Investigating Mechanisms Driving Crayfish Distribution Within Lakes

BIOS 35502: Practicum in Environmental Field Biology

Carlos G. Ramos
Advisor: Brett Peters

2006

Abstract

With laboratory and field work, some factors regulating crayfish abundance (Orconectes *virilis* and *Orconectes propinquus*.) were studied at UNDERC (Northern Wisconsin/Southern Michigan). It was tested that 1) cobble offers a refuge from predation, 2) provides more food resources (macroinvertebrates), and that 3) non-lethal effects on cobble are lower than in macrophyte and sand. The results showed that cobble offers a refuge from predation. Also the results showed that cobble provides more food resources, but it does not differ in gastropods abundance among the other substrates.

Introduction

The distribution and abundance of species is related to biotic and abiotic factors. Among-lake variation in crayfish abundance and species composition is related to human activity, calcium level, and dominant lake substrate type (Kershner and Lodge, 1995). Previous laboratory experiments demonstrate that cobble habitats provide refugia for orconectid crayfish from fish predation (Stein and Magnuson 1976, Garvey et. al 1994). Field and laboratory studies have found that crayfish abundance is generally positively related to the abundance of cobble. (Stein 1977, Lorman 1980, Hill and Lodge 1994). Recently concern has developed over the abundance of the introduced rusty crayfish (*Orconectes rusticus*). Therefore it is important to understand the factors regulating species abundance in order to manage invasive species.

The goal of this study was to determine what factors lead to high abundance of crayfish in cobble substrate relative to sand and macrophyte substrates. *Orconectes virilis* (the native species) and *Orconectes propinquus* (a non-native species) were used as our study organisms because there are no rusty crayfish populations on UNDERC property.

We identified three factors which we hypothesized may lead to higher crayfish abundances in cobble: 1) cobble offers a refuge from predation 2) cobble provides more food resources (i.e. macroinvertebrates) for crayfish and 3) the non-lethal effects of crayfish predators are reduced in cobble which allows more foraging. Based on these factors we came up with the following hypotheses: 1) the proportion of fish with crayfish in guts relative to crayfish density (PFWCGRCD) would be less in cobble than the other substrates. 2) There will be more macroinvertebrates, especially gastropods (preferred crayfish prey) in cobble than the other substrates. 3) Crayfish activity would be greater in cobble than the other substrates.

Methods

This survey was designed to determine what factors lead to higher crayfish densities in cobble habitat as compared to other substrates (sand and macrophytes). Therefore we tested whether or not crayfish density was higher in cobble in our study lakes. To do this, we sampled each site (three sites per substrate per lake for a total of nine sites per lake) for crayfish density using five randomly placed one meter^2 quadrats.

This was done three times on Tenderfoot Lake (6/7/06, 6/27/06 and 7/17/06) and twice on Plum Lake (6/9/06, 6/28/06).

Hypothesis 1

To test the hypothesis that the PFWCGRCD will be lower in cobble habitat, gut contents of fishes were sampled on three different substrates (macrophyte, cobble, and sand). Nine sites on Plum and Tenderfoot (Both on UNDERC property) lakes were sampled for crayfish, fish and macroinvertebrates. The fishes were collected using an electroshocking boat during the night (after sunset) and the gut contents were collected using gastric lavage. This was done three times on Tenderfoot Lake (on the following dates: 6/8/06, 6/29/06, and 7/17/06) and once in Plum Lake (on 6/27/06). Crayfish densities were sampled randomly in each 50 meters transects (the nine sites) using five one-squared meter quadrats. This was done three times on Tenderfoot Lake (6/7/06, 6/27/06 and 7/17/06) and twice on Plum Lake (6/9/06, 6/28/06).

Formatted: Justified

Hypothesis 2

To test whether cobble provides more food resources for crayfish, macroinvertebrates were quantified in the three different types. In the cobble, macroinvertebrates were collected by scraping all rocks within a randomly placed plastic ring (Area =1485 cm^2). In the sand and macrophyte substrates a sediment corer (Area =176.71 $cm^{2)}$ was used to sample macroinvertebrates. In every habitat, the samples were sieved to remove the macroinvertebrates. All the macroinvertebrates were identified to appropriated taxa. Each site had three samples taken on each sampling date and were pooled together per site. This was done three times at Tenderfoot Lake (6/7/06, 6/27/06, and 7/17/06), but in Plum Lake was performed two times (6/8/06, and 6/28/06).

Hypothesis 3

We quantified crayfish activity using a combination of capture techniques. The crayfishes were quantified in the three different substrates by using standard trapping technique, that uses beef liver in a minnow trap set overnight for about 24hrs (Lodge et al. 1986). The second technique used was using quadrats as described above. The trapping reflected the overall population activity (density x activity), and the quadrats quantified crayfish density. By dividing the two measures we were able to compute an index of activity for crayfish in each site for each date. We also quantified fish predation threat at each transect by calculating two metrics of fish catch per unit effort: fish/minute and mm-fish/minute.

Data Analysis

All crayfish and macroinvertebrate densities were averaged for each site for each sampling date. Crayfish activity was determined at each site and date using the following formula: (**trap catch+1)/ (average crayfish per m^2 + 1).** The PFGWCRCD was determined for each site and date using the following formula: **(Proportion of fish with crayfish in guts + 1)/ (average crayfish per m^2 +1).**

All statistical analysis was done using ANOVA, post hoc tukey's test were also performed on significant ANOVA results. The software used for running these test is Systat 11.0 (SYSTAT, Software, Inc.; Point Richmond, CA).

Results

As expected we found that substrate type has a significant effect on average number of crayfish per m^2 (F-ratio = 4.282, df = 2, p = 0.028, Figure 1). The tukey's test

showed that cobble had significantly (p= 0.049) higher average numbers of crayfish per m^2 than macrophyte and sand.

Hypotheses 1

It was found that substrate has an effect on the PFGWCRCD (F- ratio = 8.860, df = 2, p = 0.003, Figure 2). The tukey's test shows that PFGWCRCD is significantly (p=0.014) less in cobble than in the other substrates.

Hypothesis 2

It was found substrate does not have an effect on gastropod density (per cm^2) (F-ratio = 1.280, df = 2, p = 0.290, Figure 3). On the other hand, substrate was found to have an effect on macroinvertebrate individuals per cm^2 (F-ratio = 5.345, df = 2, p = 0.009). The tukey's test showed that cobble had significantly more (p=0.000) macroinvertebrates per cm^2 than either other substrate (Figure 4).

Hypothesis 3

A one-way ANOVA found that substrate had no significant effect on the crayfish index of activity (F-ratio = 0.841, df = 2, p = 0.841).

A two-way general linear model (GLM) showed that neither fish biomass (F-ratio = 0.047, df = 1, p = 0.831) or substrate (F-ratio = 0.178, df = 2, p = 0.838) have an effect crayfish activity.

A two-way general linear model (GLM) showed that neither fish abundance (F-ratio = 0.074, df = 1, p = 0788) or substrate (F-ratio = 0.186, df = 2, p = 0.832) have an effect on crayfish activity.

Discussion:

Hypothesis 1

The hypothesis that cobble provides more refuge for predation is accepted for the reason that cobble had an effect the proportion of the fish guts with crayfish relative to crayfish densities (PFGWCRCD). As we expected cobble had the lowest PFGWCRCD value, this indicates that fish consume crayfish least relative to crayfish density in cobble. This is likely due to the predation refuge that cobble provides crayfish.

Hypothesis 2

We hypothesized that there would be more gastropods in cobble because this is the preferred food source from crayfish. However we saw no difference in gastropod abundance across substrate. There was significantly more macroinvertebrates in cobble than the other substrates. It is possible that even though crayfish prefer gastropods, they still choose areas based on general prey abundances. We assumed that many taxa of macroinvertebrate, such as mayflies and amphipods would be too fast for crayfish to consume. More research needs to be conducted to determine what food items crayfish are able to capture and consume.

Hypothesis 3

We hypothesized that crayfish activity would be higher in cobble because of the availability of refugia. Our statistical analyses show that substrate does not have an effect in crayfish activity. We also included analyses which included predation threat and substrate for the reason that fish presence has been shown to affect crayfish activity. The

analyses with the two different metrics of predation threat (total biomass of fish and number of fish) still did not yield any significant effect of substrate.

Formatted: Justified

Based on the results of this study it is hard to determine what factors which cause crayfish to inhabit cobble substrate in higher abundances than other substrates. Food resources are higher in cobble, but the preferred food resource, gastropods are not. For that reason we do not think that resource abundance is important to the distribution of crayfish. Our data does suggest that in cobble the per capita predation on crayfish is less, meaning that cobble is likely providing crayfish refuge from predation. In order to improve this study we would like to sample more lakes to see if these patterns are consistent across lakes with different biotic and abiotic communities.

Acknowledgments

I would like to thank Brett Peters, Jody Murray, Rebecca Hale, Dave Costello, Tyler Cullender, and Matt Michel for providing me field work support during those night shocking Tenderfoot Lake and Plum Lake. I also would like to thank Stephen Woodard for proving support during daytime field work (especially, with the sediment corer) and lab work. Also I would like to thank all the UNDERC TA's for helping me with this writing. I acknowledge the support of the funds from The Bernard J. Hank Family Endowment.

Tables and Figures:

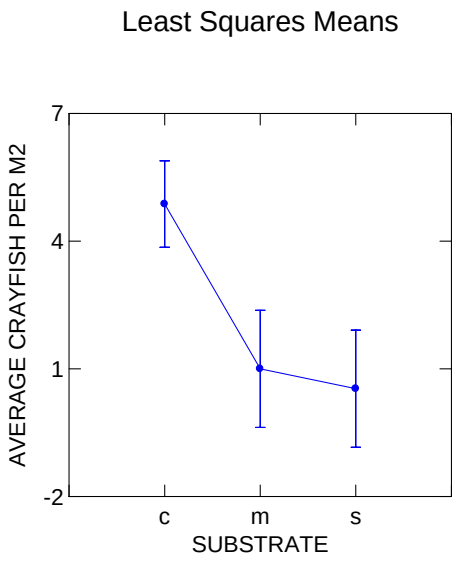

Figure 1: Substrate had an effect on crayfish abundance; specifically cobble had a significant effect on the abundance of crayfish.

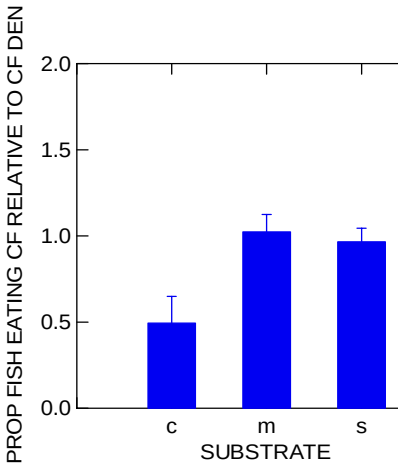

Figure 2: Substrate had an effect on the proportion of fish eating crayfish relative to the crayfish density. Cobble had significant effect on the proportion of fish eating crayfish relative to crayfish density.

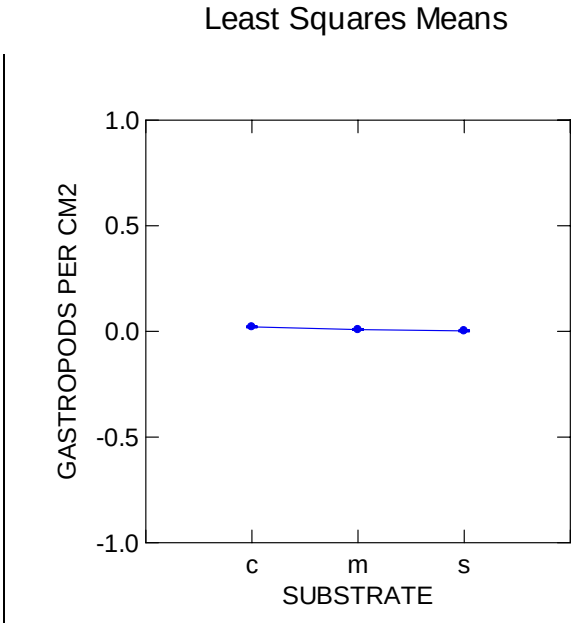

Figure 3: Substrate does not have an effect on the abundance of gastropods.

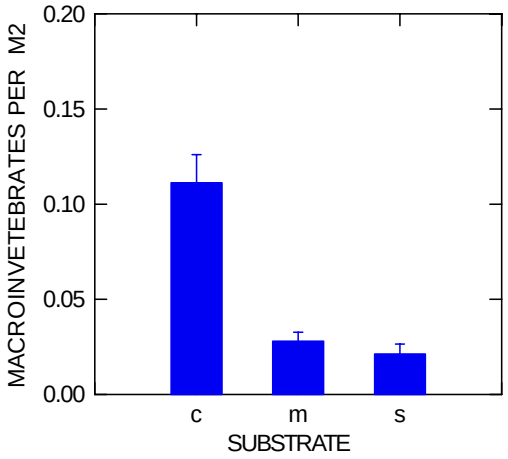

Figure 4: Substrate had a significant effect on the abundance of macroinvertebrates. Cobble had significantly higher abundances (tukey's p=0.00)

Literature Cited:

DiDonato, G.T. and D.M. Lodge. 1993. Species replacement among Orconectes crayfishes in Wisconsin lakes: The role of predation by fish. Canadian Journal of Aquatic Sciences 50: 1484-4888.

Garvey, J.E., J.E Rettig, R.A. Stein, D.M. Lodge, and S.P Klosiewski. 2003. Scale-dependent associations among fish predation, littoral habitat, and distributions of crayfish species. Ecology 84 (12) 3339-3348.

Lodge, D.M. and A.M. Hill. 1994. Factors governing species composition, population size, and productivity of cool-water crayfishes. Nordic Journal of Freshwater Resources 69:111-136.

Lodge, D.M. and A.M. Hill. 1994. Diel changes in resource demand: competition and predation in species replacement among crayfishes. Ecology 75:2118-2126

Stein, R.A., and J.J. Magnuson. 1976. Behavioral response of crayfish to a fish predator. Ecology 57:751-761