NON-LETHAL EFFECTS OF CRAYFISH AND SUNFISH PREDATORS ON ZEBRA MUSSEL (*DREISSENA POLYMORPHA*) BEHAVIOR VIA CHEMICAL CUES

HEIDI LAPPI
Clarion University, Clarion, PA 16214 USA

MENTOR SCIENTIST: DR. DAVID L. STRAYER
Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. Predation can have important non-lethal effects on prey traits, mediated by chemical cues. These cues often induce a modification in antipredator behavior within prey individuals. In this study, I tested predator effects on the exotic species, *Dreissena polymorpha* (zebra mussel) using chemical cues from *Orconectes rusticus* (rusty crayfish) and *Lepomis gibbosus* (pumpkinseed sunfish) that were fed zebra mussels. Daily, I recorded the position of the mussels and categorized them as being exposed to predation or in a refuge. This lab experiment showed a significant effect of predator treatments on mussel habitat use. The same experiment was run again, without the predator being fed zebra mussels. The trial showed no significant effect of chemical cues from the predators alone on refuge use. These results suggest that zebra mussels might adjust microhabitat use in the presence of predators, and that this shift is based on a chemical cue released from the eaten mussels.

INTRODUCTION

Predation can have important non-lethal effects that are communicated through chemical cues. These cues often modify antipredator behavior within the prey (Sih 1987, Lima and Dill 1990, Lima 1998). Chemical cue recognition may have a important function in aquatic food webs, as the trait shifts induced by predators can affect species interactions (Turner et al. 2000.)

The introduction of exotic species threatens many regions (Lodge 1993), including the Hudson. One possible methods of controlling the abundance of exotic species is using predators to reduce the population size. Zebra mussels invaded North America in the 1980's via a ballast water introduction in the Great Lakes, and have subsequently spread across much of North America. Dense populations of zebra mussels kill native unionids (Gillis and Mackie 1994, Schloessor and Nalepa 1994). As zebra mussels populations increase, refuge sites decrease, leaving many native species vulnerable to local extinction.

Zebra mussels are unlike many freshwater invertebrates because they have veligers (larvae) that live for 1-9 weeks and feed on phytoplankton (Martel et al. 1995). Juvenile mussels then attach with byssal threads to various solid substrates. They are mobile, especially in the first few weeks after settlement. A zebra mussel's movement is similar to that of snails, another freshwater mollusk. Its shell opens, releasing its foot, allowing a slow forward movement. Once it attaches its byssal threads, its attachment is semi-permanent, with some ability to break off and make further movements. This suggests that juveniles are capable of making decisions of where to colonize. One factor in deciding where to colonize is the threat of predation. Dreissenids cannot burrow into the sediment for protection but live attached and exposed on rocky substrata (Thorp, Delong and Casper 1998). Zebra mussels must therefore seek protected sites to attach and avoid predation.

Zebra mussels have many predators in North American waters such as crayfish (Stewart et al 1998), and sunfish (Magoulick and Lewis 2002, Molloy et al 1997). Biological communities are structured strongly by predator-prey interactions (Polis and Strong 1996). However, changes in zebra mussel behavior due to predation are not well studied. Therefore little is known about the interaction between fish predators and zebra mussels (Magoulick and Lewis 2002).

Hausam (1995) found that zebra mussels, along with many other mollusks in the Hudson River, settled on the bottom of hard substrates instead of on the top. She studied possible causes for this pattern. Hausam concluded that it was due to either wave or current action, avoidance to light, reproduction patterns, or refuge from predation. The Hudson River contains many predators to the zebra mussels, including blue crabs, crayfish, sturgeons, and sunfish, which may be one factor in their habitat selection.

I measured refuge use of zebra mussels in response to two different types of predators, benthic (crayfish) and pelagic (sunfish). Crayfish and fish chemical cues were used to determine if the refuge preference of the zebra mussels in the laboratory depended on whether predators were present or not.

METHODS

The study was executed in the greenhouse's cold storage shelter at the Institute of Ecosystem Studies, NY in June-July, 2003, under controlled light and temperature. Zebra mussels <15mm long were collected from the Hudson River in Tivoli, NY. The predators of the study consisted of seven rusty crayfish, *Orconectes rusticus*, collected from the Webatuck Creek in Amenia and two pumpkinseed sunfish (*Lepomis gibbosus*) purchased from a local hatchery.

The two predators were kept in separate 189.3- L aerated tubs filled with non-treated well water. Each morning at 0900 hours, the two predator tubs were fed 10 prey zebra mussels. The experiments were done in sixteen 18.9-L aerated aquaria filled with well water. Placed in the center of each aquarium was one 10cm x 10cm red ceramic tile, with two 2.5cm x 2.5cm white tiles glued in each corner that provided a protected crevice (Fig. 1). Four aquaria were given the crayfish treatment, four were given the fish treatment, four were given both fish and crayfish treatment, and four were controls and received no treatment. Treatments were assigned randomly to the aquaria. The treatment consisted of 3.79 L of the water being removed daily and replaced with the same amount of its designated treatment. The treatment was started for three consecutive days before zebra mussels were added. Ten zebra mussels were then added to each aquarium. Each tank of zebra mussels were fed 0.94 L of an algae culture made from *Spirolina* flakes daily. This trial ran for seven days.

The specific location of each mussel was recorded daily, as (1) on the top of the tile in the open or (2) in a crevice, (3) attached under the tile in a crevice or (4) in the open, (5) under the cover of the tile, not attached to it, (6) on the side of the tank, or (7) in the open of the tank not under or on the tile. Refuge was defined as going into a crevice between tiles, under the cover of the tile, or high in the water column attached to the side of the tank. These particular sites are considered protected from both predators, which allows us to analyze and compare predators with one control.

Light affects zebra mussels' orientation. It is thought that they might avoid sunlight either because of harmful effects of sunlight, or it serves as an indication of being exposed, primarily to predation. (Marsden and Lansky 2000) Light was eliminated from this project as much as possible using the dark cold storage shelter room and using light only when needed. The tanks were covered with black tarp to filter out light.

I ran a second trial to determine what cue (predator or prey) the mussels reacted to. Fish and crayfish were not fed zebra mussel prey, but instead fed shrimp pellets. In doing this, any cue given off by the eaten zebra mussel was eliminated. This trial strictly tested the effect of cues or smells given off by the crayfish and pumpkinseed themselves. The trial was set up exactly the same as the first trial and lasted one week with zebra mussels collected from the same location.

An ANOVA was used to test for differences in refuge use overtime. These numbers were calculated by averaging the percent of mussels recorded in the refuge over the seven-day period trial.

RESULTS

Trial One: Effects of Predator Cues

Introduction of cue-water into tanks had a significant effect on refuge use (Fig. 2). The treatment that contained both crayfish and fish cues had the highest percentage of mussel refuge use with 33%. Mussels responded to predators by moving into crevices between the small tiles located on the large tile in each tank. The fish treatment had the weakest effect with 22% refuge use of the mussels, while the crayfish had a slightly stronger effect of 29% (Fig. 2). Treatment effects appeared to become more pronounced over time as more zebra mussels went into refuge (Fig. 3).

Trial Two: Effects of Predators

Chemical cues from predators not fed zebra mussels had no significant effect on refuge use (Fig. 4). At the end of this trial, most of the mussels remained in the open, unprotected from predation. This indicates that the sole smell of pumpkinseed fish and crayfish had no effect on mussel's refuge use.

DISCUSSION

Zebra mussel's refuge use is influenced by predation via chemical cues. During the first trial where zebra mussels were fed to the predators, the mussels showed moved into different refuge sites such as under the tile, into a crevice, or high up the water column where they would escape crayfish predation. The treatment effect became more prominent over time with more mussels going into refuge at the end of the trial.

The second trial was run with no prey zebra mussels. This eliminated any chemical cue that may have been given off by the prey mussels. This trial showed no significant effect of predator smells. This indicates that some interaction between the predator and the prey released a cue that triggered refuge use by the mussels. Aquatic organisms in particular have to communicate through chemical cues. These cues often induce an antipredator behavior within individuals of a population (Sih 1987, Lima and Dill 1990, Lima 1998). Zebra mussels, like other mollusks, may release a chemical cue warning other mussels to go into refuge. Snails (*Physa gyrina*) responded to chemical cues by significantly increasing refuge use (McCarthy and Dickey 2002). Zebra mussels may have a similar chemical-cue system.

A further study could be to break down the cue even more and see if crushed prey mussels alone with no predator cue have any effect on refuge use. This would strengthen the idea that the mussels are releasing a chemical cue that triggers refuge and recognize the predator that is mixed in with that cue.

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LITERATURE CITED

Gillis, P.L. and Mackie, G.L. 1994. Impact of the zebra mussel, *Dreissena polymorpha*, on population of Unionidae (Bivalva) in Lake St. Clair. Canadian Journal of Zoology 72:1260-1271.

Hausam, S. 1995. Settlement and colonization preferences of mollusks in the Hudson River. Occasional Publication of the Institute of Ecosystem Studies 10: 79-86.

Lima, S.L. 1998. Non-lethal effects in the ecology of predator-prey interactions. BioScience 48: 25-34.

Lima, S.L., and Dill, L.M. 1990. Behavioural decisions made under the risk of predation: a review and prospectus. Canadian Journal Zoology 68: 619-640.

Lodge, D. M. 1993. Biological invasions: lessons for ecology. Trends in Ecology and Evolution 8: 133- 137.

Marsden, J. E., and Lansky, D.M. 2000. Substrate selection by setting zebra mussels, *Dreissena polymorpha*, relative to material, texture, orientation and sunlight. Canadian Journal of Zoology 78:787-793.

Martel, A., Hynes, T.M., and Buckland-Nicks, J. 1995. Prodissoconch morphology, planktonic shell growth, and size at metamorphosis in *Dreissena polymorpha*. Canadian Journal of Zoology 73:1835-1844.

Magoulick, D.A., and Lewis, L.C. 2002. Predation on exotic zebra mussels by native fishes: effects on predator and prey. Freshwater Biology 47: 1908-1918.

McCarthy, T.M., and Dickey, B.F. 2002 Chemically mediated effects of injured prey on behavior of both prey and predators. Behaviour 139: 585-602.

Molloy, D.P., A.Y. Karatayev, L.E. Burlakova, D.P.Kurandina, and F. Laruelle. 1997. Natural enemies of zebra mussels: predators, parasites, and ecological competitors. Reviews in Fisheries Science 5:27-97.

Polis, G.A., and Strong, D.R. 1996. Food web complexity and community dynamics. American Naturalist 147:813-846.

Schloesser, D.W., and Nalepa, T.F. 1994. Dramatic decline of unionid bivalves in offshore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha*. Canadian Journal of Fisheries and Aquatic Science 51: 2234-2242.

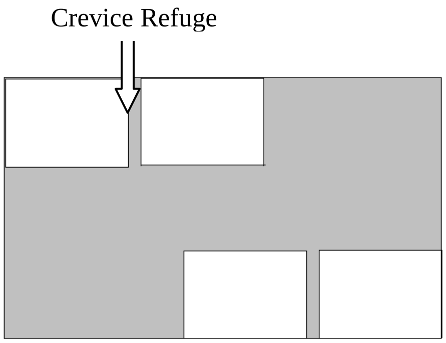
Sih, A. 1987. Predator and prey lifestyles: an evolutionary and ecological overview-in: Pages 203-224 in Predation: Direct and indirect impacts on aquatic communities (W.C. Kerfoot and A. Sih eds.) University Press of New England, Hanover.

Stewart, T. W., Miner, J.G., and Lowe, R.L. 1998. An experimental analysis of crayfish (*Orconectes rusticus*) effects on a *Dreissena*- dominated benthic macroinvertebrate community in Western Lake Erie. Canadian Journal of Aquatic Science 55: 1043-1050.

Thorp. J.H., Delong, M.D., Casper A.F. 1998. *In situ* experiments on predatory regulation of a bivalve mollusk (*Dreissena polymorpha)* in the Mississippi and Ohio Rivers. Freshwater Biology 39: 649-661.

Turner, A.M., Bernot, R.J., and Boes, C.M. 2000. Chemical cues modify species interactions: the ecological consequences of predator avoidance by freshwater snails. Oikos 88:148-158.

APPENDIX



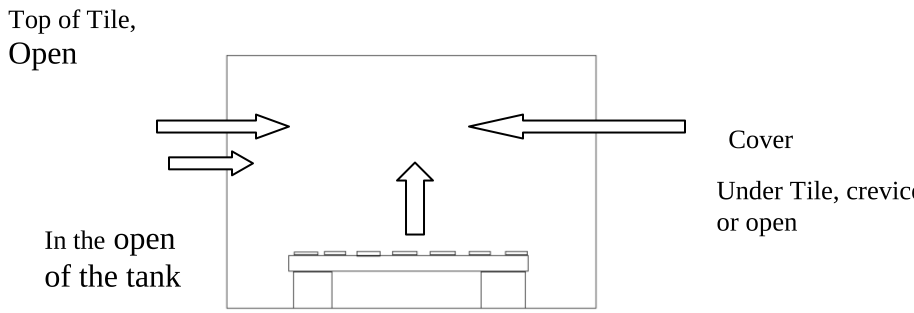


FIGURE 1. (Left) An aerial view of the tiles. The white squares represent smaller tiles that provide a crevice-like refuge. (Right) A side view of a tank.

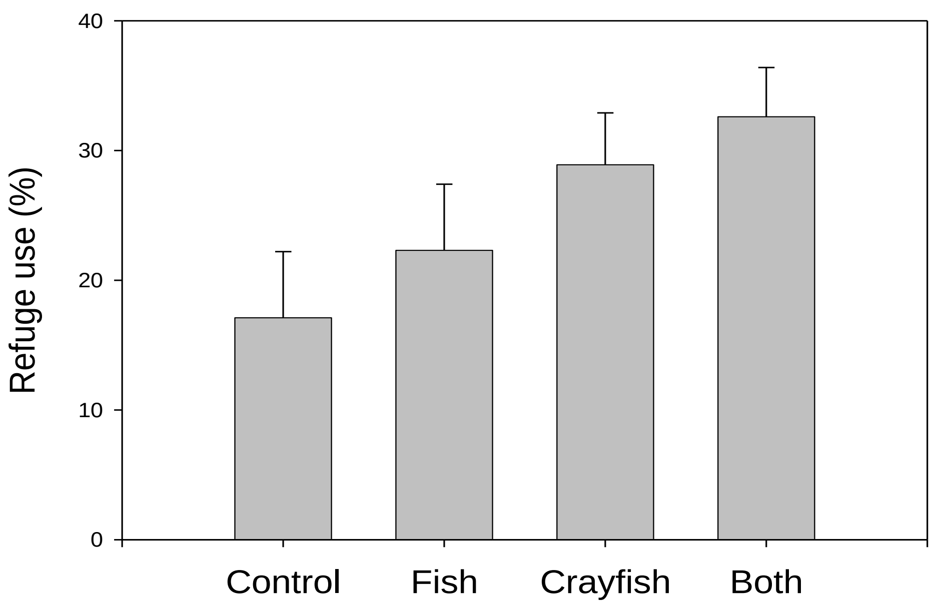


FIGURE 2. Average refuge use (mean + standard error) by zebra mussels of trial one over the whole trial. Refuge use differed across treatments (ANOVA, $p=0.047$)

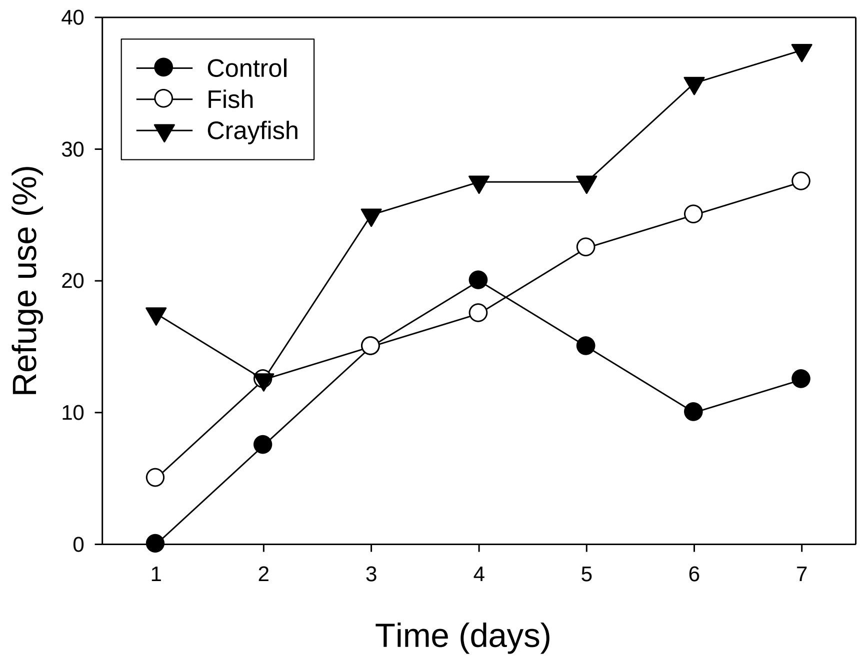


FIGURE 3. Time-course of refuge use by zebra mussels in trial one.

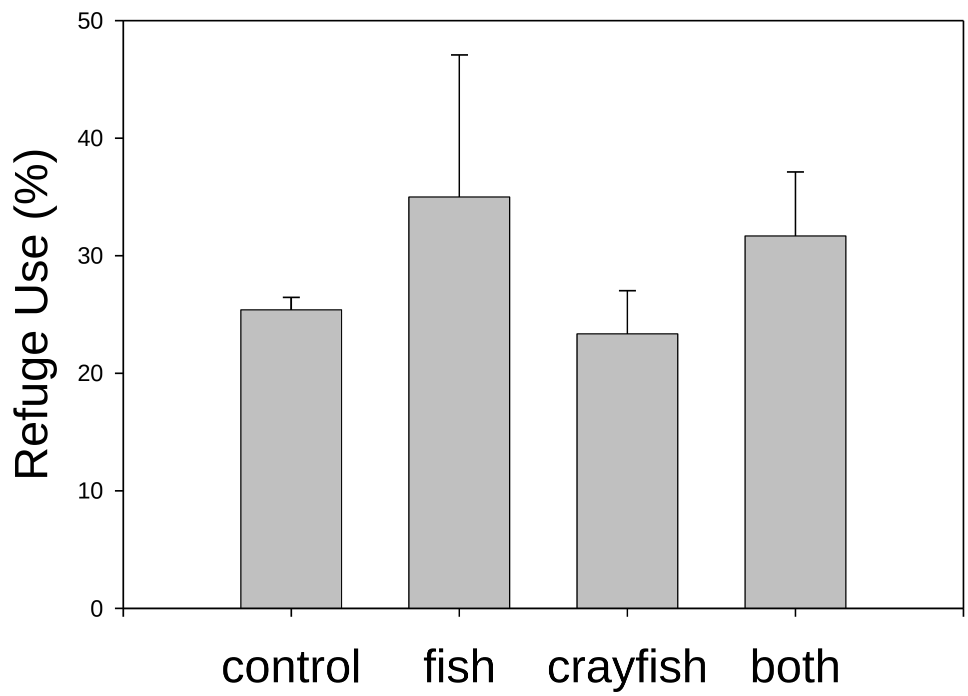


FIGURE 4. Average refuge use of trial two over whole trial. Refuge use did not differ significantly across treatments.