten and remained intact were counted and measured.

To determine size preference, trials were completed separately for each *Bulinus* spp. following the above protocol with the following exceptions. Into each of five aquaria, five snails each of the three size classes (3–6 mm, 7–10 mm, >10 mm) were introduced into one compartment and 10 *M. lanisticola* were introduced into the other compartment. Again, fish were starved for 72 h before the divider was removed.

Logistic regression analysis was used to compare fate (eaten or not eaten) relative to snail species and or snail size class after adjusting for clustering within replicate trials. *p*-Values less than 0.05 were considered significant.

For a total of 50 snails in the size class 7–10 mm of each species, crushing resistance was determined using a compression machine. Individual snails were placed on the crushing plate with the apertures facing downward. Force was applied slowly to the point where the snail shell was just crushed at which point the force was recorded. Linear regression analysis was used to find the best linear fit between crushing resistance and shell size for each species separately.

Results

In 10 trials, when *M. lanisticola* was presented with a choice of 10 of each *Bulinus* spp. they consumed a mean of 5.6 *B. nyassanus*, 4.2 *B. globosus*, and 4.9 *B. tropicus* specimens. These differences among snail species consumed were not significant when adjusted for clustering within replicate trial.

Table 1 summarizes the number of snails eaten in five trials by *M. lanisticola* when presented with a choice of five snails from each of three size groups (3–6 mm, 7–10 mm, >10 mm). Each snail species was tested separately. When presented with *B. globosus*, *M. lanisticola* selected the smallest snails; the same trend was observed for *B. tropicus*, but this was not significant. For *B. nyassanus*, small and large snails were consumed more frequently than medium-sized snails, while there were no significant differences in sizes selected for either *B. nyassanus* or *B. tropicus*. When comparing snail species and size classes, species was not significant while size was

Table 1. Mean number (range) of snails eaten for each size group for each *Bulinus* species in five trials.

Size class (mm)	*B. nyassanus*	*B. globosus*	*B. tropicus*
3–6 ($n = 5$)	4.6 (4–5)	3.6 (2–5)	3.6 (1–5)
7–10 ($n = 5$)	3.0 (2–5)	2.2 (0–3)	2.8 (0–5)
>10 ($n = 5$)	4.4 (2–5)	0.8 (0–3)	2.0 (0–4)

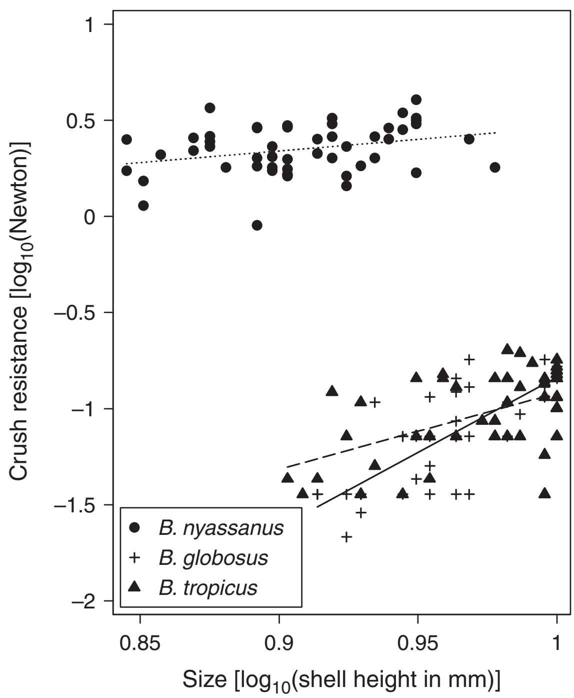

Figure 1. Crush resistance of three snail species by shell height. Regression lines are $y = 1.21x - 0.75$ ($R^2 = 0.09$, $p < 0.05$) for *B. nyassanus*, $y = 7.81x - 8.65$ ($R^2 = 0.60$, $p < 0.001$) for *B. globosus*, and $y = 3.95x - 0.87$ ($R^2 = 0.26$, $p < 0.001$) for *B. tropicus*. Slopes differ significantly between *B. globosus* and *B. tropicus* ($p < 0.05$).

($p < 0.01$); there was a significant interaction between snail species and size class ($p < 0.01$).

The three species of snails showed differences in crushing resistance which increased with size. *B. nyassanus* had the highest resistance followed by *B. tropicus* and *B. globosus* (Figure 1). The interaction between snail species and size of snails was significant ($p < 0.001$, $R^2 = 0.95$).

Discussion

There was a significant difference in crushing resistance of the three snail species even after removing the effect of size. These findings are in accordance with several studies that have demonstrated significant differences in crushing resistance and crush weights among different snail species (Chiotha et al. 1991; Evers 2011). Thickness of snail shell plays an important role in reducing susceptibility to molluscivores that feed by crushing the shells (Brodersen et al. 2002); thus, a crushing molluscivore's maximum prey size is strongly related to crushing resistance (Wainwright 1987). Molluscivorous fishes both in laboratory experiments (Chiotha et al. 1991) and in natural systems (Brönmark and Weisner 1996) have been found to select snails with thinner shells. Evers et al. (2011) also demonstrated that crush resistance was higher for *B. nyassanus* than *B. globosus*. Furthermore, using the total organic weight of the snails, Evers et al. (2011) determined that the crush value index was higher for *B. globosus* than for *B. nyassanus* and thus hypothesized that optimal foraging theory would predict that *T. placodon* should select *B. globosus* when given a choice between these two *Bulinus* species. *M. lanisticola* is an oral sheller, however, and thus does not expend any energy crushing the shells. The results presented herein (i.e., no prey selection), are congruent with our hypothesis that it does not take any more energy to shell *B. nyassanus* than *B. globosus* or *B. tropicus*. Our data further suggest that *M. lanisticola* feeds opportunistically.

Although only one size class was used, crushing resistance was found to increase with shell height *B. globosus*. Chiotha et al. (1991) and Evers et al. (2011) also reported that crush weights increased with snail size. Chiotha et al. (1991) attributed the preference of small size snails to large ones to ease of crushing by *Astatotilapia calliptera* and *T. placodon*. The preference by *M. lanisticola* for small snails may be a function of ease of capture and processing.

We hypothesize that *M. lanisticola* can play an important role in the success of schistosome infection reduction where intermediate host snails occur together. Since *M. lanisticola* is a facultative molluscivore, it can switch prey when the snails are not abundant.

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