Per capita effects of *Orconectes propinquus* on Aquatic Plant Density

BIOS 35502-01 Practicum in Field Biology

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Abstract

Invasive species, such as crayfish, are extremely detrimental to aquatic ecosystems and can have negative effects on macrophytes (Lodge and Lorman 1987). Macrophytes sustain native species by providing shelter, food, balancing abiotic factors within the system and aiding in nutrient cycling (Peters *et al*. 2008). The crayfish-macrophyte interaction is an important study system since nonnative species can alter macrophyte abundance, which can have high impacts on its community. This investigation was hypothesizing that (1) per capita destruction would decrease as crayfish density increased and (2) as crayfish density increased, preferences for macrophytes would change due to higher competition. An equal gender ratio of crayfish and approximately 5grams of each of the three macrophyte species were placed into a 0.125m^2 tank mesocosm. Densities were held at 1, 8, 16, 32 and 64crayfish/m^2 and controls for natural macrophyte growth were taken into account as a correction factor. Although this study did not find any significant results with regards to average per capita destruction, there were general non-linear trends that show a decreasing effect of each crayfish with increasing densities, which suggest that Orconectes propinquus are not as destructive as Orconectes rusticus, who were found to have increasing per capita effects as density increased, to their macrophyte environment (Pintor *et al.* 2009). General preference changes of macrophytes did seem to emerge as crayfish density increased, with a beginning preference for C. demersum and V. Americana over P. richardsonii, and an ending destruction preference for P. richardsonii over V. Americana, implying that preferences change as crayfish densities are altered within a community. Although significance was not found in this investigation, O. propinquus did not act on the same level as O. rusticus' destruction to submerged macrophytes, supporting the idea that O. propinquus are not as strong as an invader as O. rusticus. In conclusion, aquatic communities are substantially

altered by invasive crayfish and they need to be studied further in order to fully comprehend their short and long term effects for native species abundance and survival.

Introduction

One environmental stressor that commonly plagues ecosystems is invasion by nonnative species. This is an increasing problem due to increased human involvement, which contributes to the spread of exotic organisms that in turn affects how those ecosystems operate. Successful nonnative species have had an impact on environmental structure and have become a global threat to ecosystem function and native biodiversity (Wilcove 1998). Ecologists search to comprehend which mechanisms contribute to the establishment, dominance and effects of species within an environment after the introduction of nonnative species. Studying how these invasive species establish, disperse, and impact the density of native species is an integral part of conserving species within an ecosystem (Kolar and Lodge 2001).

Crayfish are the largest invertebrate freshwater herbivores and have a large impact within the food web of their ecosystem (Lorman 1980). The study of crayfish and aquatic plant interactions is important for ecosystem conservation because invasive crayfish can alter the functional role of aquatic plants, also known as macrophytes, in their aquatic environments (Carpenter and Lodge 1986). Macrophytes heavily influence the biotic, chemical and physical elements of the ecosystem and therefore are a critical component of aquatic ecosystems (Peters *et al*. 2008). As macrophytes fall prey to increasing numbers of crayfish, they indirectly alter temperature, pH, dissolved oxygen and nutrient cycling of the inhabited ecosystem, ultimately affecting the status and health of the community (Carpenter and Lodge 1986).

Preliminary studies (Lodge and Lorman 1987) imply that at higher densities *Orconectes rusticus*, a rapidly spreading invasive crayfish specie, reduce macrophyte abundance over time, suggesting that crayfish graze selectively. Freshwater crayfish make their feeding decisions based on several plant properties such as structure, nutrition and chemical defenses (Cronin et al. 2002). With nonnative crayfish reaching higher population densities than native crayfish, their collective impacts on macrophytes may lead to changes in food webs and even elimination of some species, which could lead to the degradation of freshwater environments (Lodge and Lorman 1987).

Increasing predator densities within an environment ultimately change the abundance of their prey. To further investigations on crayfish impacts within a community, it is important to focus on the pattern of total destructive impact, which in turn affects the per capita trend. If the total destruction has an increasing linear trend, then the per capita destruction would follow a horizontal trend as crayfish density increases. This implies that the per capita effect does not change with increasing densities, which would be beneficial for the macrophyte population just in case crayfish density increases; there would not be a huge change in destruction for each crayfish. If total destructive impact is a downward nonlinear curve then the per capita effect will decrease as crayfish density increases, which is another good scenario for the macrophyte community because each individual crayfish will have a decreasing effect on macrophyte destruction. Likewise, if the total destructive impact is an upward nonlinear curve, then the per capita effect will increase as crayfish density increases, which would be detrimental biomass and biodiversity of the macrophyte community. One study (Pintor *et al*. 2009) investigated high invader densities and impacts on native prey, such as macrophytes, through behavioral correlations. Their results found that intraspecific aggression, among crayfish increased with high invader densities, as did foraging activity on preferred prey. These findings are suprising, it is expected that with increasing competition, foraging would decrease due to more crayfish interactions and more energy focused on defending oneself in a highly competitive environment. This relationship between aggressiveness and foraging activity is one mechanism that allows assertive invaders to build up and maintain high densities.

One previous crayfish invader, *O. propinquus*, has not been as extensively studied as *O. rusticus*, so its effects on macrophyte populations in the north temperate lakes have yet to be determined. *O. propinquus* was introduced to Wisconsin around 80 years ago probably as bait for fishing, and it has since spread across the Great Lake region (Capelli and Munjal 1982). *O. propinquus* is an ideal study organism due to it displacing *O. virilis*, but it was not as successful as an invader because *O. rusticus* ended up dominanting over their shared territory. This is showing the importance of invasive species and their ability to disrupt aquatic ecosystems and also provides an opportunity to examine a potential mechanism for success. Even if *O. propinquus* is not as aggressive as its fellow competitor, *O. rusticus*, if it reaches the same numbers, it could also have detrimental effects on the macrophyte population, as well as other susceptible prey species.

The purpose of this study was to investigate the per capita effect of *O. propinquus* on macrophytes as well as changes in preference for the plant species as the density of crayfish increases. I hypothesized that the per capita effect would behave in a non-linear fashion because the total destruction will not increase at a constant rate along with crayfish density due to increased competition that will cause a decrease in rate. *O. rusticus* are known that with increasing competition their per capita effect increases due to their high aggression which results in high foraging activity (Pintor *et al.* 2009). Since *O. propinquus* is not as an efficient invader as

O. rusticus, perhaps it is expected that *O. propinquus* would have decreasing destructive per capita effects due to competition. Foraging activity will decrease in rate due to the increased competition within their mesocosm community. The higher level of competition would cause a change in preference amongst plant species within the environment due to a limited amount of available food and the less preferred plants may be utilized more with increasing competition.

Methods

Collection and Setup

O. propinquus and three macrophyte species (*Potamogeton richardsonii, Vallisneria americana* and *Ceratophyllum demersum*) were collected in Tenderfoot lake on the UNDERC property from May through July 2011. The crayfish used in the trials were housed in single sex tanks filled with water from Tenderfoot Lake. The tanks were aerated and water was changed once a week. The males used were all Form 2 (non-reproductive) and the females were non-gravid. Crayfish with a carapace range of 20-25mm were used in the trial in order to reduce variability due to size. The macrophytes species were selected due to their structural characteristics (single-stemmed vs. highly branched) and previous known crayfish selectivity (Lodge and Lorman 1987). The mesocosms were established in small glass aquaria (0.125m^2) that contain an equal biomass of each plant species (approximately 5 g). Each tank had identical plant species composition. The plant stems were secured with paper clips to a rigid plastic grid on the bottom of the tanks anchored by rocks on the edges of the tanks. The control aquaria (n=4) contained only macrophytes in order to account for destruction or weight change not due to crayfish. Treatment aquaria each had a different density of crayfish. The different densities were: 8 crayfish/m^2, 16 crayfish/m^2, 32 crayfish/m^2 and 64 crayfish/m^2. Equal gender ratios were used in the aquaria in order to best reflect natural crayfish community composition. In the tank with just one crayfish, one male was used. All of the crayfish used in each trial were starved at a minimum of 24hrs before the start of the trial.

Trials

I conducted four weeklong trials. To track the effect of crayfish density on macrophytes, I analyzed the density of the crayfish, which was the independent variable, in each aquarium compared to the weight differences in each macrophyte species, which was the dependent variable. I collected data by using the spun dry weight of macrophytes attached to the grid before and after each trial. Floating and clipped contents were also collected in order to look at consumption.

Statistical Analysis

ANOVA through SYSTAT was used for the statistical analysis of this project. Each density level was treated as a categorical factor and the per capita destruction and per capita consumption were the response variables. We ran a series of ANOVAs for each plant species, as I cannot assume that they are independent of each other. To control for Type I error, I adjusted the alpha level using the sequential bonferroni correction. Logarithmic transformations were necessary to normalize the data. I followed the methods of Olsen *et al*. (1991) to correct for natural plant growth and degradation of the macrophytes. The first equation was the final live macrophyte biomass in the control aquaria divided by the initial macrophyte biomass in the control aquaria. The resulting number from the previous equation will be multiplied by the initial macrophyte biomass in the experimental aquaria, and then subtracted from the final macrophyte biomass in the experimental aquaria.

Results

In this scientific investigation, I expected the crayfish per capita destruction to decrease if the average total destruction behaved in a downward non-linear fashion. This could occur due to increased competition and foraging, which would increase the rates of destruction (Pintor *et al.* 2009). I also hypothesized that with increasing crayfish densities, preferences of macrophytes would decrease due to limited food sources and a highly stressed environment. The average destruction behaved in a general linear fashion. *C. demersum* seemed to be destroyed the most, while *P. richardsonii* destruction seemed to increase at the crayfish density of four (Figure 1). *V. Americana* seemed to be destroyed at a constant level, only with an increase at the highest density. The per capita destruction for *V. Americana* was non-significant ($F_{3,12}$=1.86, p=0.189, Figure 2). The per capita destruction for *C. demersum* ($F_{3,12}$=0.69, p=0.975, Figure 2) and *P. richardsonii* ($F_{3,12}$=0.25, p=0.859, Figure 2) were also found to be non-signficant.

Although this investigation primarily focused on crayfish destruction, per capita crayfish consumption was analyzed in order to look for further relationships. Crayfish destruction was focused on due to the destruction having more relevant impacts on damage, viability and regeneration of the plant. Consumption on the other hand usually deals with bits and pieces of the macrophyte being eaten. A one-way ANOVA for per capita consumption of *V. americana* as crayfish density increases was found non-significant ($F_{3,12}$=2.47, p=0.111, Figure 3). *C. demersum* ($F_{3,12}$=0.493, p=0.694, Figure 3) and *P. richardsonii* ($F_{3,12}$=1.49, p=0.265, Figure 3) were also found to be non-signficant. Although no significance was found, *C. demersum* was destroyed the most, *V. Americana* at low densities was consumed more than *P. richardsoniii*, but at the crayfish density of 4 per a tank, *P. richardsonii* surpassed *V. Americana* in amount destroyed (Figure 4).

Discussion

This scientific experiment investigated the potential effects of *O. propinquus* on its surrounding macrophyte population. I hypothesized that (1) as crayfish density increases, the per capita effect will behave in a decreasing fashion due to higher stress levels of competition and (2) preferences of macrophyte species will decrease due to a competitively stressed environmental system. Overall, our investigation showed no statistically significant per capita destruction and consumption as crayfish density increases.

In our study, we were expecting to see decreased per capita effects on macrophytes due to an increase in crayfish competition, which do not follow characteristics of well-established invasive species (Pintor *et al.* 2009). The findings of Pintor (*et al.* 2009) suggest that even with higher crayfish density and interference competition, they found increased foraging activity, which in turn are key mechanisms that allow aggressive invaders to maintain their high densities and lifestyles. An exponential curve was expected for per capita destruction of each macrophyte species when crayfish density increased.

Along with the expected result of an increasing per capita effect in a non-linear fashion, I expected the preferred species to be *P. richardsonii* and *V. americana* due to higher susceptibility as single-stemmed species (Lodge and Lorman 1987). *C. demersum*, in my study, tended to be preferred over the other two macrophytes throughout the whole trial. At increasing densities, *P. richardsonii* was destroyed and utilized through consumption at a higher level than *V. americana*, showing a change in preference as competition levels increased with increasing densities. Unfortunately this data was not statistically analyzed due to high variability throughout the trials, only general conclusions can be made, such as that preferences for macrophytes did change as density increased. Implying, but not fully supporting my hypothesis, that crayfish utilize and destroy certain macrophytes depending on the density of crayfish.

Overall, my results consisted of a general decreasing non-linear trend of per capita destruction, meaning that as crayfish density increased, the per capita effect of crayfish on macrophytes decreased. The presence of this trend is compelling but of course this does not fully support my hypothesis in this investigation due to non-significance. This could be a result of high variability within the trial as well as *O. propinquus*' characteristic of not being as aggressive as *O. rusticus,* who most of the case studies have been focused on due to *O. rusticus* being a highly detrimental nonnative species. Also found in a previous study (Olsen and Lodge 1991) when comparing *O. rusticus* to *O. propinquus*' feeding rates, it was determined that *O. rusticus* caused more damage and consumed more than *O. propinquus,* which could have been due to larger size and relatively higher aggression. This decreasing per capita effect could mean that at higher densities, *O. propinquus* crayfish are not as detrimental to macrophyte abundance and biodiversity due to its differences in characteristics from *O. rusticus*. The results found in this investigation were not substantial enough in order to create a significant difference between the densities and per capita effects, but a general pattern was observed. In my investigation, *O. propinquus* did not follow the trend of *O. rusticus* and resulted in decreasing per capita effects as crayfish density increased. *O. propinquus,* a previous invasive specie that has been found to be less destructive than *O. rusticus* (Lodge and Lorman 1991) may not have as detrimental effects to its surrounding environment.

This scientific experiment could have been improved in several ways in order to obtain less variability within trials as well as a more representative crayfish-macrophyte interaction. Instead of only running the trials for a week, the tests could be extended for another week in order to fully embody crayfish interactions and allow them to acclimate within the mesocosms. Most published studies ran their trials for at least three weeks at a time. Another improvement would be to increase the biomass of each macrophyte species from 5grams to 10grams, so that if one-stem is clipped by the crayfish it will not have a disproportionate effect. Higher replication also needs to be considered in order to account for their variable behavior. Also, the usage of *Elodea canadensis,* a highly preferred species could have made preference levels clearer and less variable.

Invasive crayfish are extremely detrimental to aquatic food webs and can have negative effects on surrounding native species, such as submerged macrophytes (Lodge and Lorman 1987). Macrophytes provide food, shelter and aid in nutrient cycling as well as other abiotic factors within the environment (Peters *et al.* 2008). Although this study did not find any significant results with regards to average per capita destruction, there were general non-linear trends that show a decreasing effect of each crayfish with increasing densities, which do not follow previous case studies (Pintor *et al.* 2009 and Peters *et al.* 2008) of per capita effects of *O. rusticus* on macrophyte consumption and destruction. General preference changes of macrophytes did seem to emerge as crayfish density increased, with a beginning preference for *C. demersum* and *V. Americana* over *P. richardsonii*, and an ending destruction preference for *P. richardsonii* over *V. Americana*, implying that preferences change as crayfish densities are altered within a community. Although significance was not found in this investigation, *O. propinquus* did not act on the same level as *O. rusticus'* destruction to submerged macrophytes. Overall, invasive crayfish are able to substantially alter their aquatic communities and they need to be studied further in order to fully comprehend their short and long term effects on native species abundance and survival.

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Figures

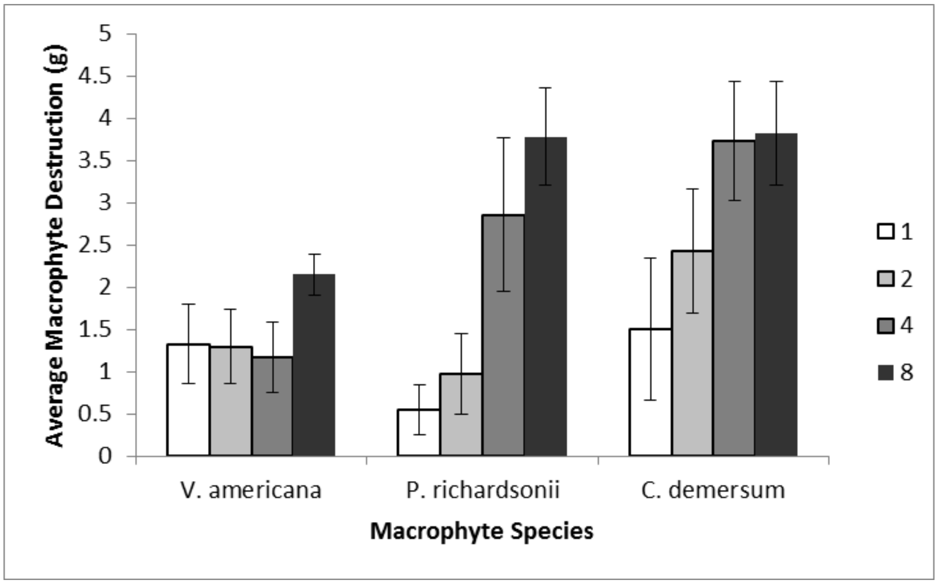

Figure 1. Average total macrophyte destruction was analyzed along with increasing crayfish density. *P. richardsonii* and *C. demersum* had a general increase in destruction through all of the densities while *V. Americana* had an irregular pattern but ultimately increased.

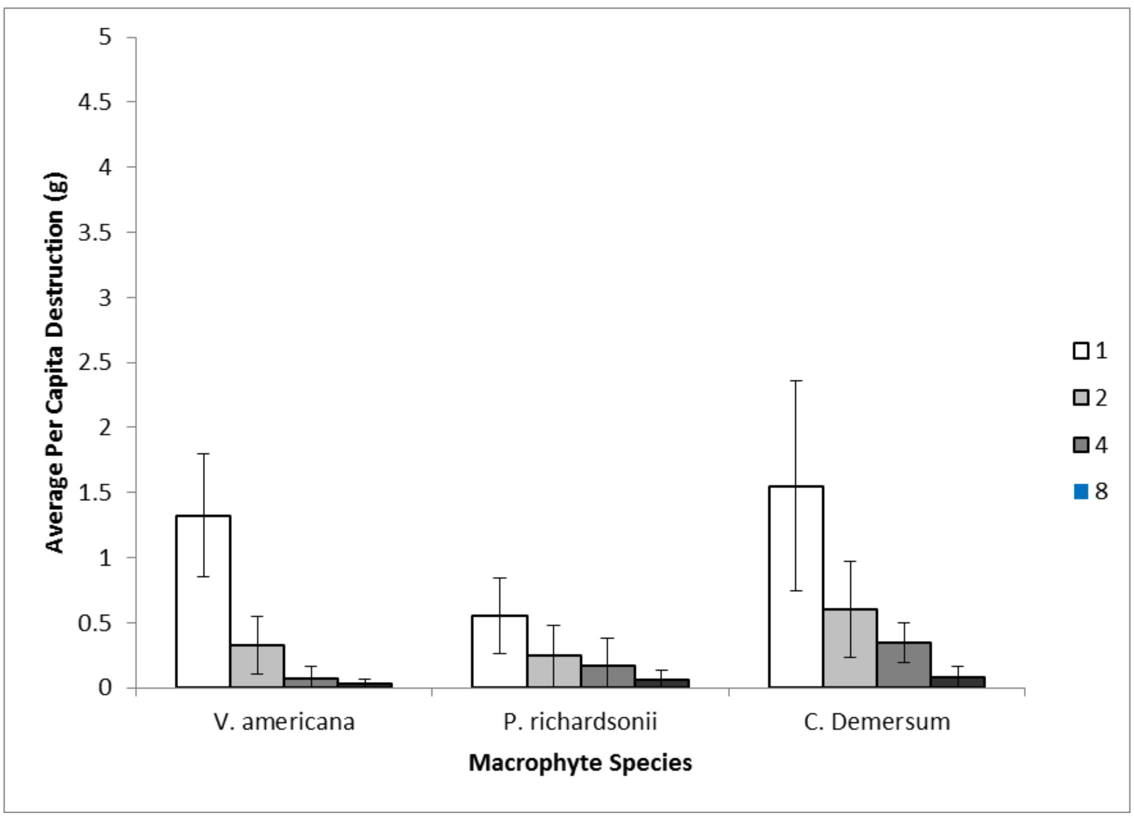

Figure 2. The average per capita destruction as crayfish density increased was examined for each plant species. Per capita destruction as crayfish density increased was non-significant for all

three species: *V. Americana* ($F_{3,12}$=1.86, p=0.189), *C. demersum* ($F_{3,12}$=0.69, p=0.975) and *P. richardsonii* ($F_{3,12}$=0.25, p=0.859).

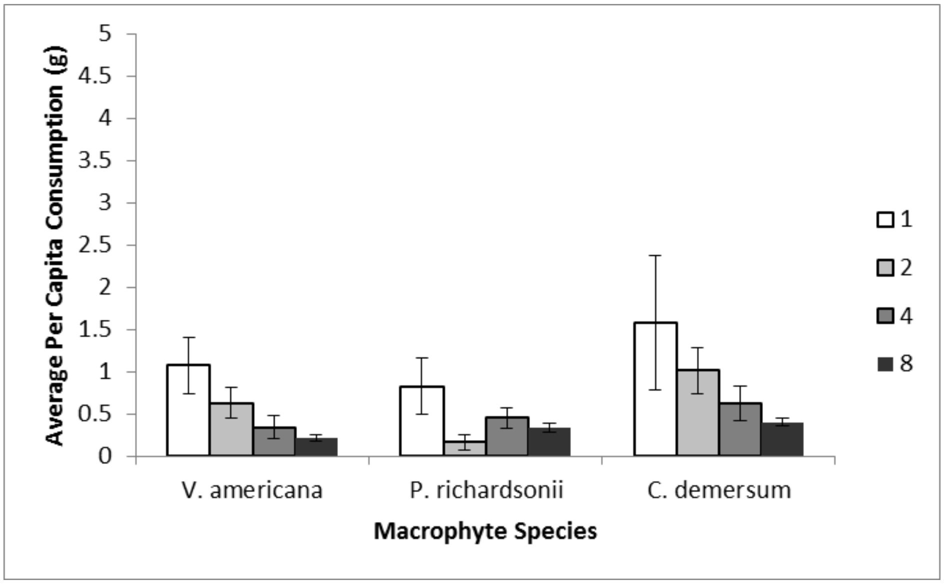

Figure 3. The average per capita consumption was analyzed against increasing crayfish density with respect to each macrophyte species. There was a general decreasing trend for per capita consumption although there was no significance found. *V. americana* ($F_{3,12}$=2.47, p=0.111), *C. demersum* ($F_{3,12}$=0.493, p=0.694) and *P. richardsonii* ($F_{3,12}$=1.49, p=0.265).

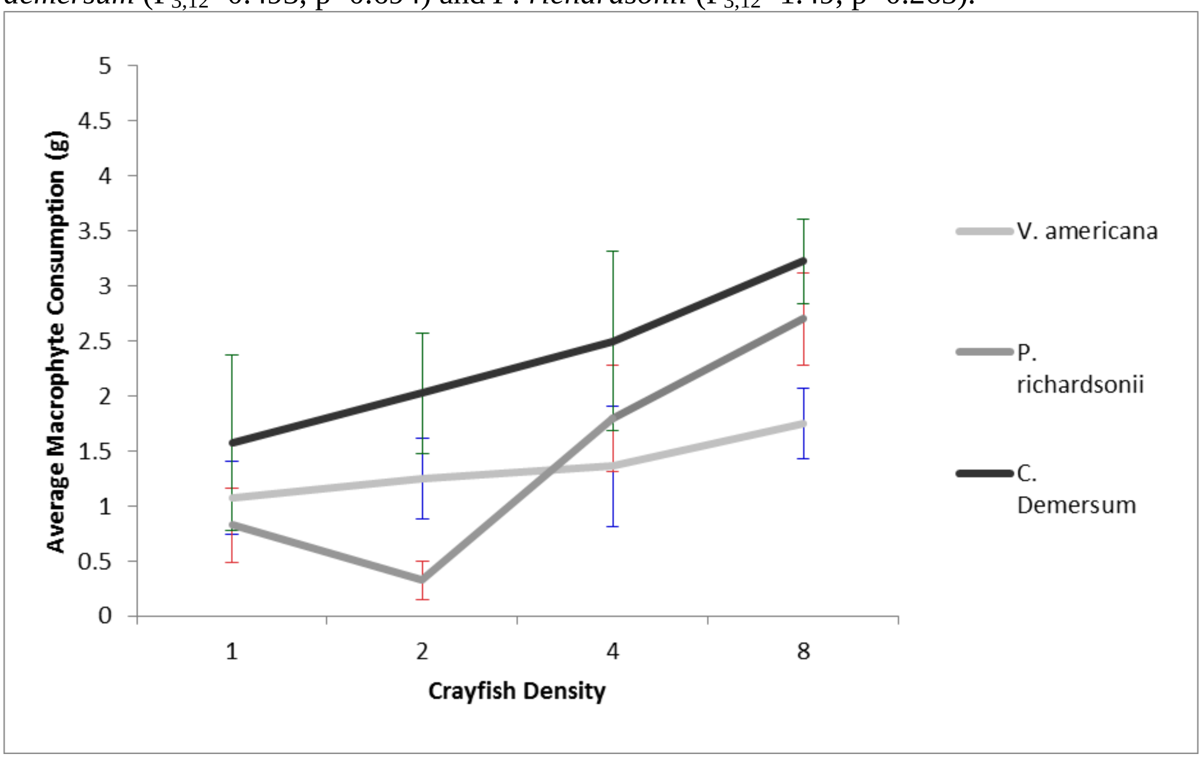

Figure 4. The average macrophyte consumption of the three species was evaluated against increasing crayfish densities. Overall, *C. demersum* was preferred the most, *V. Americana* was surpassed by *P. richardsonii* as the crayfish were at a density of 4 per a tank.