PENNSYLVANIA SEA GRANT FINAL REPORT (Bucknell)

Rusty Crayfish and Smallmouth Bass in the Susquehanna River: Who's Eating Whom?

Investigators

Brian P. Mangan, Ph.D., PI
Professor/Director
King's College
Environmental Program/ Susquehanna River Institute
133 N. River St.
Wilkes-Barre, PA 18711

Michael Bilger, M.S. Co-PI
Research Scientist
Susquehanna University
RK Mellon Freshwater Initiative
514 University Avenue
Selinsgrove, PA 17870

Sean P. Reese, M.S. Co-PI
Aquatic Biologist
Bucknell University
Susquehanna River Initiative
One Dent Drive
Lewisburg, PA 17837

Robert H. Michener, M.S. Co-PI
Laboratory Manager
Boston University
Stable Isotope Laboratory
5 Cummington Mall
Boston, MA 02215

Introduction: Anthropogenic introduction of alien species outside of their native geographic distributions can be one of the most enduring, and unchangeable effects humans can bring upon naturally occurring communities and ecosystems (Strayer and Malcom 2007). Historically, freshwater systems of North America have been especially susceptible to invasion by these alien species, with Pennsylvania being no exception (e.g. Kuhlmann and Hazelton 2007). One such invader, the rusty crayfish (*Orconectes rusticus*), which is native to the Ohio River drainage was first recorded in foreign freshwater systems across the northeastern United States as early as the 1960's (Kuhlmann and Hazelton 2007). Their dispersal was believed to be due to fishermen and bait-bucket releases. *O. rusticus* are discernibly larger, more combative, and able to withstand colder temperatures compared to the native congeners (Bobeldyk and Lamberti 2008). This higher fitness allows *O. rusticus* to significantly reduce the abundance of basal resources such as aquatic macrophytes and leaf material, prey on benthic invertebrates such as snails, and reduce the abundance and growth of other amphibians and fish (Twardochleb, Olden and Larson 2013). In many cases *O. rusticus* has completely outcompeted the native congeners for food and habitat (e.g. Bobeldyk and Lamberti 2008, Szela and Perry 2013). While the ecological effects of invasive crayfish may vary based on the species, *O. rusticus* invasions often reveal their largest negative effects on benthic invertebrate communities (Twardochleb, Olden and Larson 2013). In a long-term study done by Wilson et al. (2004) on an *O. rusticus* invasion of a temperate lake in Wisconsin, native crayfish were found to be almost entirely extirpated, macrophyte species richness was reduced up to 80%, and some snail communities had trouble sustaining their numbers. Aside from being a popular food choice for foraging crayfish freshwater gastropods serve as calcium sources, contribute to nutrient exchange processes, help maintain water quality, and clean substrates for other bottom-dwelling organisms in aquatic ecosystems. It is crucial when investigating effects of an invasive species on an ecosystem, to consider all of the effects that can span multiple levels of that ecosystem. Through experimentally determined predation rates by *O. rusticus* on different snail communities native to the Susquehanna River system and community and habitat surveys, our study sought to investigate the overall impact of the ongoing *O. rusticus* invasion, on multiple ecosystem levels.

Methodology: Experiments were conducted at the Bucknell Center for Sustainability and the Environment, Bucknell University. Field sites were selected in concurrence with sites from a previous study by Mangan, Savitski, and Fisher (2009), that had known crayfish populations and densities and were located at public boat launches on the Susquehanna River near Wilkes-Barre, Sunbury, Halifax, Halstead, Harding, and Tunkhannock, PA. Wire mesh crayfish traps as described by Mangan, Savitski, and Fisher (2009), were used to collect specimen for laboratory mesocosm experiments. Larger male crayfish were selected over smaller crayfish. *P. virginica L. carinata* and *P. acuta* were also collected at these boat launch sites along the Susquehanna River using visual snorkel searches, and collected at various depths. Crayfish traps were left overnight and baited with Purina® Friskies® cat food. Traps were then tied via metal wire to a stake driven into the ground to prevent the trap from getting carried away with the river current. Predation rates were determined through laboratory mesocosm experiments. Crayfish were held at ambient room temperature, starved for 48 hours prior to the experiment, and then put into a 10 gallon mesocosm (20” x 11” x 13”) with a mixed size class of 30 adult and/or juvenile snails. One crayfish was put into each mesocosm were it was filled with water until the crayfish was entirely submerged. A light coat of Vaseline® was spread across the glass walls of each mesocosm, above the water line (~1”), to prevent refuge for the snails. The snails were spread evenly throughout the mesocosm at the beginning of the 48 hours, and the experiments were monitored every few hours; trials were repeated for three snail species: *P. virginica*, *P. acuta*, and *L. carinata*. Daylight cycles were mimicked for the crayfish using artificial light to match natural timetables. The number of snails consumed was recorded after 24 hours, and again after 48 hours; the experiments were terminated after 48 hours. Each tank was kept at constant ambient room temperature, monitored by thermometer strips adhered to the outside of the mesocosms, and kept oxygenated with an air stone. Snails were collected from 6 boat launch sites along the Susquehanna River. Snails were collected at various depths using snorkel and visual searches. Snails were kept in 10-gallon tanks, analogous to the crayfish mesocosms, filled with water from the Susquehanna River with one aerator in each tank. The snails were separated into different tanks by species, and mollusk shells were placed into each tank to provide calcium for the maturing snails, assuming copulation between snails would occur. The snails were fed with Wardley® shrimp pellets and kale, and the water was kept oxygenated with a constantly running air stone. The water in each tank was filtered and replaced every few days, to ensure a clean environment for the snails.

At each boat launch site, six 1m^2 plots were arbitrarily chosen for each survey area. A 1m^2 PVC pipe was used to outline the chosen plot, and an exhaustive search for snails was run inside the 1m^2 PVC square. Because the plots varied in depth, wetsuits and snorkels were used for each survey, to ensure consistent visibility. Two shoreline timed-searches (~5min) were also conducted. The snails from each of the m^2 surveys and timed searches were placed into plastic jars with River water and both the number of alive snails as well as the number of dead snails were recorded. The snails were returned to their approximate plot location after being recorded. Habitat assessments were given for each plot, with percentages given for each of the following categories, totaling 100%: bedrock, boulder, cobble, gravel, woody debris, mud, fines, sand, and/or other. Species diversity indices and evenness values were calculated using a Shannon-Wiener equation and independent sample *t*-tests were performed to analyze predation rates.

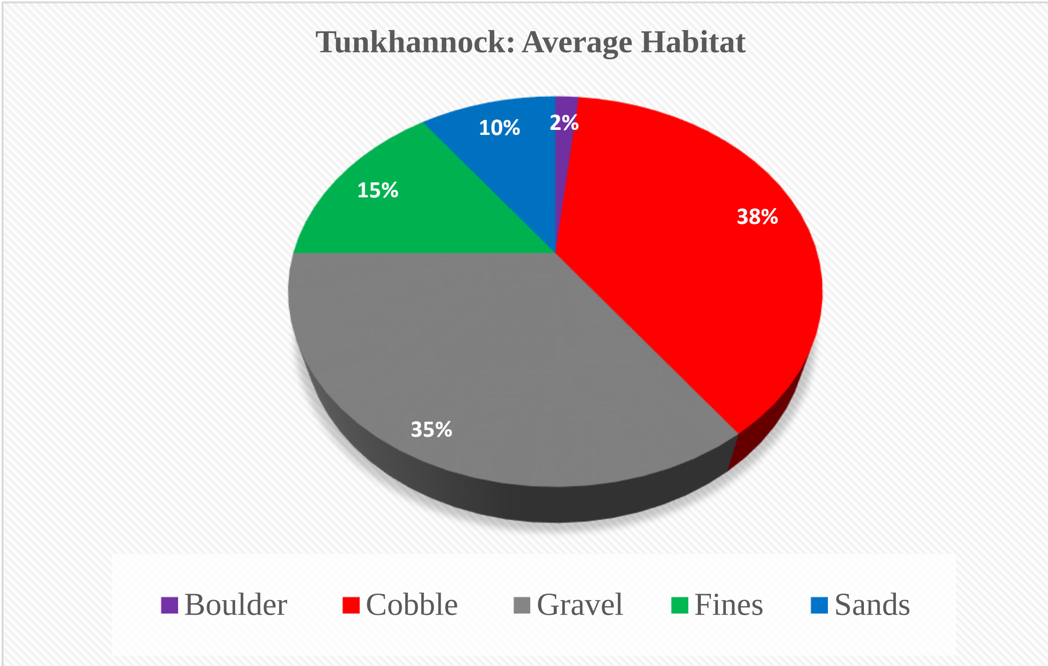
Results: *O. rusticus* exhibited significantly higher mean predation rates on *P. acuta* than did *O. obscurus* ($p = 0.011$). *O. rusticus* also exhibited significantly higher mean predation rates on *L. carinata* than did *O. obscurus* ($p = 0.002$). Although both *O. rusticus* and *O. obscurus* had extremely low mean predation rates on *P. virginica*, *O. obscurus* still exhibited higher mean predation rates on *P. virginica* than did *O. rusticus* ($p = 0.051$). Habitat assessment data showed *P. virginica* to be the most abundant species among snail communities, and *P. acuta* to be the least abundant. Habitat assessment data also showed snail species diversity and richness to be highest at Harding, dominated by cobble and gravel (Figure 1). Although the highest number of specimen collected was in Halifax, it was dominated by one single species (Table 1). Observations at the time of collection noted a much higher *O. rusticus* presence than at any other site. No snails were able to be collected at Halstead where the habitat was dominated by fines (Table 1). Researchers were unable to find any snails outside of our search areas as well. Our habitat observations are consistent with research documenting cobble substrates as favorites among benthic invertebrate species for refuge and habitat (Bobeldyk and Lamberti 2008). *O. rusticus* were found to have strong, negative effects on benthic invertebrates, specifically snails, which is consistent with prior research (Twardochleb and Larson 2013). Invertebrate (i.e. snails) abundance decreased with increases in *O. rusticus* abundance, a trend commonly observed in similar research (e.g. Wilson et al. 2004, Bobeldyk and Lamberti 2008). There was a conspicuous favoritism by *O. rusticus* for smaller-bodied, softer-shelled snails, evidenced by the high mean predation rates on *P. acuta* and *L. carinata* (Figure 2). Previous studies have shown drastic changes in these [smaller-sized] benthic invertebrate communities, so it is quite possible that the *P. acuta* and *L. carinata* populations could have difficulty recovering from an *O. rusticus* invasion (e.g. Twardochleb and Larson 2013, McCarthy et al. 2006). While direct consumption effects are obvious when studying invasive species, it is also important to consider the indirect effects that could cascade through the ecosystem of a river system such as the Susquehanna. A long-term study by Kuhlmann and Hazelton (2007) saw new crayfish species arise through the course of an invasion, along with previously documented species disappearing completely. Crayfish serve as consumers in the ecosystems they inhabit, but they also serve as agents of disturbance, where increases in their density, especially when nonnative, can have significant direct and indirect effects on many levels of the ecosystem.

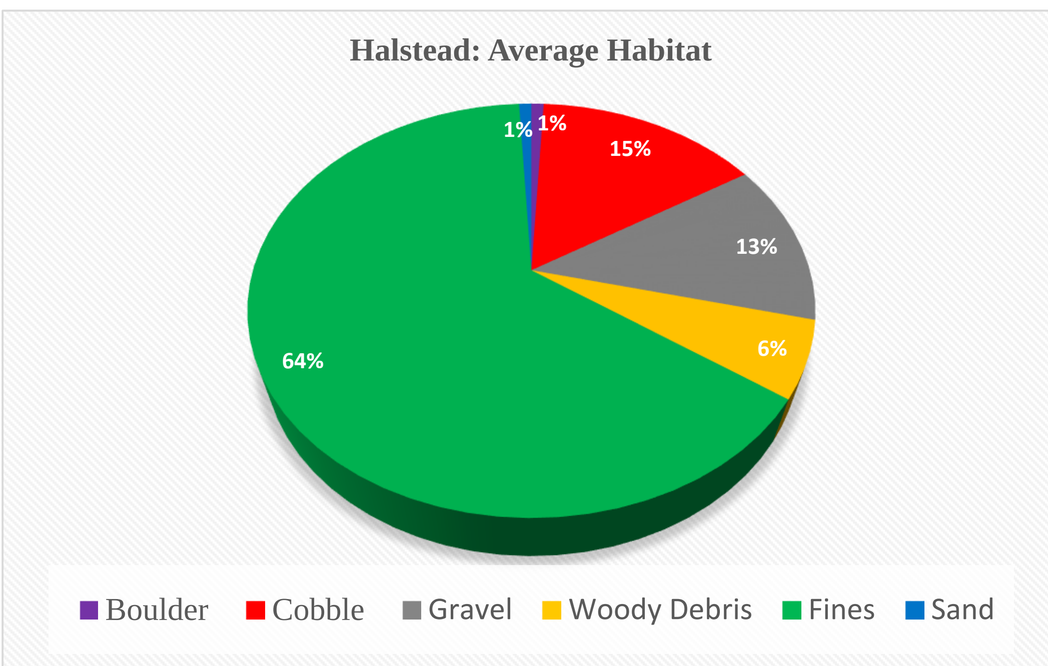
Conclusions: Our research suggests that an invasion in the Susquehanna watershed by *O. rusticus* has the potential to decrease species richness and diversity among native gastropods, and permanently reduce and alter their community structures. Such an invasion also has the possibility of completely extirpating other native crayfish species. While *O. rusticus* had higher predation rates on *P. acuta* and *L. carinata*, *O. obscurus* had higher predation rates on *P. virginica*. Thus, a possible extirpation of native crayfish could not only wipe out *O. obscurus*, but also diminish *P. acuta* and *L. carinata* populations, while permitting an expansion of *P. virginica* populations. While surveying some of our sites, *O. rusticus* populations were at such high densities that we could not go one step without kicking up/stepping on multiple crayfish. Previous research has shown *O. rusticus* achieving extremely high population densities (>19 individuals/m^2), which could have drastic effects for native congeners trying to flourish in the same domain (Kuhlmann and Hazelton 2007). As for the fate of native gastropods such as snails, the literature has consistently found *O. rusticus* densities to be higher and quicker to spread in cobble habitats, which, according to our surveys, are the most favored habitats for snails (Wilson et al. 2004). This shared preference for cobble habitat could result in disastrous effects for the snail communities residing there. Another potential effect of an *O. rusticus* invasion that is well-documented, although we did not get the chance to investigate such an impact, is the reduction in macrophyte abundance (Lodge and Lorman 1987.) This has the potential to hinder native gastropod communities even more as it is a major food source for them. We can only suspect the impacts of an *O. rusticus* invasion of the Susquehanna River to be accentuated over time if nothing is done to start reversing the effects. Through shifts in the littoral food web structure and energy flows, *O. rusticus* can induce changes on all levels of the ecosystem, and these impacts could be widespread along a longitudinal scale in large rivers and watersheds such as the Susquehanna.

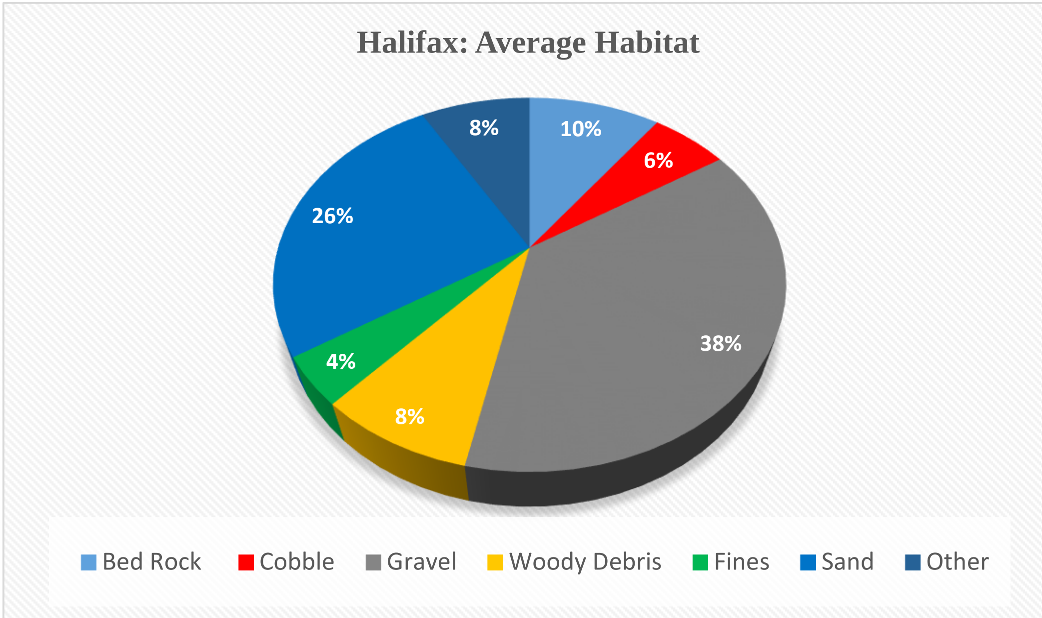
Tables/Graphs: Table 1: Species richness and diversity by site

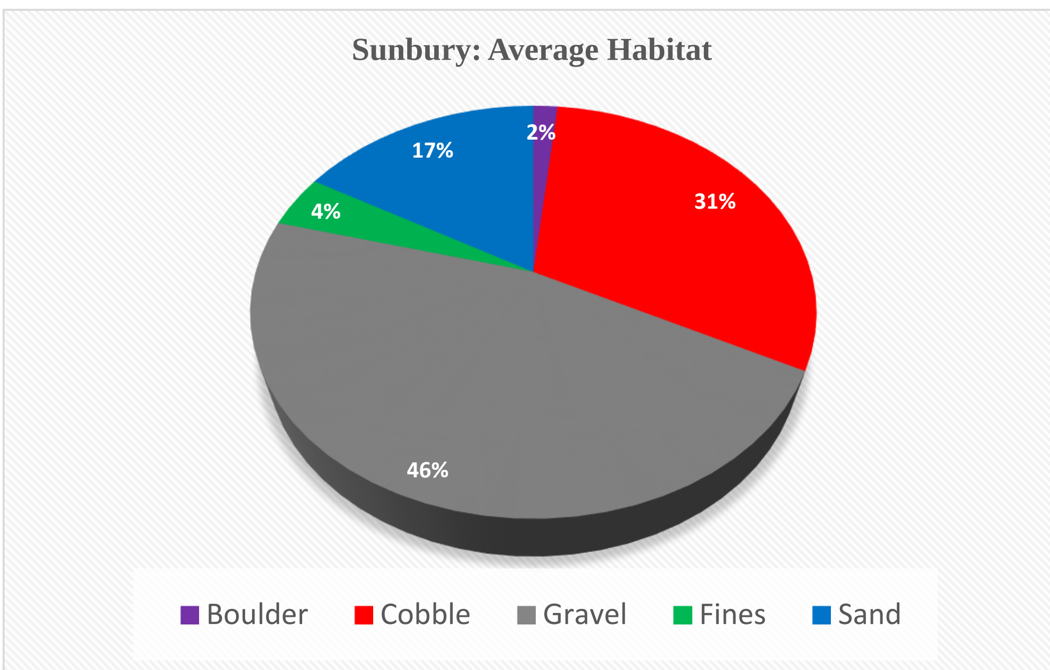
Site	Number of Specimens	Species Richness	Shannon-Wiener Diversity Index	Evenness
Halifax	326	1	0	0
Halstead	0	0	0	0
Harding	298	3	0.586	0.533
Sunbury	278	2	0.249	0.359
Tunkhannock	308	3	0.24	0.218
Wilkes-Barre	324	3	0.199	0.181

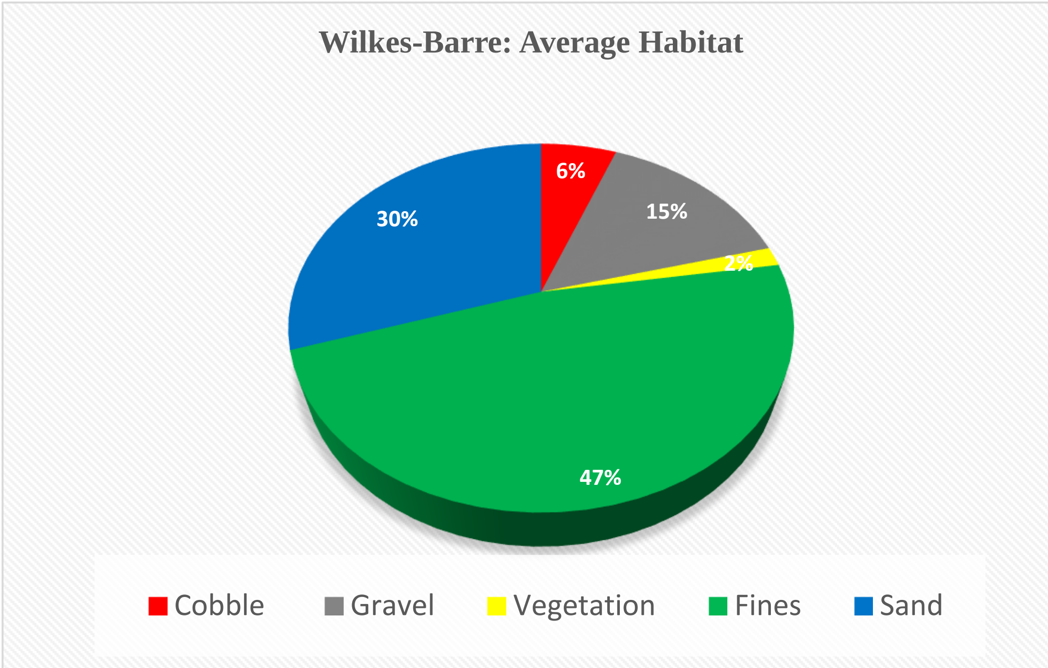
Figure 1. Average habitat for each site






Halifax: Average Habitat
8%
10%
6%
26%
38%
4%
8%
Bed Rock
Cobble
Gravel
Woody Debris
Fines
Sand
Other


Sunbury: Average Habitat
2%
17%
31%
4%
46%
Boulder
Cobble
Gravel
Fines
Sand


Wilkes-Barre: Average Habitat
6%
15%
2%
30%
47%
Cobble
Gravel
Vegetation
Fines
Sand

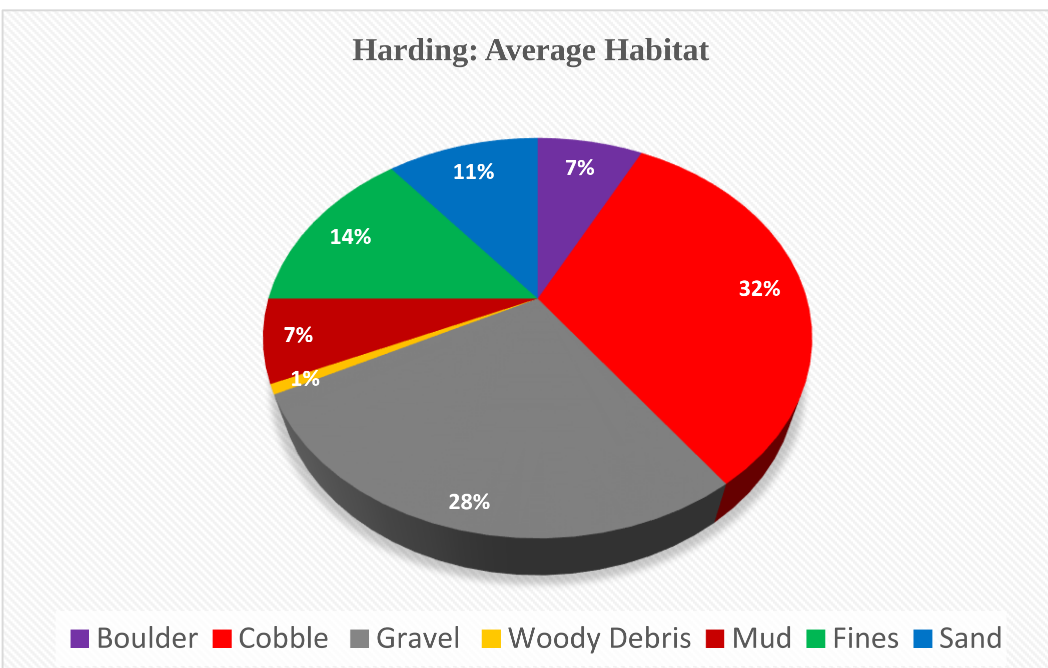
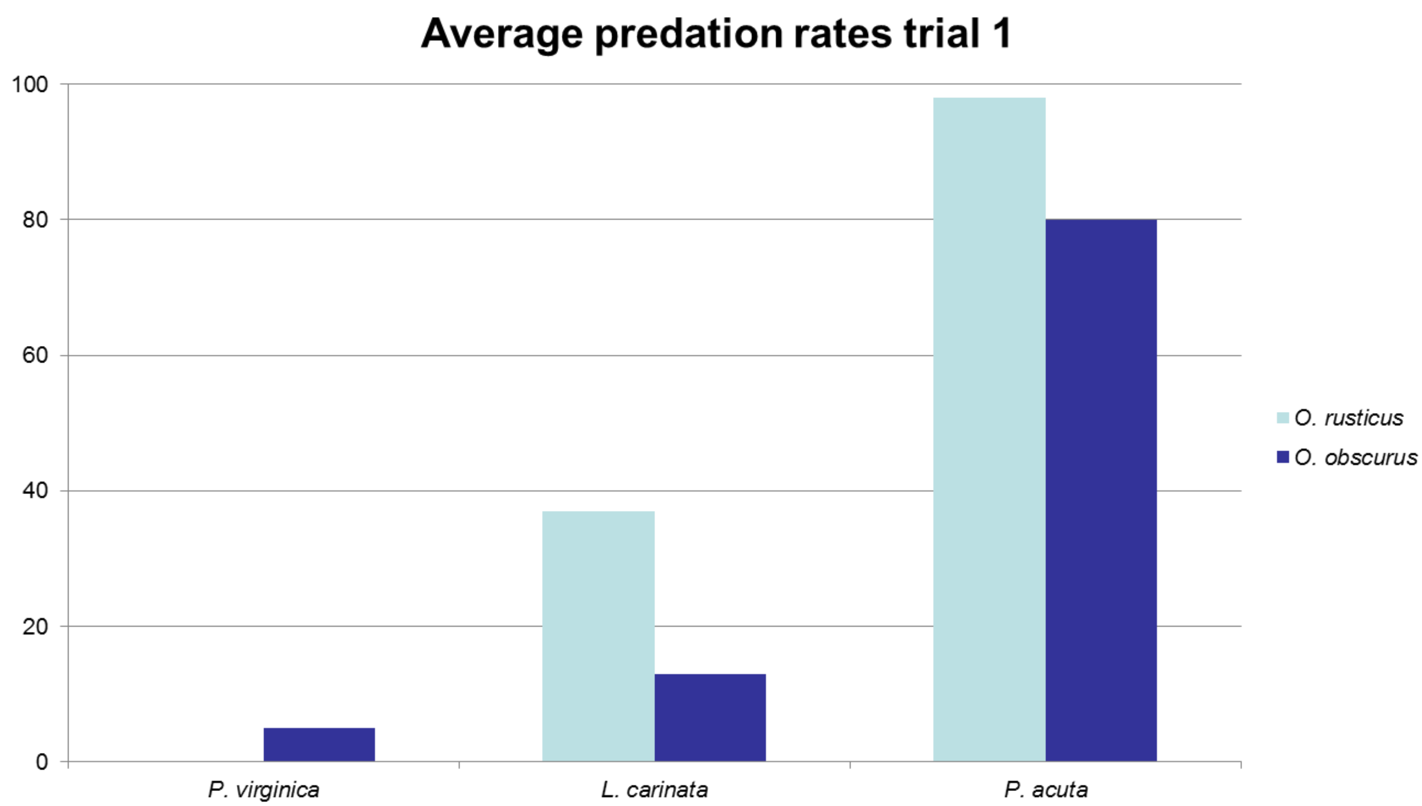
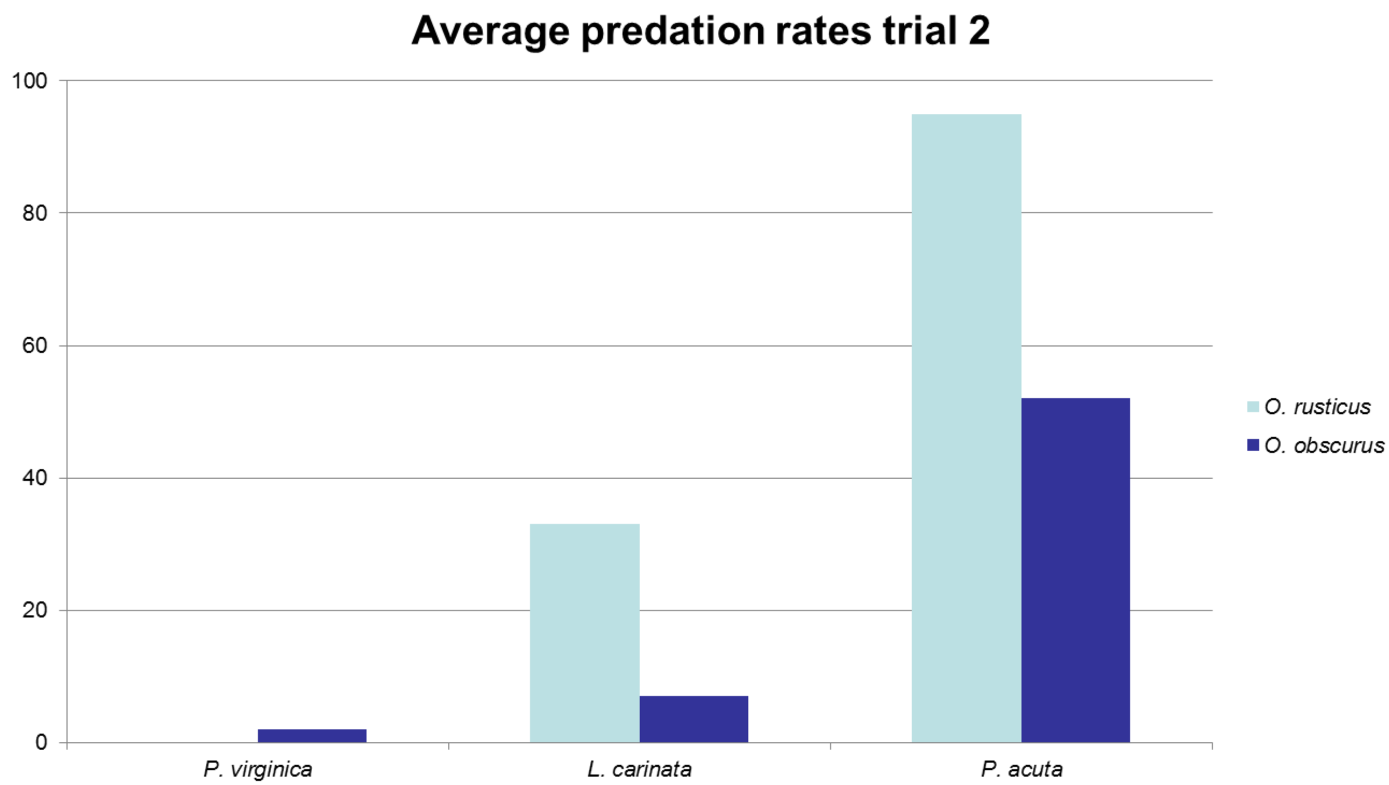

Harding: Average Habitat
7%
11%
14%
32%
7%
1%
28%
Boulder
Cobble
Gravel
Woody Debris
Mud
Fines
Sand

Figure 2: Predation rates





Average predation rates trial 2
100
80
60
40
20
0
P. virginica
L. carinata
P. acuta
O. rusticus
O. obscurus

Citations:

Bobeldyk, A. M., and Lamberti, G. A. 2008. A Decade after Invasion: Evaluating the Continuing Effects of Rusty Crayfish on a Michigan River. *Journal of Great Lakes Research*. 34.2: 265-275.

Kuhlmann, M. L., and Hazelton, P. D. 2007. Invasion of the Upper Susquehanna River Watershed by Rusty Crayfish (Orconectes rusticus). *Northeastern Naturalist*. 14.4: 507-518.

Lodge, D.M., and Lorman, J.G. 1987. Reductions in submersed macrophyte biomass and species richness by the crayfish *Orconectes rusticus*. *Can. J. Fish. Aquat. Sci.* 44:591-597.

Mangan, B.P., Savitski, J.J., and Fisher, N.T. 2009. Comparison of Two Traps Used for Capturing Wild Crayfish. *Journal of Freshwater Ecology*. 24.3: 445-450.

McCarthy, J.M., Hein, C.L., Olden, J.D., and Vander Zanden, M.J. 2006. Coupling long-term studies with meta-analysis to investigate impacts of non-native crayfish on zoobenthic communities. *Freshwater Biology.* 51: 224-235.

Strayer, D.L., and Malcom, H.M. 2007. Effects of zebra mussels (*Dreissena polymorpha*) on native bivalves: the beginning of the end of the end of the beginning? *J. N. Amer. Benthol. Soc.* 26: 111-122.

Szela, K., and Perry, W. L. 2013. Laboratory Competition Hierarchies between Potentially Invasive Rusty Crayfish (Orconectes rusticus) and Native Crayfishes of Conservation Concern. *The American Midland Naturalist*. 169.2: 345-353.

Twardochleb, L. A., Olden, J. D., and Larson, E. R. 2013. A global meta-analysis of the ecological impacts of nonnative crayfish. *Freshwater Science*. 32.4: 1367-1382.

Wilson, K. A., Magnuson, J. J., Lodge, D. M., Hill, A. M., Kratz, T. K., Perry, W. L., and Willis, T. V. 2004. A long-term rusty crayfish (Orconectes rusticus) invasion: dispersal patterns and community change in a north temperate lake. *Canadian Journal of Fisheries and Aquatic Sciences*. 61.11: 2255-2266.