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Feeding behavior of black carp *Mylopharyngodon piceus* (Pisces: Cyprinidae) on fry of other fish species and trematode transmitting snail species

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HIGHLIGHTS

- Black carp consumes snails in both aquaria and under semi-field conditions.
- It eats fry of other species whether snails are provided in aquaria as food or not.
- Under semi-field conditions, black carp does not prey on fry.

GRAPHICAL ABSTRACT

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ABSTRACT

Fish raised in aquaculture ponds may get infected with fishborne zoonotic trematodes (FZT) during the nursing stage. Freshwater snails serve as intermediate hosts for FZT and we wanted to explore the possibility of controlling snails by stocking nursery ponds with a few juvenile specimens of the mollusc-eating fish, black carp (*Mylopharyngodon piceus*). Obviously, the risk that black carp might also prey on the juvenile fishes in nursery ponds should first be assessed. Laboratory trials showed that all size classes of juvenile black carp consumed fry of common carp (*Cyprinus carpio*) even when offered snails as food; the odds of survival of fry from tanks with medium sized and large black carp was 5.6% and 39.9%, respectively of that of fry in tanks with small sized black carp. Since the large black carp also consumed fewer snails than medium sized fish, we believe that large specimens were stressed in the experimental aquaria. Under semi-field conditions, presence of the black carp had no effect on survival of fry of *Oreochromis niloticus* and *C. carpio* both in the absence and presence of snails as alternative food. The black carp consumed most snails offered with the exception of some of the large snails. We conclude that under field conditions, predation by black carp on fish fry is minimal and field trials in nursery ponds are warranted. Due to the risks that black carp pose to native imperiled snails and other molluscs, trials should be restricted to ponds within the fish's native or existing range.

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1. Introduction

Fish-borne zoonotic trematodes (FZT) constitute an important problem in fish culture in many parts of Vietnam (Thien et al., 2007; Thu et al., 2007; Phan et al., 2010a). Not only do these parasites retard fish growth, but they pose potential health risks to local people (De et al., 2003; Dung et al., 2007; Olsen et al., 2006); these health risks also reduce marketability of fish commercially produced for export.

Studies (Thien et al., 2009; Phan et al., 2010b) on FZT transmission in Vietnam have shown that fishes raised in aquaculture may become infected already in nursing ponds; sale of these fish to upland grow-out facilitates the spread of FZTs. Hence, production of FZT-free juvenile fishes should be a priority. The black carp, *Mylopharyngodon piceus* (Richardson, 1846) is large cyprinid fish, with a maximum reported size of about 2 m and a weight of 70 kg (Nico et al., 2005; Nico and Jelks, 2011). The native range of black carp includes most major Pacific Ocean drainages of eastern Asia from Amur River Basin of Russia to the West-Pearl River Basin of China (Nico et al., 2005) and Northern Vietnam (Yen, 1983). The black carp feeds mainly on molluscs, both gastropods and bivalves (Nico et al., 2005) and has been used for snail control in various parts of the World (Ben-Ami and Heller, 2001; Ledford and Kelly, 2006; Nico et al., 2005; Venable et al., 2000). Polyculture operations which include black carp would be an economical method to reduce FZT, by eliminating the intermediate gastropod hosts. There are concerns, however, that the black carp, which would have to be considerably larger than the fish fry in order for it to be able to consume intermediate host snails, would also prey on the juvenile fishes. Venable et al. (2000) showed that juvenile black carp fed on fry of other species; and also other carp species may display the same behavior as small juveniles, for example grass carp, *Ctenopharyngodon idella* (Valenciennes, 1984) (Singh et al., 1976). Larval and small *M. piceus* feed mostly on zooplankton and aquatic insects and later shifts to a diet of molluscs as they grow and their pharyngeal teeth become more developed (Nico et al., 2005). Once fixed teeth are formed in juvenile fish at 3.3–33 cm TL, the fish can feed on snails (Liu et al., 1990; Nico et al., 2005).

The purpose of this study was to determine consumption of common carp (*Cyprinus carpio* Linnaeus, 1758) and "tilapia" *Oreochromis niloticus* (Linnaeus, 1758)) by various sizes, and densities of black carp in the presence/absence of the different quantities of snails as a natural food source for the black carp.

2. Materials and methods

2.1. Fishes

Specimens of juvenile black carp were purchased from farmers in Tu Son, Bach Ninh. The fishes were grouped into three size classes based on weight and fork length, small (100–350 g; 210–270 mm), medium (351–750 g; 300–350 mm) and large (751–1250 g; 400–480 mm). Prior to the trials, 40 specimens of three size classes were kept separately in three cement tanks (1.2 × 3 × 1.4 m W × L × H) for at least for one week before they were used in experiments. Specimens used in trials and those remaining after the trials were released into nearby grow-out ponds. Water level in these holding tanks was kept at 1.2 m, and constantly aerated and re-circulated through a filter system at a rate of 0.5 m^3/h. The filter contained a net (mesh size 0.5 × 0.5 mm), and water passed through a layer of foam rubber and a layer of sand before returned to the tank. Snails were supplied as food for the black carp and were collected daily from rice fields and small canals in the neighborhood. The most common species used were the thiarid species, *Melanoides tuberculata* (Müller, 1774), *Thiara scabra* (Müller, 1774) and *Tarebia granifera* (Lamarck, 1822), and the viviparid species, *Angulyagra polyzonata* (Frauenfeld, 1862) and *Sinotaia aeruginosa* (Reeve, 1863). The number of snails provided, their size ranges and total wet weight was recorded. Snails of different species and sizes were supplied as food for the black carp at a rate of 10% of their body weight per day; this amount is close to satiation level (Nico et al., 2005). Twenty-four hours prior to experiments, black carp specimens were measured and released in the experimental arena (glass tank or enclosure) and no food was provided during this period.

Fry of common carp, *C. carpio*, or tilapia, *O. niloticus*, were supplied by the Research Institute for Aquaculture No. 1 (Aquatic Counseling Design and Technology Transfer Centre). Food for fry was rice bran and supplied once/day during the experiments. Surviving fry were transferred to ponds. Experiments were conducted following the EU Directive 2010/63/EU for animal experiments http://ec.europa.eu./environment/chemicals/lab_animals/legislation_en.htm which provides guidelines to ensure optimal conditions for the individual fish.

2.2. Laboratory experiments

Seven glass tanks (0.4 × 0.6 × 0.45 m W × L × H) were prepared for experiments with well-water to a level of 0.4 m (96 L) and constant aeration (Fig. 1a). One specimen of black carp was introduced

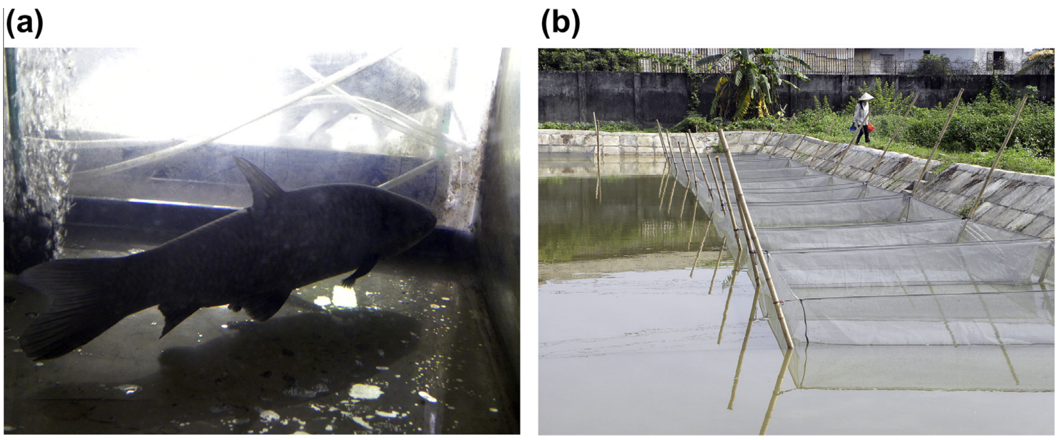

Fig. 1. Experimental setup. (a) Aquaria, (b) pond.

in each of 6 tanks. The next day, 50 specimens of common carp fry were introduced alone or together with 25 snail specimens of *M. tuberculata* and 25 specimens of *A. polyzonata*. After another 24 h the black carp was removed and survival of fish fry and snails was recorded. A black carp specimen was used in only one trial. Six tanks with black carp were set on each occasion and one tank without black carp served as control for survival of fish fry. Experiments were repeated 5 times.

2.3. Pond experiments

An experimental pond at the Research Institute for Aquaculture No. 1, Tu Son, Bac Ninh was used for the experiment. The size of pond is 20 × 30 m (W × L) with the depth throughout is 1.6 m and the sloping sides were concrete-lined (Fig. 1b). Water depth was always maintained at 1.1–1.3 m in the pond. The trials were conducted during April – September of 2010 and 2011. During this period, the average temperature and rainfall are the highest during the year i.e., 28.9 °C; 1400–1600 mm (Vietnam Center for Meterology Forecast, 2010). The parameter of water quality was checked 5 times during the experiment using a product of TOA company, model: WQC-22A, i.e., water temperature at 30 cm depth varied between 25.2 and 33.4 °C; pH between 7.8 and 8.3; salinity was 0.01%; turbidity between 40 and 65 mg/l and conductivity was about 100 μS/cm. The measurements were conducted in the morning from 8:30 to 10:00 h.

In case black carp specimens died during the experiment, they were immediately replaced by another specimen of similar size from the holding tanks.

2.3.1. Effect of black carp size

Twelve enclosures (3 × 3 × 1.4 m W × L × H) were established in the pond. The enclosures were made of nylon net with a mesh size of 1 × 1 mm at the bottom and of 2 × 2 mm around the sides to permit water circulation. The enclosures were fixed to a bamboo pole in each corner and in each corner of the enclosure a brick was placed to ensure that the enclosure would always be extended. Water level was maintained at 0.8 m inside the enclosures. Enclosures were assigned to treatments randomly in a factorial design with 4 classes of black carp (none, small, medium and large; 2 specimens of one size class in one enclosure) and three feeding regimens (no food provided, low feeding and high feeding). For low feeding at total of 50 specimens of thiarid snails and 20 specimens of viviparid snails were provided every second day and for high feeding regimen, the double amount of snails was added. The low feeding regime corresponded to 11.3–14.7%, 2.9–4.7% and 1.1–1.7% of the total fish weight per day for small, medium and large black carp, respectively; similar values for the high feeding regime were 21.0–27.4%, 6.3–9.6% and 2.5–3.7%, respectively. A total of 500 fry specimens were released in each enclosure 24 h after releasing the black carp. The trial was repeated 4 times, twice using fry of common carp and twice using tilapia fry. The first trial using fry of common carp was continued for 4 weeks, while the other 3 trials (1 with fry of common carp and 2 with tilapia fry) were stopped after 2 weeks. At the end of the experiment, fry and live snails were collected and counted. The black carp specimens were weighed at termination.

2.3.2. Effect of black carp density

A total of 20 enclosures (1 × 2 × 1.4 m W × L × H) was prepared and established as described in the previous experiment. Enclosures were divided into 5 equal groups and assignment to one of 4 treatments within each was done at random. Zero, one, two or four specimens of black carp (weight: 300–500 g, fork length: 250–310 mm) were introduced. All black carp specimens used in this experiment were caught from one grow-out pond. The day before the experiment was started, a total of 100 g of thiarid snails and 2000 g of viviparid snails and 100 fry of *O. niloticus* was introduced in each enclosure. The experiment was terminated after 2 weeks.

2.4. Statistical analysis

Survival of fry or snails was compared between treatments using logistic regression (Hilbe, 2009) with data arranged in binomial form using a generalized linear model with a logit link function; snail species was entered as a predictor as well; mean survival and standard errors were predicted from these models. All standard errors were adjusted for clustering within container (glass tank or enclosure). Variation in average fish weight among trials was done using one-way analysis of variance for each fish class separately. Regression analysis was used to compare fish weight before and after the trial (stage) after adjusting for trial, fish size class and the interaction between fish size class and stage. All analysis was done in STATA 12 (StataCorp LP, USA) and differences with probability value below 0.05 were considered significant.

3. Results

3.1. Laboratory trials

None of fish fry of common carp died in the control tanks except on one occasion presumably because the air supply failed. Hence the control tanks were excluded from the analysis and reduction in survival of fry were assumed to be due to black carp. All sizes of black carp were observed to consume fish fry, whether snails were available or not (Fig. 2). The interaction between black carp size class and presence of snails was not significant and presence of snails was not a significant predictor of fry survival when adjusting for black carp size class. The odds of survival of fry from tanks with medium sized black carp was 5.6% ($p < 0.001$) of that of fry in tanks with small sized black carp and odds of survival of fry from tanks with large sized black carp was 39.9% ($p < 0.05$) of that of fry in tanks with small sized black carp. The overall survival of fry in tanks with small black carp was 48.2%. The difference in fry survival in tanks with large and medium sized black carp was statistically significant ($p < 0.05$). Medium sized black carp also fed more on snails, both *M. tuberculata* and *A. polyzonata*, than small and large black carp ($p < 0.001$ for each comparison) (Fig. 3).

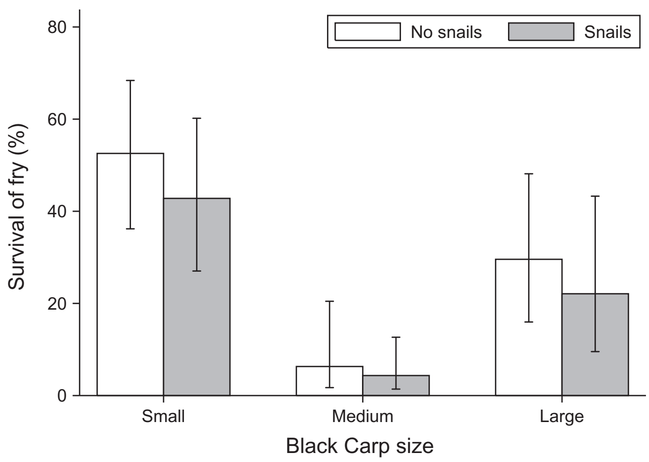

Fig. 2. Survival among common carp fry kept in aquaria with 1 specimen of juvenile black carp of different size and presence or absence of snails as alternative food. Error bars show 95% CL of the predicted means and are adjusted for clustering within tanks.

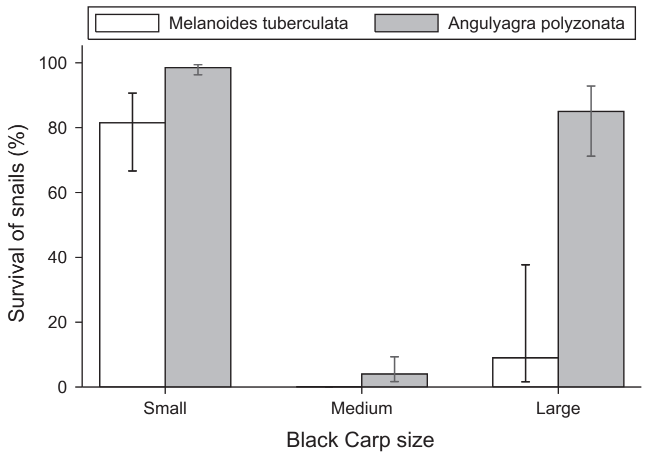

Fig. 3. Survival among snails (25 specimens of each species in each tank) kept in aquaria with 1 specimen of juvenile back carp of different size. Error bars show 95% CL of the predicted means and are adjusted for clustering within tanks.

3.2. Effect of black carp size in semi-field trials

During the first trial, 3 black carp specimens (1 medium sized and 2 large sized) died and therefore we reduced the duration to 14 days in subsequent trials. The sizes (length and weight) of black carp introduced did vary somewhat among trials; thus average size varied significantly among the repeat trials for the medium ($p < 0.01$) and large ($p < 0.01$) size classes. This was mainly due to availability of fish. On average, there was no significant change in weight of the black carp during these experiments and the interaction between fish size class and stage was not significant. The common carp fry used in trial 1 ranged from 18 to 19 mm in total length and at termination from 27 to 75 mm, while tilapia fry ranged from 11 to 14 mm at the beginning and at termination 2 weeks later 24 to 46 mm.

Fry survival differed significantly among trials ($p < 0.001$) and the lowest was in trial 1 because of the longer duration and high temperatures during the trial (Fig. 4); overall survival of fry in enclosures without black carp was 19.5%, 62.3%, 84.4% and 86.1% in trial 1–4, respectively. There was, however, a significant interaction between trial and black carp size ($p < 0.001$) which is mainly due to a lower survival of fry in the presence of large sized black carp in trial 1; i.e., in this trial there was no effect of small and medium sized black carp, while the odds of survival in the presence of large black carp was only 0.55 ($p < 0.001$) as compared to enclosures without fish. The odds ratio for fry survival in the presence of snails was 1.25 ($p < 0.05$) as compared to enclosures without snails and this holds also for enclosures without black carp.

Snail consumption by black carp size classes is shown by snail family in Fig. 5 and overall in Table 1. Medium and large sized black carp consumed almost all snails fed to them (Table 1). Average weight of snails that survived was higher than that of snails originally introduced indicating that smaller snails were more likely to be consumed (Table 2). Snail consumption differed among trials and with black carp size class. The odds of survival did not differ between the two thiarid snail species and they were therefore combined. The odds of survival of *A. polyzonata* was 5.43 ($p < 0.001$) times greater than that of the thiarid snails and for *S. aeruginosa* it was 8.67 ($p < 0.01$). The difference between these two viviparid species was not significant.

Consumption of snails in terms of weight of snails differed among size classes of fish used, i.e., small, medium and large fish consumed on average 0.61, 0.94 and 0.99 of the weight of snails fed to them. The daily consumption in terms snail weight as percentage of black carp weight was 6.74 (0.1–23.5%), 4.70 (0.01–23.5%) and 1.64 (0.02–3.20%) for small, medium, and large fish respectively.

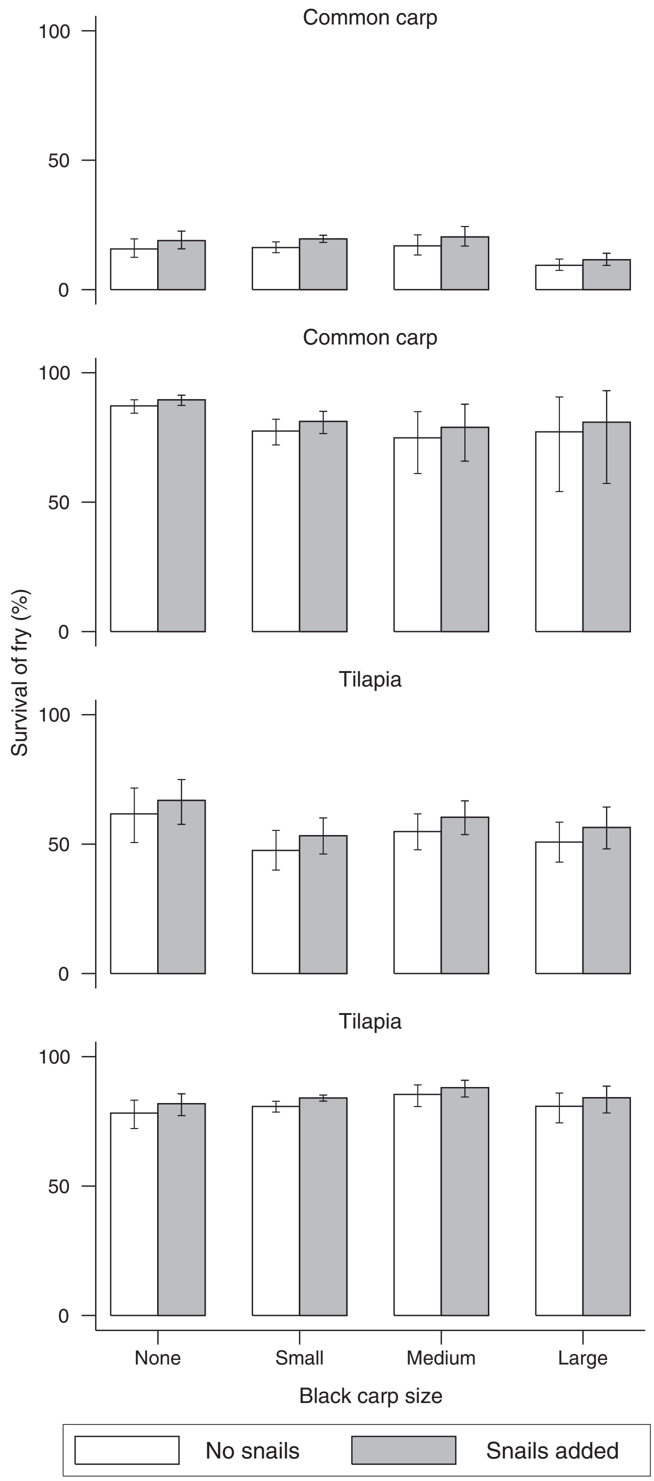

Fig. 4. Survival among fry kept in enclosures with no or 2 juvenile black carp specimens of different size and presence or absence of snails as alternative food. Error bars show 95% CL of the predicted means and are adjusted for clustering within enclosures.

3.3. Effect of black carp density in semi-field trials

The black carp used in this trial ranged in weight from 300 to 500 g and fork length 250–310 mm and only 1 specimen died

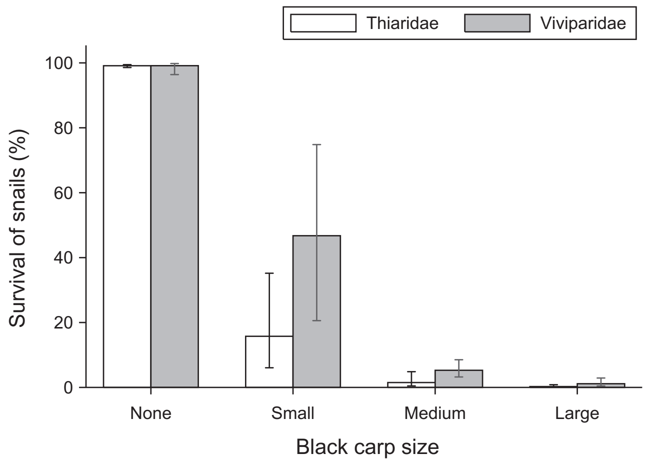

Fig. 5. Survival among snails kept in enclosures with no or 2 juvenile black carp specimens of different sizes. Error bars show 95% CL of the predicted means and are adjusted for clustering within enclosures.

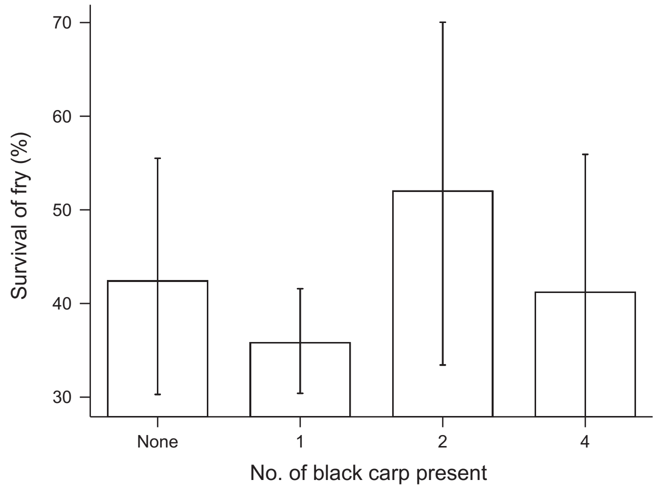

Fig. 6. Survival among fries kept in enclosures with no or 1, 2 or 4 juvenile black carp specimens present. Error bars show 95% CL of the predicted means and are adjusted for clustering within enclosures.

Table 1
Overall survival (%) among snails added to the enclosures.

	Thiaridae		Viviparidae	
	Melanoides tuberculata	*Thiara scabra*	*Angulyagra polyzonata*	*Sinotoia aeruginosa*
App. no of snails per group	5170	70	1940	160
None	99.4	86.3	100.0	85.6
Small sized black carp	15.8	11.9	45.9	57.0
Medium sized black carp	1.5	1.4	4.0	20.0
Large sized black carp	0.3	0.0	0.6	7.9

Table 2
Mean weight (g) of snails introduced and of those surviving.

Size of black carp	Thiaridae		Viviparidae	
	Introduced	Surviving	Introduced	Surviving
None	0.41	0.59	2.07	2.05
Small	0.40	0.73	2.13	2.12
Medium	0.40	1.58	2.09	2.33
Large	0.41	1.66	2.11	3.02

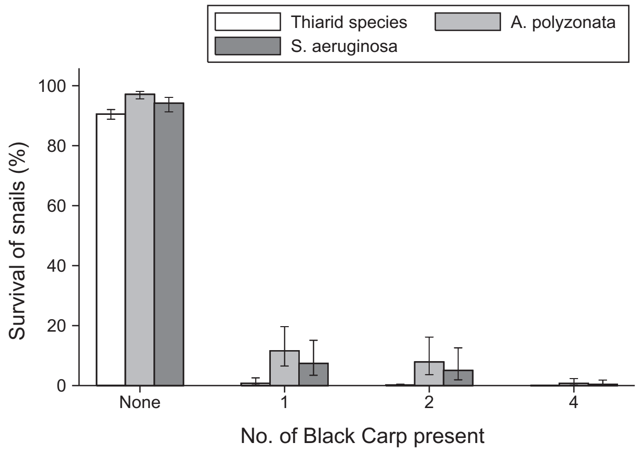

Fig. 7. Survival among snails kept in enclosures with no or 1, 2 or 4 juvenile black carp specimens present. Error bars show 95% CL of the predicted means and are adjusted for clustering within enclosures.

during the experiment. Fish weight at termination of the trial was on average 29.7 g less than at the beginning of the trial. Fry size (*O. niloticus*) ranged from 11 to 14 mm at start and from 24 to 36 mm at termination.

Survival of fry in enclosures without black carp was 42.4% and the impact of black carp density on fry survival was not statistical significant (Fig. 6). Snail consumption by the various densities of black carp is shown in Fig. 7. The number of *T. scabra* and *T. granifera* were few compared to *M. tuberculata*, so they were combined into one group (Thiaridae). The viviparid snails had a higher chance of survival than the thiarid snails, i.e., odds ratio 5.42 ($p < 0.001$) for *A. polyzonata* and 3.00 for *S. aeruginosa*; the difference between the two viviparid species was also significant ($p < 0.001$). These comparisons, however, should be interpreted with caution as we do not have detailed size distribution for the two species. The reduction of snails increased with the number of black carp in enclosures. On average, the proportion of the total weight of snails consumed was 0.87, 0.91 and 0.99 in the treatments with 1, 2, and 4 specimens of black carp, respectively. These proportions for thiarid snails alone were 0.97, 0.99 and 1.00, while for viviparid snails they were 0.87, 0.91 and 0.99. The daily consumption averaged over the entire period as snail weight as percentage of black carp weight was 38.0 (31.8–46.8%), 18.7 (14.8–21.8%) and 13.4 (12.1–15.4%) for treatments with 1, 2 and 4 specimens of black carp respectively.

4. Discussion

These experiments demonstrate that even young black carp primarily feed on snails, although they readily consume fry of other species under laboratory conditions, they have little impact on survival of fry in enclosures even though they were fed snails in short supply or not fed snails at all. Thus in these enclosures, the black carp tend to forage at the bottom where the snails are. It seemed, however, that large black carp did reduce fry survival in one trial, but that trial was conducted during a time when temperatures were high and the black carp had a short supply of food (snails) for 4 weeks. Thus, it cannot be ruled out that black carp might start feeding on fry/fingerlings if snail population density in nursery ponds gets very low. During the period of experiments, the water temperature at 30 cm depth could reach 33.4 °C in the morning. Each fish species has different abilities to respond to severe weather conditions. Indeed, the tolerance of *O. niloticus* to high temperature and other extreme values of physical factors were better than that of common carp *C. carpio* (Zambrano et al., 2006). This at least could be part of the explanation for differences in fry survival among the trials.

In the laboratory, the impact of black carp on fry survival was obvious. Aquaria were small and no refuges were available for the fry. Medium sized black carp had the most pronounced effect, but it is possible than the large fish were stressed in these aquaria; the fact that they also consumed fewer snails than the medium sized snails would indicate this. Even the movements of the black carp could harm the fry. Thus we did observe a few dead (0–5%) fry specimens in the aquaria. Presence of snails does not protect fry from predation in the aquaria; in fact it seemed that black carp fed more intensively on fry in the presence of snails.

Our results suggest that black carp more readily consume thiarid snails especially for the smaller sized fish but this primarily is related their smaller size than viviparid snails. The size of snails that the black carp can handle depends on its gape size and the force required crushing a shell (Shelton et al., 1995; Nico et al., 2005). Thus Evers et al. (2011) mentioned that the prey selection by snail-feeding cichlid, *Trematocranus placodon* (Regan, 1922), depends on the crush value index, which was expressed as the ratio between benefit (weight of snail tissue) and the cost (crush resistance of snail shell). Further studies comparing crush resistance between these snail species should be done.

When we terminated the field trials, we found large amounts of crushed snail shells in the enclosure, but we also found some large almost intact shells. These shells often had a hole in the body whorl but were not crushed. Black carp may have attempted to crush these shells without success, but still inflicted fatal damage to the snail. The preference for thiarid snails may just be related to these being generally smaller than the viviparid snails and the difference in shell shape may also make them easier to crush. Otherwise, comparisons between snail species cannot really be made from these studies because we do not have detailed size distributions of snails added.

The black carp were fed snails at a rate that was below their potential consumption. Data summarized by Nico et al. (2005) suggest that large black carp (4 years old) consumed 1.4–1.8 kg of molluscs per day. Shelton et al. (1995) found that black carp between 100 and 200 g (21–27 cm total length) were satiated at a daily consumption rate of 1.5–13% of their body weight, while fish around 300 g (about 32 cm) were satiated at 1–6% of body weight. In our studies we have, however, observed considerably higher rate of daily consumption, especially in the trial on effect of black carp density where all snails given were added from the beginning. Over the entire period we observed values as high as 38.0% of body weight, but since all groups almost exhausted the snails supplied, figures from the initial period must have been higher.

If thiarid snails really are more vulnerable to black carp predation this would be extremely important because they are the intermediate hosts for many of the intestinal trematodes, i.e., *Centrocestus formosanus* (Scholz and Salgado-Maldonado, 2000), *Echinostoma* spp. (Dung et al., 2010), *Haplorchis* spp. and *Stellanchasmus falcatus* (Le et al., 1990).

Black carp has been introduced into different regions and more than 30 countries in the World (Nico et al., 2005; Nico and Jelks, 2011) for a variety of reasons. Some countries, e.g., Japan, Taiwan and South Africa introduced it for culture or polyculture with the intent to produce fish for human consumption (Nico et al., 2005). Other countries want to create a new commercial fishery or for use as a biological agent to reduce mollusc populations e.g., United States, Israel, or for research and experimental purposes, or/and accidental/unintentional introductions (Nico et al., 2005). The major concern about using black carp outside its natural distribution is its potential spread to large river, where it may establish populations, with potential severe effect on native mollusc populations. That is why in some states of United States, aquaculture laws require that black carp used for snail control are triploids, to render them sterile, and thus minimize the potential for the fish to escape and create self-sustaining populations (Nico and Jelks, 2011).

We conclude that small black carp can be applied to control snail populations in nursery ponds within its native range probably without seriously affecting survival of fry of species kept in these ponds, but this should obviously be evaluated carefully also under real-life conditions before this control approach is widely advocated.

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References

Ben-Ami, F., Heller, J., 2001. Biological control of aquatic pest snails by the black carp *Mylopharyngodon piceus*. Biol. Control 22, 131–138.

De, N.V., Murrell, K.D., Cong, L.D., Cam, P.D., Chau, L.V., Toan, N.D., Dalsgaard, A., 2003. The food-borne trematodes zoonoses of Vietnam. Southeast Asian J. Trop. Med. Public Health 34, 12–34.

Dung, D.T., De, N.V., Waikagul, J., Dalsgaard, A., Chai, J.Y., Sohn, W.M., Murrell, K.D., 2007. Fishborne zoonotic intestinal trematodes, Vietnam. Emerg. Infect. Dis. 13, 1828–1833.

Dung, B.T., Madsen, H., The, D.T., 2010. Distribution of freshwater snails in family-based VAC ponds and associated waterbodies with special reference to intermediate hosts of fish-borne zoonotic trematodes in Nam Dinh province, Vietnam. Acta Tropica 116, 15–23.

Evers, B.N., Madsen, H., Stauffer, J.R., 2011. Crush-resistance of soft-sediment gastropods of Lake Malawi: implications for prey selection by molluscivorous fishes. J. Freshwater Ecol. 26, 85–90.

Hilbe, J.M., 2009. Logistic Regression Models. Chapman & Hall/CRC, pp. 1–656.

Le, N.T., The, D.T., Ngai, D.D., 1990. Examination of freshwater snails as intermediate host of trematodes, causing trematodosis in poultry. Research Work Collection on Ecology and Biological Resoures, pp. 318–323. (in Vietnameses with English summary).

Ledford, J.J., Kelly, A.M., 2006. A comparison of black carp, redear sunfish, and blue catfish as biological controls of snail populations. North Am. J. Aquacult. 68, 339–347.

Liu, H., Li, H., Zhai, B., Liu, W., 1990. Post-larval development of the masticating apparatus of black carp *Mylopharyngodon piceus* (Richardson). Acta Hydrobiol. Sin. 14, 310–320 (in Chinese with English summary).

Nico, L.G., Jelks H.L., 2011. The black carp in North America: an update. In: American Fisheries Society Symposium 74, pp. 89–104.

Nico, L.G., Williams, J.D., Jelks, H.L., 2005. Black Carp Biological Synopsis and Risk Assessment of an Introduced Fish. American Fisheries Society Special Publication 32, Bethesda, Maryland, pp. 1–337.

Olsen, A., Thuan, L.K., Murrell, K.D., Dalsgaard, A., Johansen, M.V., De, N.V., 2006. Cross-sectional parasitological survey for helminth infections among fish farmers in Nghe an province, Vietnam. Acta Tropica 100, 199–204.

Phan, T.V., Ersbøll, A.K., Te, B.Q., Hang, N.T., Murrell, K.D., Dalsgaard, A., 2010a. Fish-borne zoonotic trematodes in cultured and wild-caught freshwater fish from the Red river delta, Vietnam. Vector Borne Zoonotic Dis. 10, 861–866.

Phan, T.V., Ersbøll, A.K., Thanh, N.T., Khue, V.N., Ha, T.N., Murrell, K.D., Dalsgaard, A., 2010b. Freshwater aquaculture nurseries and infection of fish with zoonotic trematodes, Vietnam. Emerg. Infect. Dis. 16, 1905–1909.

Scholz, T., Salgado-Maldonado, G., 2000. The introduction and dispersal of *Centrocestus formosanus* (Nishigori, 1924) (Digenea: Heterophyidae) in Mexico: a review. Am. Midland Nat. 143, 185–200.

Shelton, W., Soliman, A., Rothbard, S., 1995. Experimental observations on feeding biology of black carp (*Mylopharyngodon piceus*). Israeli J. Aquacult. 47, 59–67.

Singh, S.B., Dey, R.K., Reddy, P.V.G.K., 1976. Some additional notes on the piscivorous habits of the grass carp (*Ctenopharyngodon idella*). Aquaculture 9, 195–198.

Thien, P.C., Dalsgaard, A., Thanh, B.N., Olsen, A., Murrell, K.D., 2007. Prevalence of fishborne zoonotic parasites in important cultured fish species in the Mekong delta, Vietnam. Parasitol. Res. 101, 1277–1284.

Thien, P.C., Dalsgaard, A., Nhan, N.T., Olsen, A., Murrell, K.D., 2009. Prevalence of zoonotic trematode parasites in fish fry and juveniles in fish farms of the Mekong Delta, Vietnam. Aquaculture 295, 1–5.

Thu, N.D., Dalsgaard, A., Loan, L.T.T., Murrell, K.D., 2007. Survey for zoonotic liver and intestinal trematode metacercariae in cultured and wild fish in An Giang province, Vietnam. Korean J. Parasitol. 45, 45–54.

Venable, D.L., Gaude, A.P., Klerks, P.L., 2000. Control of the trematode *Bolbophorus confusus* in channel catfish *Ictalurus punctatus* ponds using salinity manipulation and polyculture with black carp *Mylopharyngodon piceus*. J. World Aquacult. Soc. 31, 158–166.

Vietnam Center for Meterology Forecast, 2010. Annual Summary Report of Climate (by Vietnamese), pp. 1–24. Available at: (<http://www.hymetdata.gov.vn/?u=con&cid=1037&t=1>).

Yen, M.D., 1983. Commercial Freshwater Fishes in Vietnam. Science and Technical Publishing House, Hanoi, pp. 1–124 (by Vietnamese).

Zambrano, L., Enrique, M.M., Menezes, N., Peterson, A.T., 2006. Invasive potential of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in American freshwater systems. Can. J. Fish. Aquat. Sci. 63, 1903–1910.