Selective Foraging and Intraguild Competition Between Northern Crayfish, *Lepomis*, and *Perca*

Justin Poinsatte
BIOS 35502-01
Mentor: Ashley Baldridge
2008

Abstract

Intraguild competition occurs when two species can either prey upon or compete with each other for resources, usually depending on specific conditions. In the littoral zone of Tenderfoot Lake, a competitive or predatory relationship between common species like northern crayfish (*O. propinquus*), bluegill (*L. machrochirus*), and yellow perch (*P. flavescens*) can affect the foraging behaviors of these species as well as the population of macroinvertebrates and macrophyte growth. Intraguild predation, when members of the same trophic level prey upon one another, usually under occurs when mature individuals of one species attack the juvenile individuals the other species. The focus of my study was to examine the aspects of this intraguild competitive relationship. Using large aquaria and macroinvertebrates of the orders *Ephemeroptera*, *Odonata*, and *Gastropoda*, feeding trials were conducted to analyze foraging efficiency. My results indicated that there was a significant decrease in foraging activity by the crayfish in the presence of either fish species, due to the increased amount of time spent defending itself rather than foraging. The macroinvertebrate order that the crayfish more frequently preyed upon was also affected by what species of fish was present. To analyze the effects of intraguild predation, perch and crayfish were starved together to determine the maximum size of crayfish that the perch were able to consume. My results indicated that there was a significant positive correlation between perch size and crayfish size. Observation also showed that perch would prey upon recently molted crayfish, due to their softened exuvia and inability to defend themselves.

Introduction

In ecological communities, species typically form a food chain or hierarchy that is defined by the type of prey each species feeds upon. However, these positions in the hierarchy are not static and can vary with specific conditions. An example of this is intraguild predation, where two species will prey upon or compete with the other if the conditions for this interaction are available (Burley et al. 2006). For example, an adult crayfish will feed upon the eggs of smallmouth bass but an adult smallmouth bass will feed upon juvenile crayfish (Dorn and Mittelbach 1999). This occurs because predators have been shown to utilize selective foraging techniques to maximize energy gain (Stein 1977) and the foraging of immobile eggs or slow-moving juvenile crayfish will provide a sufficient energy gain for the amount of energy expended. Other studies have explored the effects of intraguild predation as it relates to habitat characteristics, resource productivity, life history stage, population size structure, and the density of interacting species (Denno et al. 2002; Balfour et al. 2003; Borer et al. 2003; Walzer et al. 2004).

Intraguild predation does not only directly affect the success of these species by their predation of one another but also by their competition for a shared guild of resources. For the northern crayfish, *Orconectes propinquus*, these resources include prey such as other species of small fish, macroinvertebrates, and macrophytes. Competitors for these resources, such as yellow perch (*Perca flavescens*), bluegill (*Lepomis machrochirus)*, and smallmouth bass (*Micropterus* dolomieui) reside in the pelagic zone and crayfish typically dwell and forage in the benthic zone. Thus, most intraguild competition between these fish species and the *Orconectes propinquus* occurs in well-lit areas along shoreline. For example, cobble substrate has been shown to be the most beneficial environment for crayfish due to the numerous spaces for refuge and it creates a large surface area to collect macro invertebrate prey (Lorman 1980). Similarly, juvenile smallmouth bass also prefer cobble substrate over vegetation because it provides more refuge from predators and they have been shown to feed at higher rates in these habitats (Olson et al. 2003). Thus, interactions between crayfish and their intraguild fish competitors may have an impact on the macroinvertebrate communities that reside in this cobble substrate. Another example of an indirectly competitive relationship has been illustrated between bluegill and the invasive rusty crayfish (*O. rusticus*) in northern Wisconsin lakes, where the bluegill reduce crayfish numbers by feeding upon juveniles but the adult crayfish feed heavily on the macrophytes and macroinvertebrates in the littoral habitat (Roth et al. 2007). The presence of the crayfish can damage or destroy the macrophytes that the bluegill use as foraging sites or as predator refuge and the bluegill populations may therefore decrease due to indirect competition (Roth et al. 2007). Thus, interactions between crayfish and their intraguild fish competitors may have an impact on the macrophytes and macroinvertebrate communities that reside in cobble substrate.

The focus of my study was to measure how the presence of an intraguild competitor affects the foraging activity of the northern crayfish, *Orconectes propinquus*. The null hypothesis is that there will be no difference in the amount of macroinvertebrates consumed in either the presence or absence of the competitor. My alternative hypothesis is that the foraging efficiency of the crayfish will decrease when a competitor is present. Also, the number of macroinvertebrates of each order will be measured to compare their survival in the presence and absence of a crayfish competitor. The null hypothesis is that there will be no difference in consumption of each of the macroinvertebrate types when a crayfish competitor is present or absent. My alternative hypothesis is that the more active macroinvertebrates, such as *Odonata*, will be consumed less frequently because the crayfish not be foraging as actively and thus will not chase these prey types down. Consequently, macroinvertebrates that cannot quickly escape, such as *Gastropoda*, may be consumed more frequently in the presence of a fish species.

Methods

To examine competition between crayfish, *Orconectes propinquus*, and common fish species, *Lepomis machrochirus* and *Perca flavescens*, for macroinvertebrate prey, I conducted a series of simple foraging trials. These trials were performed in 10 gallon glass aquaria with a dark cover around three panes of the glass to minimize outside distraction to the test subjects. Three types of trials were performed to observe the the foraging behavior of each fish species alone, *O. propinquus* alone, and of both subjects together. Competition trials with both fish and crayfish also used an opaque mesh screen to split the tank in half during the acclimation period. This screen attempted to mimic the natural occurrence of suddenly encountering the competition in the presence of food and also to reduce competitive interaction between the fish and crayfish before the trial began. For all three types of trials, a broad size range was used for both the fish and crayfish species but the competition trials matched the size ranges of both test subjects to ensure that the fish were not able to prey upon the crayfish. Each trial had a five minute duration, which reflects the minimum amount of time it took the crayfish to forage but the maximum amount of time most of the fish needed. Each trial also used 5 individuals of one of the macro invertebrate orders: *Odonata*, *Ephemeroptera*, and *Gastropoda*. The total number of consumed macro invertebrates was recorded, as well as which competitor ate them and at what time in the trial. These data were then analyzed using analysis of variance (ANOVA) to determine if the feeding efficiency of either the fish or crayfish is affected by presence of a competitor. After each trial, the tank was cleaned to remove chemical cues from either the fish or crayfish and to remove detritus that the crayfish could forage on.

In addition, prey preference trials were run using bluegill and *O. propinquus* to determine if the prey that the crayfish prefers will change when an intraguild competitor is present. These trials were performed in the same tanks as the previous foraging trials. The five minute duration remained but the number of macro invertebrate prey was changed to two individuals per order with two Orders in the tank, for a total of 4 prey items available during the trial. The same macro invertebrate orders were used for these trials. The total number of consumed macro invertebrates was recorded, along with what organism consumed them and at what time in the trial, similar to the previous foraging trials. The results of these tests were analyzed using the Manly prey preference index (Manly 1974).

A final type of trial measured the approximate size range of *O. propinquus* that various sizes of yellow perch could consume. Five yellow perch of a size range extending from 11.9 cm to 20.5 cm were placed in separate tanks with four crayfish in an appropriate size range. After 96 hours, the carapace lengths of the *O. propinquus* were remeasured to determine the minimum size of the crayfish that could avoid consumption by the perch.

The crayfish were collected from the littoral zone of Tenderfoot Lake by hand while snorkeling.

The bluegill and perch were collected via seine-netting and electro-shocking techniques from Tenderfoot and Brown lakes. The macroinvertebrates were collected in Tenderfoot Lake and Tenderfoot Creek.

Results

ANOVA was used to examine the relationship between fish, crayfish, and their macroinvertebrate prey. There was a statistically significant difference in the total amount of macroinvertebrate prey consumed when in competition with fish species compared to without fish species (p value - 0.001, F - 11.348). Specified to species, further testing illustrated that both bluegill and perch statistically significantly reduced the amount of macroinvertebrates consumed (p value - 0.038 and 0.003, respectively). The presence of crayfish did not statistically significantly affect the amount of macroinvertebrates consumed by fish species (p value - 0.216). There was also a strong tend which illustrated that crayfish showed a preference in the type of macroinvertebrate consumed (p value - 0.117). Further testing showed that in the presence of bluegill, the crayfish consumed significantly fewer *Ephemeroptera* than in the absence of bluegill (p value - 0.035). Similarly, the crayfish consumed significantly less *Ephemeroptera* in the presence of yellow perch than in their absence (p value - 0.003). There was also a trend suggesting that crayfish consume *Gastropoda* in the presence of bluegill than in their absence (p value - 0.074). The results for consumption of *Gastropoda* and *Odonata* in the presence of yellow perch did not show statistically significant differences. Prey preference, calculated using the Manly index of preference (Manly 1974), illustrated that when fish were not present, crayfish showed a 0.6434 preference of *Odonata* against *Gastropoda* and a 0.6434 preference for *Ephemeroptera* against *Odonata*. When yellow perch were present, the crayfish showed a 0.5 preference for *Odonata* against *Ephemeroptera* and a 0.779 preference for *Odonata* against *Gastropoda*. A linear squares regression was used to analyze the relationship between perch size and the maximum size of crayfish that it could consume. The results indicate that there is a statistically significant positive correlation between perch size and crayfish size (p value – 0.028, F – 15.982).

Discussion

As the results indicate, the foraging activity of *Orconectes propinquus* statistically significantly decreased in the presence of competitive fish species, for both yellow perch and bluegill. However, the presence of crayfish did not have a statistically significant impact on the foraging of either fish species. These results show that the null hypothesis was proven false and that my alternative hypothesis, that crayfish foraging efficiency would be affected by the presence of an intraguild competitor, was proven true. These results are supported by previous work on the subject, which states that in the presence of a predatory fish, crayfish will spend more time in defensive activities, such as burrowing and chelae display, while making fewer attempts to forage and will reduce their movement overall (Stein and Magnuson 1976). While not quantified, I did observe in my individual trials that crayfish spent more time in a defensive stance when either yellow perch or bluegill were present than when no fish were present. I suggest that further study into this subject, possibly recording the amount of time a crayfish spends either foraging, in a defensive stance, or attempting to flee could be analyzed to see if there is a significant difference across fish species. In addition to my comparison of their effect on foraging efficiency, this study could help clarify if either bluegill or yellow perch affect crayfish foraging more significantly.

I also analyzed the effects of fish presence on the prey preference of crayfish. There was a strong trend toward significant differences among the three orders of macroinvertebrates used in the trials: *Ephemeroptera*, *Odonata*, and *Gastropoda*. Further testing illustrated that fish species affected how much the crayfish chose to eat of some macroinvertebrate orders. The crayfish consumed significantly fewer *Ephemeroptera* in the presence of both yellow perch and bluegill and *Gastropoda* was consumed significantly less in the presence of yellow perch and very nearly significantly in the presence of bluegill. The consumption of *Odonata* was not significantly affected by the presence of either yellow perch or bluegill, thus the crayfish continued to consume them at similar rates whether fish were present or not. The evidence seems to indicate that the change in how much each macroinvertebrate type was affected was based largely on the behavior of the macroinvertebrates. The prey was dropped in the middle of the tank, which would require the crayfish to actively move to forage. However, as Stein and Magnuson (1976) have indicated, crayfish spend less time foraging in the presence of predators. The *Gastropoda*, which usually remained still in the middle of the tank, were foraged upon less in the presence of fish since the crayfish were less willing to actively forage on them. *Ephemeroptera*, being on average smaller than *Odonata* larvae, appeared to be more difficult for the crayfish to catch without chasing their prey and thus were also preyed upon less in the presence of fish species. *Odonata*, which are on average larger than *Ephemeroptera* larvae, were easier for the crayfish to catch without moving much. Some *Odonata* also indicated a tendency to attempt to perch on the crayfish, which typically resulted in cost-efficient foraging for the crayfish.

The results from the crayfish predation trial indicate that there is a significant positive correlation between larger perch consuming larger crayfish. Yellow perch were used for this test after it was determined that they affect *O. propinquus* foraging more strongly than the bluegill test subjects. This test was designed to determine appropriate sizes for the yellow perch that will act as competitors for *O. propinquus* without danger of crayfish consumption by the perch. However, due to the small sample size of the trial, I recommend that this experiment should be performed more extensively in the future, with a higher number of replicates and encompassing a larger number of fish species.

The majority of the crayfish consumed in this trial had recently molted, which illustrates that the perch may opportunistically feed upon the crayfish when they are most vulnerable. This may be an indication that the perch illustrated optimal foraging techniques as they chose to consume the largest size of crayfish without much cost, since the main defense mechanism of the crayfish, its exuvia, was weakened. The crayfish preference for cobble substrate becomes even more important during molting periods because it can provide protection from predators since the exuvia is softer following a molt.

Intraguild competition has been shown to influence many facets of the life history and foraging of the species involved in the relationship. Thus, to fully understand how intraguild competition applies, it was necessary to analyze several aspects of relationship, such as the effects on the foraging crayfish, on macroinvertebrate populations, and on predation choices by the fish species. By combining this information and by using common species in Tenderfoot Lake, it is possible to understand the trophic level mechanics in the littoral zone of the lake. Unfortunately due to time limitations, I was unable to complete the other half of my study by measuring the effects of crayfish presence on fish foraging activity. Further studies could investigate the effects of intraguild competition on macrophyte growth in the littoral zone, perform similar feeding trials but analyzing the effects on fish foraging more closely, or continue to test the preferred crayfish size by perch predators of different sizes. Another study could repeat similar feeding trials to my own but measure the amount of time the crayfish spends in either a defensive stance, attempting to escape, or attempting to forage. This would further analyze how effectively fish presence reduces the foraging activity of the crayfish.

Acknowledgements

I would like to thank the University of Notre Dame and the Hank family for their endowment, which allowed me to perform research at the facility this summer. I would like to thank Gary Belovsky, Michael Cramer, and Heidi Mahon for their guidance. Ashley Baldridge was a great help, providing the materials and supplies necessary to perform these experiments as well as giving guidance on possible projects and helping to devise possible methods to achieve the results. I would like to thank Mia Puopolo for her assistance in macroinvertebrate collection, tank set-up and preparation, and being another pair of eyes to watch the tanks while trials were occurring. I would like to tank Tori

Mork for her assistance in snorkeling for more crayfish samples and Kelly Garvy for providing extra crayfish for predation trials.

Literature Cited

Balfour, R.A., Buddle, C.M., Rypstra, A.L., Walker, S.E., and S.D. Marshall. 2003. Ontogenetic shifts in competitive interactions and intra-guild predation between two wild spider species. Ecological Entomology 28: 1: 25-30.

Borer, E.T., Briggs, C.J., Murdoch, W.W., and S.L. Swarbrick. 2003. Testing intraguild predation in a field system: does numerical dominance shift along a gradient of productivity? Ecology Letters 6: 10: 929-935.

Burley, L.A., A.T. Moyer, and J.W. Petranka. 2006. Density of an intrigued predator mediates feeding group size, intraguild egg predation, and intra- and Interspecific competition. Oceologia 148: 641-649.

Denno, R.F. and D.L. Finkle. 2002. Intraguild predation diminished in complex-structured vegetation: Implications for prey suppression. Ecology 83: 3: 643-652.

Dorn, N. J., and G. G. Mittelbach. 1999. More than predator and prey: a review of interactions between fish and crayfish. Vie Et Milieu–Life and Environment 49:229–237.

Lorman, J.G. 1980. Ecology of the crayfish *Orconectes rusticus* in northern Wisconsin. Ph.D. thesis, University of Wisconsin, Madison, Wisconsin, USA.

Manly, B.J.F. 1974. A model for certain types of selection experiments. Biometrics 30: 281–294.

Olsen, T. M., D. M. Lodge, G. M. Capelli, and R. J. Houlihan. 1991. Mechanisms of impact of an introduced crayfish (*Orconectes rusticus*) on littoral congeners, snails, and macrophytes. Canadian Journal of Fisheries and Aquatic Science 48:1853-1861.

Roth, B.M. 2001. The role of competition, predation, and their interaction in invasion dynamics: predator accelerated replacement. M.Sc. thesis, University of Wisconsin, Madison, Wisconsin, USA.

Roth, B.M., Tetzlaff, J.C., Alexander, M.L., and J.F. Kitchell. 2007. Reciprocal Relationships Between Exotic Rusty Crayfish, Macrophytes, and *Lepomis* Species in Northern Wisconsin Lakes. Ecosystems 10: 74-85.

Stein, R.A. 1977. Selective predation, optimal foraging, and predator-prey interaction between fish and crayfish. Ecology 58: 6: 1237-1253.

Walzer, A., Paulus, H.F., and P. Schausberger. Ontogenetic shifts in intraguild predation on thrips by phytoseiid mites: the relevance of body size and diet specialization. Bulletin of Entomological

Research 94: 6: 577-584.

Weigmann, D. D., J. R. Baylis, and M. H. Hoff. 1997. Male fitness, body size and timing of reproduction in smallmouth bass, *Micropterus dolomieui*. Ecology 78:111-128.

Figures

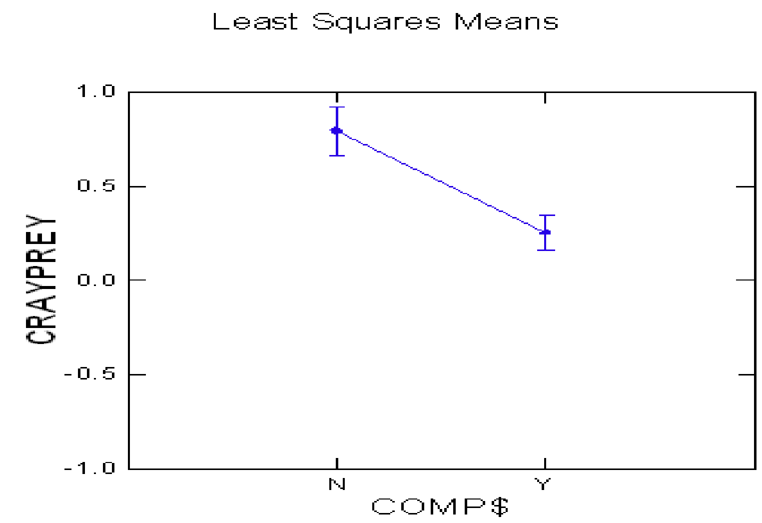

Figure 1: The effects of the presence (Y) or absence (N) of a fish species (COMP$) in the feeding trial (p-value = 0.001). CRAYPREY refers to the least square mean number of macroinvertebrates eaten in the trial. In the absence of fish, crayfish ate an average of .792 macroinvertebrates while they ate an average of .250 in the presence of a fish species. The error bars illustrate the standard error.

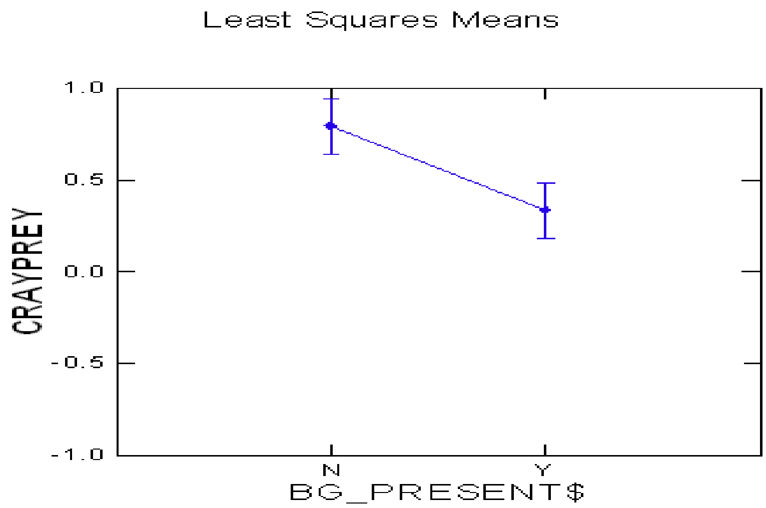

Figure 2: The effects of the presence (Y) or absence (N) of bluegill (BG_PRESENT$) in the feeding trial (p-value = 0.038). CRAYPREY refers to the least square mean number of macroinvertebrates eaten in the trial. In the absence of bluegill, crayfish ate an average of .792 macroinvertebrates while they ate an average of .33 in the presence of bluegill. The error bars illustrate the standard error.

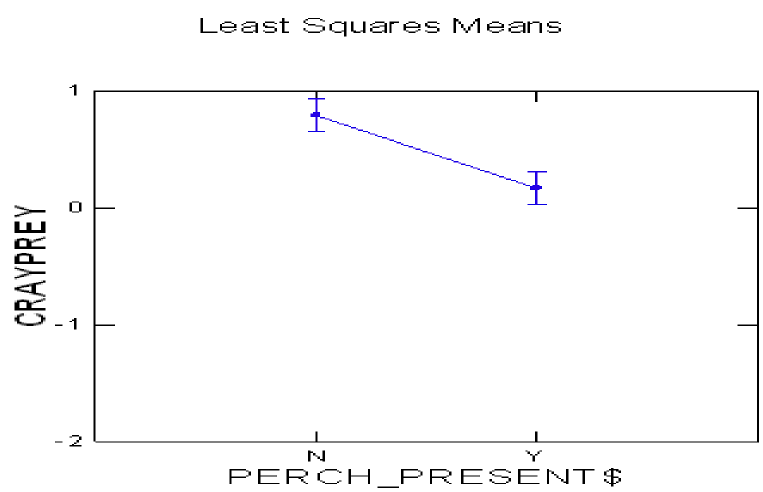

Figure 3: The effects of the presence (Y) or absence (N) of yellow perch (PERCH_PRESENT$) in the feeding trial (p-value = 0.003). CRAYPREY refers to the least square mean number of macroinvertebrates eaten in the trial. In the absence of bluegill, crayfish ate an average of .792 macroinvertebrates while they ate an average of .167 in the presence of bluegill. The error bars illustrate the standard error.

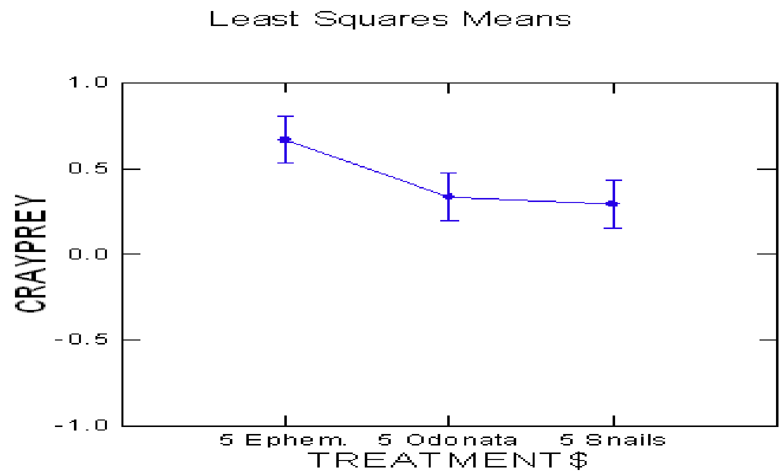

Figure 4: The effects of crayfish foraging on each macroinvertebrate treatment in the feeding trials (p-value = 0.117). CRAYPREY refers to the average number of macroinvertebrates eaten in the trial. The least square mean number of macroinvertebrates eaten was, by type: .667 for *Ephemeroptera*, .333 for *Odonata*, and .292 for *Gastropoda* (Snails). The error bars illustrate the standard error.

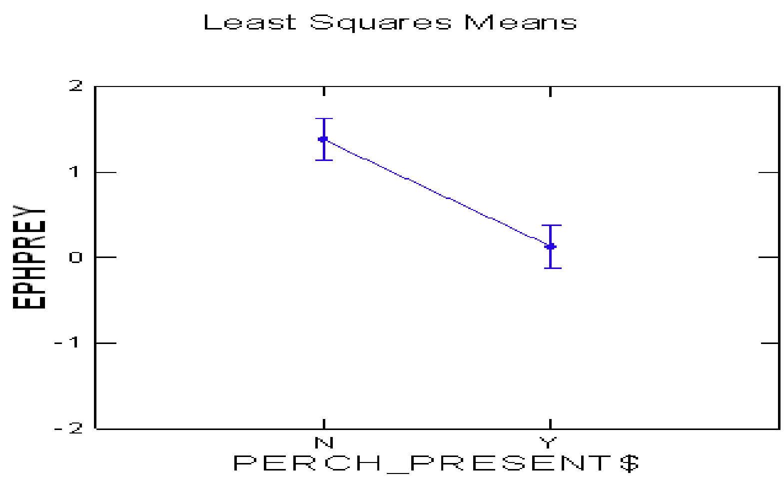

Figure 5: The effects of crayfish foraging on *Ephemeroptera* when yellow perch are present (Y) or absent (N) (p-value = 0.003). EPHPREY refers to the least square mean number of *Ephemeroptera* eaten in the trial. The error bars illustrate the standard error.

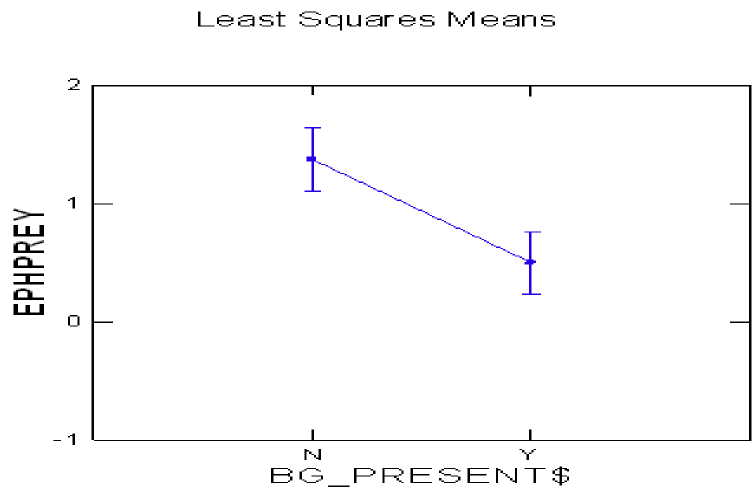

Figure 6: The effects of crayfish foraging on *Ephemeroptera* when bluegill are present (Y) or absent (N) (p-value = 0.035). EPHPREY refers to the least square mean number of *Ephemeroptera* eaten in the trial. The error bars illustrate the standard error.

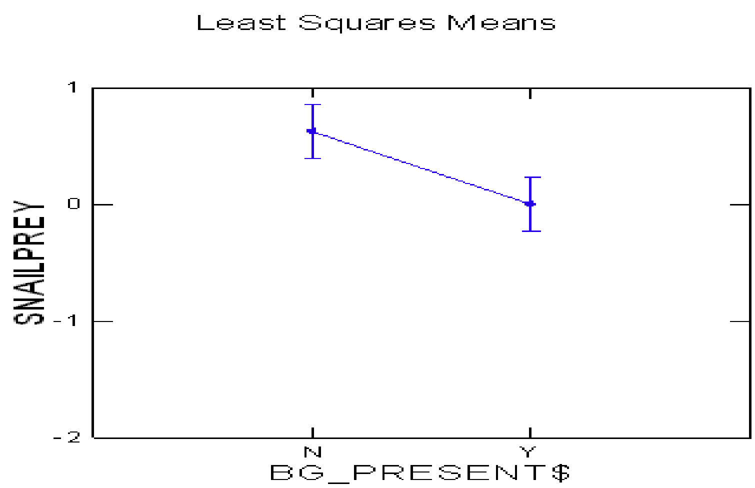

Figure 7: The effects of crayfish foraging on *Gastropoda* when bluegill are present (Y) or absent (N) (p-value = 0.035). SNAILPREY refers to the least square mean number of *Gastropoda* eaten in the trial. The error bars illustrate the standard error.

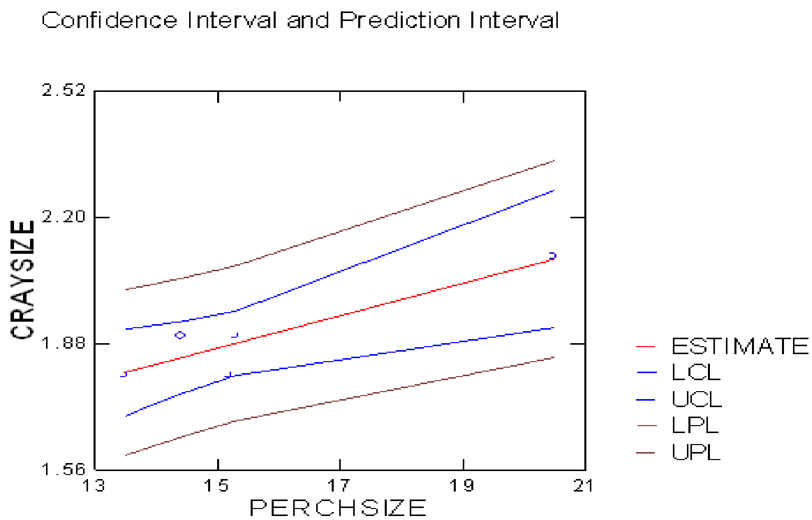

Figure 8: The positive correlation between perch size (PERCHSIZE) and the size of crayfish that it could consume (CRAYSIZE), measured by the carapace length (p value – 0.028). Larger perch chose to consume larger sizes of crayfish. The error bars illustrate the standard error.