Biological Control of Aquatic Pest Snails by the Black Carp
Mylopharyngodon piceus

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Some freshwater snail species are severe pests to human health or agriculture. We tested the hypothesis that the fish Mylopharyngodon piceus, the black carp, may serve as a biological control agent of two pest snails, Physella acuta (a bank-dwelling snail) and Melanoides tuberculata (a substratum-dwelling snail). Experiments were carried out in the laboratory and under controlled field conditions. In the laboratory, small fish (30–50 g) consumed up to about 300 P. acuta per day. Under field conditions in which snails could not shelter, and where fish were absent, snail densities peaked at 181% of their initial density. Where large M. piceus (4–5 kg) were present, snail densities during this period declined to 79%. Under field conditions in which snails could shelter among boulders, and where fish were absent, snail densities decreased to 80% of their initial density. Where large M. piceus (3–4 kg) were present, snail densities declined to 34%. In the laboratory, small fish (30–100 g) consumed 19 g of M. tuberculata/day at 19°C and 17 g at 25°C. There was no difference in the rate of consumption of snails placed upon the substratum or buried at two depths. We conclude that M. piceus may be an efficient biological control agent of pest snails that shelter among boulders and of substratum-dwelling species that bury into sand.

Key Words: Mylopharyngodon piceus; biological control; snails; Melanoides; Physella.

INTRODUCTION

In Israeli reservoirs, aquatic snails can be pests. Their densities may reach 2580/m², blocking filters and pipes and reducing water flow (Leverter, 1981). Snails are pests also in fish ponds. They host fish parasites and cause severe economic losses (Paperna, 1995). To control these snails in reservoirs, the black carp Mylopharyngodon piceus (Richardson, 1846) was introduced to Israel in the 1970s. However, the fish was not subjected to any experiments before it was introduced, and it was not monitored afterward. Also, elsewhere where M. piceus was introduced as a biological control agent, no comprehensive research has been carried out (e.g., in Taiwan, where one million black carp fry were released to control the snail Pomacea canaliculata (Lamarck, 1819); Halwart, 1994).

M. piceus is distributed in rivers of China, Taiwan, and Siberia. Its natural food is snails (Sizhong and Fang, 1990), which are crushed with its well-adapted pharyngeal teeth (Huanliang et al., 1990). Apart from laboratory studies (Shelton et al., 1995), there is little information on its snail-feeding biology and no studies have been conducted to evaluate its efficiency in controlling snail populations under field conditions. Accordingly, the present research had two aims: (1) to test, in the laboratory, the extent to which M. piceus consumed two snail species, Physella acuta (Draparnaud, 1801), a usually episubstratum dweller found on boulders, vegetation, and mud (F. Ben-Ami, unpublished observations), and Melanoides tuberculata (Müller, 1774), a dweller of muddy habitats, which crawls upon the muddy surface when active and when inactive (i.e., during the day) buries into the mud to a depth of about 2 cm (J. Heller, unpublished observations) and (2) to test the efficiency of M. piceus in controlling P. acuta populations under two field conditions, no shelter for the snails and with a shelter of boulders.

MATERIALS AND METHODS

Experiments were carried out during the summer of 1996 from May to August, when snail populations peak (J. Heller and F. Ben-Ami, unpublished observations). The precise length/weight of the fish used depended on the availability at the farm that supplied the fish (Hama’apil kibbutz). In general, fish for laboratory experiments measured 150–210 mm in total length (TL) and 115–170 mm standard and weighed 30–100 g. Fish for the field experiments measured 500–700 mm in TL (estimated) and weighed 3–5 kg.

Physella Experiments

Satiation. The aim of this experiment was to gain some broad idea as to the satiation point of M. piceus in...
the laboratory. The setup consisted of 10 aquaria (50 × 50 × 120 cm), each with a separate water supply, drainage, and heating system. *P. acuta* (6–10 mm shell height) were collected from fish ponds and fed boiled lettuce (De Witt, 1991) until the beginning of the experiment. One fish of 30–50 g was placed into each aquarium at 25°C. In each experiment, each fish received a predetermined number of adult snails, (100, 200, 300, or 500). After 24 h, all remaining snails were removed and counted. Before this experiment started, all fish were fed to satiation on standard commercial fish food (cichlid food—6.4-mm sinking pellets of 35% protein). There were seven replicates for each of the 10 fish. The fish and snails were subjected to daylight during the day (14 h) and 10 h of darkness.

Fish predation where snails cannot shelter. The aim of this experiment was to test the predation ability of *M. piceus* under field conditions in which snails have no shelter. A concrete-walled fish pond (60 × 11 m, 0.7–2.1 m depth) that contained a population of *P. acuta* was subdivided by 2-mm snail-proof mosquito shadow-nets into 20 cells (33 m² each). Eighteen cells in the center of the pond had two concrete walls (3 m each), and the 2 cells at the ends of the pond thus had walls on three sides (17 m total).

Snail density in each cell was monitored once a week over a period of 76 days as follows: metal frames (quadrats of 20 × 20 cm) were hung (at water level) from the walls of the pond, evenly spaced 1 m apart, at a position fixed throughout the experiment. The snails inside each quadrant were counted (six quadrats in each cell) 1 week before and once every week throughout the experiment. All counting was carried out at a fixed hour (sunrise), since preliminary investigations of densities at different depths at different hours revealed that the snails migrate vertically on a diurnal basis. During the experiment, no account was taken of density in the deeper parts of the cells. However, by snorkel diving into the pond before the fish were introduced, we observed that the majority of the *P. acuta* population was at water level or slightly above.

One fish of 4–5 kg was released into each of 10 cells and the other 10 cells (alternating with the fish-containing cells) served as controls. During the experiment, average water temperature was 25.6 ± 0.9°C in both ponds.

Fish predation where snails can shelter. The aim of this experiment was to test the predation ability of *M. piceus* under field conditions in which the snails can shelter among boulders. Two fish ponds (30 × 7 m, 1 m depth, dry during the 2 months preceding the experiment), with banks consisting of boulders (0.3–0.5 m in size, throughout the water column), were each subdivided into eight cells by nets (with floats every 20 cm above and lead weights every 50 cm below; net mesh size was 28 mm knot-to-knot, which allowed the snails but not the fish to pass through). Once the net partitions were set up, the ponds were filled with water and *P. acuta* (collected from nearby ponds) were introduced (about 1500 snails per cell). Two weeks later, the fish were introduced.

Into each of six cells, one fish of 3–4 kg was released; two cells (in each pond) served as controls and were without fish. One control cell was located at the center and the other at the end of each pond. Snail density was measured as follows: metal frames (quadrats of 20 × 20 cm) were placed (at water level) along the banks, evenly spaced 1 m apart at the same position throughout the experiment. The snails inside were counted (eight quadrats in each cell) 1 week before and every 3 days throughout the 2-months-long experiment. Again, all counting was carried out at a fixed hour (sunrise). No account was taken of the density in the deeper parts of the ponds. During the experiment, average water temperature was 26.5 ± 0.9°C in both ponds.

Melanoides Experiments

Satiation at different temperatures. The aim of this experiment was to estimate the capacity in the laboratory of *M. piceus* to consume snails at such different temperatures as may vary among the seasons. *M. tuberculata* was collected from fish ponds and temporarily kept in plastic tanks in the laboratory. In each of 10 aquaria (those of the Physella satiation experiment), one fish of 30–100 g was allowed to feed ad libitum on *M. tuberculata* (adults of 12.0–20.5 mm shell height), and after 24 h, all remaining snails were removed, counted, and weighed. The fish and snails were subjected to daylight during the day (14 h) and 10 h of darkness. Prior to the experiment, fish were fed to satiation on standard commercial fish food (cichlid food—6.4-mm sinking pellet of 35% protein). Temperature in the pond where the fish were collected was 26–28°C. In the laboratory, the fish were allowed 10 days of acclimation before the experiment started. The experiment was conducted at 2 temperatures, 19 and 25°C, with 10 repetitions for each of the 10 fish. At first, 5 of the fish were in aquaria kept at room temperature (19°C), and the other 5 were in heated aquaria (25°C). Later, the experiment was reversed: the five aquaria of 19°C were heated to 25°C, and in those of 25°C the heating was disconnected and the water left to cool to 19°C.

Predation of snails placed within the substratum. The aim of this experiment was to test the ability of *M. piceus* to prey on snails buried in sand. *M. tuberculata* were collected in ponds and killed by freezing in the laboratory to prevent them from moving and thereby control their depth in the substratum. Freezing kills the snails but we found that if they are freshly defrozen, the fish eat them readily. Therefore, only freshly
thawed snails were offered. Ten aquaria were each divided by a white, opaque PVC partition (4 mm thick) into two compartments: a waiting compartment (50 × 50 × 50 cm) from which the fish could not see the preparation of the treatment and an experimental compartment (70 × 50 × 50 cm). In each experiment, the fish was gently ushered into the waiting compartment and the partition lowered. One hundred thawed snails were then randomly placed into the experimental compartment, a process that took no more than 5 min. The partition was then removed and each fish was allowed to enter its experimental compartment to consume snails. After 24 h, the fish was returned to its waiting compartment, and all remaining snails were collected by pumping the sand, snails, and part of the water through a filter, in which the snails were trapped (as a side effect, this reduced the effects of snail odor between trials). The remaining snails were counted and the sand and same water returned to the aquarium.

The fish and snails were subjected to daylight during the day (14 h) and 10 h of darkness. Throughout the experiment, each fish was kept in its own aquarium, to which it was accustomed, and the same fish was thus used for each of the 10 repetitions of the three treatments. This method (rather than the alternative of introducing a new fish for each treatment) was used because only 10 fish were available. It is advantageous in that it reduces handling, transferring, and acclimation of fish into new aquaria; it is disadvantageous in that it does not take account of learning.

In the first treatment, the snails were placed on the bare aquarium floor. In the second treatment, the snails were buried 0.5 cm beneath the surface of a 3-cm layer of sand. In the third treatment, they were buried 2 cm beneath the surface of the sand (this is the maximum depth to which most M. tuberculata bury in nature; J. Heller, unpublished observations). Temperature was 25°C throughout the experiment.

Satiation data and differences in predation of snails within the substratum were analyzed by the Kruskal–Wallis nonparametric test or one-way ANOVA when possible. Differences among treatments in the shelter and no-shelter experiments were analyzed by repeated-measures ANOVA and specific samples were examined by one-way ANOVA or t test. The Tukey’s HSD test was used to find differences among treatments. All statistical tests were performed with SPSS (SPSS, 1999).

RESULTS AND DISCUSSION

Physella Experiments

Satiation. The fish consumed on average 257.0 ± 14.0 snails/day. They did not differ significantly in the number of snails that they consumed (Kruskal-Wallis, df = 9, P = 0.08). In retrospect, it would perhaps have been preferable to allow the fish to eat ad libitum on 500 snails per day from the start. However, when the experiment was conducted, we were unaware that such small fish could consume over 100 snails per day, and our stock of P. acuta was limited.

Fish predation where snails cannot shelter. Initial snail density in the controls was 16.4 ± 4.0 snails per quadrat, and in the experimental cells it was 17.2 ± 4.4 snails per quadrat. This initial stocking density had no effect on the results. These mean densities represent the initial 100%, of which the later samples are expressed as percentages, which enable easier comparisons among the various experiments that differed in their initial densities. All statistics were, however, carried out on the density data.

In the control cells (Fig. 1a, fish absent), there was no change in snail density during the first week. From day 7 until day 19, the snail density increased to a maximum of 181%. From day 19 to day 34, density decreased to 21% and remained broadly stable at this level until day 55. After day 55, density increased to 82% on the last day.

In the treatment cells (Fig. 1a, fish present), the snail density decreased to 87% during the first week. From day 7 until day 12, density increased to 106%. From then until day 34, density decreased to 21% and remained broadly stable at this level until day 55. After day 55, density increased to 82% on the last day.

In the control cells (Fig. 1a, fish absent), there was no change in snail density during the first week. From day 7 until day 19, the snail density increased to a maximum of 181%. From day 19 to day 34, density decreased to 21% and remained broadly stable at this level until day 55. After day 55, density increased to 82% on the last day.

In the treatment cells (Fig. 1a, fish present), the snail density decreased to 87% during the first week. From day 7 until day 12, density increased to 106%. From then until day 34, density decreased to 21% and remained at this level until day 55. After day 55, density decreased to 15% on the last day.

On the first sampling day, before the fish were introduced, there was no difference in snail density in the treatment and control cells (t test, df = 19, P = 0.785). On the other sampling days, density in the
control and experimental cells were significantly different (repeated-measures ANOVA, df = 22, P < 0.001).

Though this experiment was originally intended to consist of only treatment versus control (no fish), the sudden death of four fish in the middle of the experiment caused us to differentiate between "full treatment" (6 cells with one fish throughout the experiment), "partial treatment" (4 cells in which the fish lived until day 28 and then died, so the cells remained without fish), and "control" (10 cells without fish throughout the experiment). The fish died during an exceptionally hot summer week, in which the usually stable water level dropped by 35 cm and an exceptionally low oxygen level was recorded (0.5 O_2 mg/liter, as compared to the usual value of 3.4 mg/liter at sunrise).

In the control cells, the most noticeable event was the crash of the snail population (Fig. 1a). It started after day 20 and by day 30 the numbers were down from a peak of 29.8 ± 9.2 snails per quadrat to 3.8 ± 3.2. Eventually the numbers slowly recovered and reached 13.5 ± 1.7 by day 75. We are not aware of any external environmental factor that could have caused this crash (a similar one occurred in the summer before, also in the boulder experiment, see below). It may perhaps be that _P. acuta_ in Israel undergoes several density cycles throughout the summer, as part of its natural population dynamics.

Before the fish were placed into the experiment, there were no differences in snail density among the three treatments (one-way ANOVA, df = 19, P = 0.53). Later, snail density in the full-treatment cells differed from that in the control cells throughout the experiment (repeated-measures ANOVA, df = 22, P < 0.001). The partial-treatment cells differed from the control cells, from the beginning of the experiment until day 19; from day 28 until the end of the experiment they did not differ (except for the last day). Further, the partial-treatment cells did not differ from the full-treatment cells from the beginning of the experiment until day 19; then they differed from day 28 until the end of the experiment. Thus, when a fish was present in a cell of the partial-treatment, this cell "behaved" like a cell of the full-treatment; from the moment the cells remained without fish, it "behaved" like the controls (Fig. 1b).

Though all cells had the same water surface, their depths differed from 0.7 to 2.1 m. During most weeks of the experiment, there was no significant correlation between cell depth and snail density (Spearman correlation, P = 0.09). Whereas 18 cells were in the center of the pond, the 2 cells at the ends of the pond each had an additional wall of 11 m. There was no significant difference between the control cell at the end of the pond and the 9 control cells in the center of the pond (except on day 7; t test, df = 19, P < 0.001). There was no significant difference between the partial-treatment cell at the end of the pond and the three partial-treatment cells in the center of the pond (except on day 41; t test, df = 19, P = 0.015).

Fish predation where snails can shelter. Initial snail density in pond A was 45.0 ± 12.4 snails per quadrat (54.6 ± 24.4 in the control cells, 48.3 ± 18.9 in the experimental cells); in pond B it was 25.9 ± 4.7 snails per quadrat (28.5 ± 10.1 in the control cells, 24.1 ± 12.7 in the experimental cells); see Figs. 2–4. We cannot explain why snail density in pond A was almost double that of pond B, just 1 week after they were seeded with the same number of snails (this difference continued throughout the experiment; repeated-measures ANOVA, df = 14, P < 0.001). Because of this difference in initial density, we describe the results from the two ponds separately (Fig. 4).
The values of initial mean densities represent the initial 100%, of which the later samples are expressed as percentages. In pond A, there was no significant difference in snail densities in the control and experimental cells on the first day of the experiment (t test, df = 7, P = 0.445). In all the next samples, there was a significant difference between the control and the experimental cells (repeated-measures ANOVA, df = 28, P < 0.001). In the control cells (Fig. 2a, fish absent), the snail density at first decreased to 39.5% on day 23. It then stabilized (19–39%) until day 33, increased to a maximum of 80% by day 50, and finally decreased to 12%. In the experimental cells (Fig. 2a, fish present), the density fluctuations paralleled those of the control, but were lower. Initially the density decreased to 3% by day 16 and then it stabilized at about 2–9% until day 33. From this point it increased to 31% and decreased from day 50 to 2%.

It may perhaps be argued that the number of control cells should have been higher. However, as virtually nothing is known concerning variation in snail predation by *M. piceus*, we preferred to allocate more cells to the treatment than to the control.

**Melanoides Experiments**

**Satiation at different temperatures.** Fish of 30–100 g crushed snails of up to 19 mm shell height. The maximum weight of snails consumed was 25 g (about 200 snails). At 19°C, the fish consumed 18.6 ± 6.7 g per day (~124 snails). At 25°C, they consumed 16.7 ± 7.6 g per day (~111 snails), but this difference in consumption rates at different temperatures was not significant (t test, df = 19, P = 0.14).

There was a difference among fish in the weight (=number) of snails consumed (t test, df = 19, P < 0.001). At 19°C, a correlation was found between fish weight and weight of snails consumed per day (Spearman correlation, r = 0.088, P = 0.02); at 25°C, this correlation was not significant (r = 0.55, P = 0.125).

**Predation of snails placed within the substratum.** When the snails were placed upon the glass bottom of the aquarium, predation averaged 63.1 ± 4.1 snails per day. When buried 0.5 cm into the sand, predation averaged 54.6 ± 3.8 snails per day. When the snails were buried 2 cm deep, predation averaged 52.5 ± 3.8 snails per day. However, these three treatments were not different in the number of snails consumed (Kruskal–Wallis, df = 29, P = 0.116). Also, there was no correlation between fish weight and percentage of snails consumed in the three treatments (Spearman correlation: no sand, r = 0.53, P = 0.2; 0.5 cm in sand, r = 0.43, P = 0.3; 2 cm in sand, r = 0.42, P = 0.4). When buried 2 cm into the sand, a low but significant correlation was found between the serial number of the experiment (i.e., time) and the percentage of snails consumed (Spearman correlation, r = 0.314, P = 0.013). This may perhaps indicate some inclination of the fish to learn and thereby to improve, with time, their search for food within the substratum. In the no-sand and 0.5-cm sand experiments, no such correlation was found.
This present research investigated predation efficiency of the black carp. Shelton et al. (1995) found that in small fish of this species (150–280 mm total length), maximum size of consumed snails is determined by gape size. In our satiation experiments, the fish reached 210 mm total length, and maximum size of the snails that these fish consumed was 19 mm shell height. We observed that fish would take in bigger snails that these fish consumed was 19 mm shell height. This suggests that fish may not be able to eat snails that are bigger than their gape if they have a hard shell. The snail-crushing ability of small M. piceus is considerable, but not unlimited.

In our experiments, fish of 30–50 g that fed upon Physella consumed the equivalent of 22–55% of their body weight per day, and fish of 30–100 g that fed upon Melanoides consumed 15–56%. Both these values are higher than those of Shelton et al. (1995), 1–6 or 8–13%, depending on the conditions of the experiment. Shelton et al. (1995) experimented with several snail species (Physa, Helisoma, Bellamya, Melanoides, Lanistes, Lymnaea, Bulinus, and Biomphalaria). They do not present their results for each species separately and therefore we cannot compare their data with ours.

In our feeding experiments, the predation rates varied considerably between individual fish, but we did not find any significant correlation between fish weight and weight of the snails consumed. Shelton et al. (1995) commented that snail consumption is correlated negatively with fish size, but did not offer any statistical analysis on this matter.

In experimental cells where the fish died, the snail population recovered rapidly and reached densities similar to those in the controls during a short period of time. This rapid recovery of the population suggests that for efficient biological control of the snails, continued presence of the fish is required. It is noteworthy that without shelter, in the controls, the snail population peaked at 181% and in the experimental cells at only 79% of the initial density. Under shelter-providing conditions, in the controls the population peaked at 80% and in the treatment only at 20%. It is this ability to decrease pest densities at population peaks that represents the efficiency of M. piceus as a biological control agent.

Some aquatic snails respond behaviorally to cues from nearby predators by increasing growth rates and reducing reproduction, until they reach a refuge size (Crowl, 1990; Crowl and Covich, 1990). Further, in the presence of predators, small individuals tend to crawl above the waterline more than large individuals, presumably because they are more vulnerable to predation (Alexander and Covich, 1991; Covich et al., 1994). It could perhaps be argued that since the barriers between the fish and the no-fish treatments were permeable in our experiment, some response to predator odor would have occurred even in the control. However, if this were indeed the case, one would expect results in the treatment and control to be similar. The considerable differences between the fish and the no-fish treatments suggests that whatever sheltering that may have occurred in response to the presence of M. piceus was not relevant to the overall efficiency of snail consumption.

Similarly, it could perhaps be argued that since the barriers between the fish and the no-fish treatments were snail permeable in our shelter experiment, the snails could migrate from the treatment (fish-containing) cells to the control cells. This would explain the density increase in the controls once the fish were released into the neighboring cells. If this were so, then one would expect that in the no-shelter experiment, where the net was not snail permeable, the snail density in the controls would not increase. However, in the no-shelter experiment, the density in the controls increased by 181%

Further, if this were so, and if in the shelter experiment snails from treatment cells could migrate directionally toward the control cells, then one would expect the population decrease in the treatment cells closest to the control cells to be more rapid than that in the more distant cells. This was not so. The treatment cells were side by side and therefore the snail between two treatment cells could not know that there was a place to the control cells to be more rapid than that in the no-fish experiment. This was not so. The treatment cells were side by side and therefore the snail between two treatment cells could not know that there was a place of safety.

Two basic methods are currently in use for biological control of snails. One is by competitive displacement by snails of another species (McCullough, 1981; Pointier and Guyard, 1992; Pointier, 1993; Pointier et al., 1993). One disadvantage of this method is that the displacing snail may itself become a pest, since it may be infested with parasites. Indeed, M. tuberculata in Israel hosts heterophyid trematodes, especially Centrocestus sp., that parasitize fish (Paperna, 1995).

Another basic method to control pest snails is by use of predators that decrease snail density until a low-level balance is reached between predator and prey populations. Experiments have been carried out with snails, leeches, insects, and crabs as predators (Jobin et al., 1977; Kesler and Munns, 1989; Roberts and Kuris, 1990; Hofkin et al., 1991; Moser and Willis, 1994). However, best results have been attained with fish.

Many fish species that are diet generalists may have a significant impact on snail densities under certain conditions. Generalists that may also consume snails and their eggs include Serranochromis sp., Macropodus opercularis (Linnaeus, 1758), Cyprinus carpio (Linnaeus, 1758), Gambusia affinis (Baird and Girard,
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1854), Tilapia rendalli (Boulenger, 1896), and Sargochromis codringtoni (Boulenger, 1908)—(De Bont and De Bont, 1952; Stein and Kitchell, 1975; Graber et al., 1981; Acra et al., 1986; Consoli et al., 1991; Chimbari et al., 1997). Their efficiency as biological control agents of pest snails is doubtful (Berg, 1964, 1973). Fish that are molluscivores may seem to have a more promising potential to become successful biological control agents of pest snails. However, in the actual habitats where snail pests occur, they too may fail, because of specific environmental conditions (Slootweg et al., 1994). In reservoirs of western Kenya, the molluscivorous cichlid Astatorechromis alluaudi (Pellegrin, 1904) was introduced to control the snail Biomphalaria pfeifferi (Krauss, 1848). Snail densities were indeed reduced during the first 15 years (McMahon et al., 1977), but not in later years (Kat and Kibberenge, 1990), because in habitats with plentiful soft food (as found in reservoirs), A. alluaudi will not develop the strong pharyngeal teeth required for shell-crushing; it will switch to a generalist diet, and therefore in these environments, it will not be effective (Kat and Kibberenge, 1990; Brown, 1994). The molluscivorous lungfish Protopterus annectens (Owen, 1839) seems more promising as a biological control agent of snails. In the laboratory, it prefers snails to mosquito larvae or other types of food and may consume 200 snails per day. In a concrete pond, it decreased snail density by 90% within 2 weeks, and this low density was maintained for 4 months (Daffalla et al., 1985).

This present study suggests that (1) small M. piceus have a good potential to be an efficient biological control agent of Melanoïdes and Physella, even when snails are buried in sand; (2) large M. piceus have a good potential to be biological control agents of Physella, even in reservoirs and ponds consisting of concrete or boulders; and (3) continued presence of M. piceus is necessary to efficiently control snail populations.

This research is only a first step in investigating the suitability of M. piceus as a biological control agent. One further step should be to extend parasitological studies; centrencestisias was discovered in the first fingerling generation of M. piceus in Mexico (Amaya-Huerta and Almeyda-Artigas, 1994). Another step should be to ascertain that M. piceus cannot multiply and cause ecological damage to neighboring natural ecosystems. Thus, M. piceus was introduced into the state of Mississippi, first (accidentally) in the 1970s, later (intentionally) in the 1980s, and again in 1999, this time to control populations of the snails Planorbula trivolvus (Say, 1817) and P. subcrenata (Carpenter, 1857), which are intermediate hosts to the digenetic trematode Bolbophorus confusus (Krause, 1914). There is serious concern that M. piceus may reproduce and attain large populations (as have other introduced Asian carp species) and thereby endanger many of Mississippi's endemic species (Cummings, 2000). Fortunately, for its reproduction, M. piceus seems to require rising water from torrential rains at temperatures of 26–36°C (Etvuschenko et al., 1994). Such specific environmental conditions do not occur in Israel.

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