Feeding electivity of *Pugettia gracilis,* the graceful kelp crab (Decapoda: Epialtidae), and its potential importance to nearshore kelp forests

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Abstract

Kelp forests are an integral part of complex marine food webs, and it is important to be aware of the roles of the varied consumers in kelp forests to understand the complexity of the food webs in such an ecosystem. The traditional ecological paradigm in regards to kelp bed food webs is the top down control by sea otters, which has been studied in great detail in Alaska. However, an experimental urchin removal study in the San Juan Channel showed that neither a monthly complete harvest of sea urchins (simulating sea otter predation), nor an annual size-selective harvest of sea urchins (simulating commercial urchin harvest), significantly increased the density of perennial or annual (incl. *Nereocystis luetkeana*) species of macroalgae after 2 years. These results suggest that other factors, such as grazing by other invertebrates, may play a large role in influencing community structure in the San Juan Channel. Invertebrate herbivores have been shown to play a crucial role in kelp bed destruction in *N. luetkeana* systems and it is known that crabs are important trophic links in kelp-dominated habitats and can influence food web dynamics by acting as consumers.

I explored the potential role of *Pugettia gracilis* as kelp consumers using controlled choice and no-choice feeding experiments. I hypothesized that *P. gracilis* would show a feeding preference for *N. luetkeana* over two other local abundant kelp species. I performed my feeding trials with ten *P. gracilis* individuals, and three kelp species: *Alaria marginata, Nereocystis luetkeana,* and *Saccharina latissima.* The results of my trials showed that *P. gracilis* shows a feeding preference for *N. luetkeana* over *A. marginata* and *S. latissima.* These results show that despite the small size of *P. gracilis,* in dense population abundances it may be an important part of current trophic dynamics

and population changes of *N. luetkeana* forests in the San Juan Islands and elsewhere in the Salish Sea.

1. Introduction

Kelp forests play an important ecological role in marine environments, providing a wide variety of species with food, protection, and habitat for many life stages. Primary production provided by kelp dominated habitats is not restricted to use in the photic zone, but also supplies detrital material to organisms living below the photic zone (Duggins and Eckman, 1994). Kelp forests are an integral part of complex food webs, which include important apex vertebrate predators and many levels of invertebrate grazers. Pacific kelp forests have experienced a significant population decline since the unregulated harvest of sea otters, *Enhydra lutris,* which began in the 1780s and peaked in the first half of the nineteenth century (Szpak et al. 2011). The significant decrease in populations of *E. lutris*, the sea urchin's main predator, has led to outbreaks of sea urchin, *Strongylocentrotus spp*., populations and probably small-scale kelp deforestation (Steneck et al. 2002).

The canopy forming *Nereocystis luetkeana* kelp forests in the San Juan Islands and elsewhere in the Salish Sea have seen a significant decrease since the early 20th century (Thom and Hallum, 1991; Spencer 2006), and while globally urchin-induced deforestation has been increasing over the past 2–3 decades (Steneck et al. 2002), this does not necessarily mean that urchins are the sole herbivore threatening well-developed kelp forests. An experimental urchin removal study in the San Juan Channel showed that neither a monthly complete harvest of sea urchins (simulating sea otter predation), nor an annual size-selective harvest of sea urchins (simulating commercial urchin harvest), significantly increased the density of perennial or annual (incl. *N. luetkeana*) species of macroalgae after 2 years. These results suggest that other factors, such as grazing by other invertebrates, may play a large role in influencing community structure in San Juan Channel (Carter et al., 2007).

Pugettia gracilis, the graceful kelp crab, occupies a diverse range of habitats from the low intertidal to significant depths in kelp and eelgrass forests, in the North Pacific Ocean ranging from Monterey, California to the Aleutian Islands, Alaska (Daley and Konar, 2010). Invertebrate herbivores have been shown to play a crucial role in kelp bed destruction in *N. luetkeana* systems (Leighton, 1966; Foreman, 1977), and it is known that crabs are important trophic links in kelp-dominated habitats and can influence food web dynamics by acting as consumers (Hines, 1982; Polis and Strong 1996). Despite the small size of *P. gracilis*, it may be an important part of current trophic dynamics and population changes of *N. luetkeana* forests in the San Juan Islands and elsewhere in the Salish Sea. It is important to be aware of the roles of the varied consumers to understand the complexity of the food webs in such an ecosystem.

I explored the potential role of *Pugettia gracilis* as kelp consumers using controlled experiments adapted from a similar feeding preference experiment on another local kelp crab, *Pugettia producta. P. producta* showed a higher electivity for *N. luetkeana* than two other local kelp species, as well as four other macroalgal species (Dobkowski, *forthcoming)*. I hypothesized that because *P. gracilis* is similar to *P. producta*, it would also show a feeding preference for *N. luetkeana.*

2. Methods

2.1 Study Site

All experiments and collections of animals and algae occurred at Friday Harbor Laboratories, San Juan Island, Washington, USA, from April to June 2013. Feeding experiments were held in clear plastic storage tubs (42.5 cm x 30.2 cm x 17.8 cm) with three holes drilled in one wall to allow for water flow. Tubs sat in the flow-through seawater tables (60 cm x 124 cm x 124 cm) and were covered in plastic grating to allow for airflow and to prevent *P. gracilis* from escaping.

2.2 Study Species

All animal and algae species used are native to the San Juan Islands and co-occur in the Friday Harbor Laboratories vicinity. Ten specimens of *P. gracilis* with a carapace width of 2.3 cm to 3.3 cm were used to perform all experiments. Both male and female individuals were used. Carapace width of each *P. gracilis* individual was recorded. Three abundant kelp species found in the San Juan Islands: local species of macroalgae were used for feeding experiments: *Nereocystis luetkeana, Saccharina latissima,* and *Alaria marginata.*

2.3 Algal Tissue Experiment

A choice, no-choice intact algal tissue experiment was used to determine consumption and electivities of *P. gracilis* among *N. luetkeana, S. latissima,* and *A. marginata.* This experiment was conducted in four trials with the same *P. gracilis* individuals, and the change in mass was averaged for each crab upon completion of all trials. Kelp blades (fresh vegetative tissue only) were cut into pieces of 5 cm x 7.5 cm, wiped with a paper towel to reduce contaminants, epiphytes, and excess water, and weighed. Midribs and sporophylls were not used. Ten tubs were set up in the flow-through seawater tables, and each crab remained in its designated tub for the duration of the experiments. Each of the ten crabs was assigned at random one of four trials (one piece of *N. luetkeana*, *S. latissima,* or *A. marginata*, or a buffet of the three kelp species) until each crab participated in all trials. Control trials were held for each test alga, in pieces of 5 cm x 7.5 cm, in tubs identical to those used for feeding trials (without crabs), to account for any change in mass *not* due to herbivory. *P. gracilis* were starved for 24 hours prior to a 24 hour period of feeding during each trial. After the 24 hour feeding period, the remaining algal tissue was collected, wiped dry with paper towel, and its mass was recorded.

2.4 Statistical Methods

All analyses were completed using R version 2.15.1. Two-way ANOVA tests were run to analyze the results of all trials of the intact algal tissue feeding experiments.

3. Results

P. gracilis consumed different amounts of the three local kelp species, *A. marginata, N. luetkeana,* and *S. latissima*, however, the results of combined choice and no-choice show that among the three kelp species, *N. luetkeana* had higher electivity than *A. marginata* (p=0.002), and *S. latissima* (p=0.001) (Table 1). There was no significant difference between the consumption of *A. marginata* and *S. latissima* (p=0.983) (Figure 1).

In choice trials, there was no statistical significance between the consumption of *N. luetkeana* and *A. marginata*, as well as between *N. luetkeana* and *S. latissima,* but the statistics show there is no difference between the consumption of *A. marginata* and *S. latissima* (Table 2). In no-choice trials, this trend is still supported; crabs consumed significantly more *N.* luetkeana than *A. marginata* (p=0.0382), and there was no statistical difference between the consumption of *A. marginata* and *S. latissima* (Table 3). This trend was apparent in the analysis of both choice, no-choice, and combined data, suggesting that *P. gracilis* prefers *N. luetkeana* over both *A. marginata* and *S. latissima.*

The results of the control trials showed that the change in mass not due to herbivory was about -3% for *A. marginata*, about 4% for *N. luetkeana*, and about 2% for *S. latissima.* I did not do a correction in my data for this as it was a small difference, and would likely not show much significance (Figure 2).

4. Discussion and Conclusions

Graceful kelp crabs, *P. gracilis,* eat several species of kelp and show a significant preference for *N. luetkeana* over *A. marginata* and *S. latissima*. Although *P. gracilis* may be a small crab, in high enough densities, they could have a population level impact on kelp, for example *N. luetkeana.* In situations where *P. gracilis* might graze on juvenile or solitary *N. luetkeana,* an even greater impact could occur. To gain a greater understanding of the role *P. gracilis* may play in local *N. luetkeana* food webs, data on local *P. gracilis* population abundances must be obtained, along with feeding rates, which could be studied in lab and extrapolated to predict the effects of *P. gracilis* grazing at higher population densities.

Feeding trials conducted with the larger kelp crabs, *Pugettia producta,* indicated no preference between *N. luetkeana* and snails as a food source (Dobkowski et al, *Forthcoming*). There is little known in regards to the complete diet of *P. gracilis,* but it is plausible that *P. gracilis* could also incorporate small invertebrates such as snails into its diet. Observational evidence in my research shows that *P. gracilis* also eats invertebrates. I found my crabs consuming large pieces of dead sea cucumber, suggesting that *P. gracilis* also plays a role as a scavenger in kelp bed food webs, which would be another interesting topic to investigate further.

Unlike *P. producta, P. gracilis* decorates its rostrum and sometimes its carapace. It would be interesting to explore whether *P. gracilis* has a preference for the alga it chooses to decorate its rostrum, and whether such preferences match its food choices. During feeding trials I discovered that after a 24 hour or longer starving period, many of the crabs would remove and eat their decoration. It would also be interesting to see if after a longer period of starvation, the crabs use a larger piece of algae, or possibly even choose an alga of higher caloric content, to replace their decorations with.

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5. Figures:

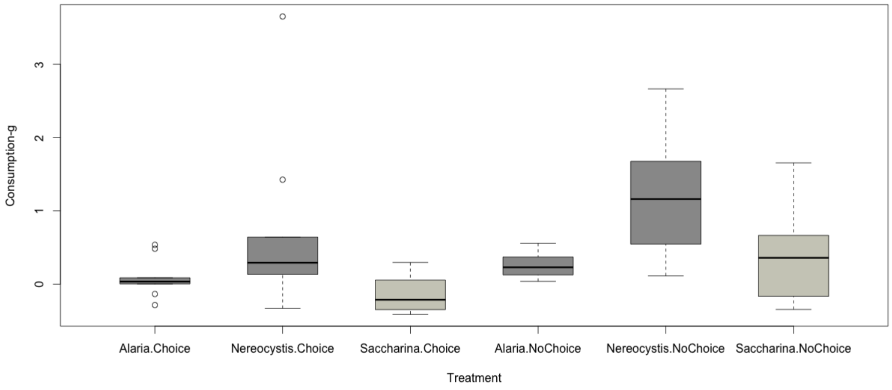

Figure 1: Consumption in grams of *Alaria, Nereocystis,* and *Saccharina* in choice and no-choice feeding trials. The consumption medians for each alga in each trial are shown with a horizontal line through the interquartile range box. The lines extending above and below the boxes are the highest and lowest observations within each treatment. In two choice trials, *Alaria* and *Nereocystis*, there were significant outliers.

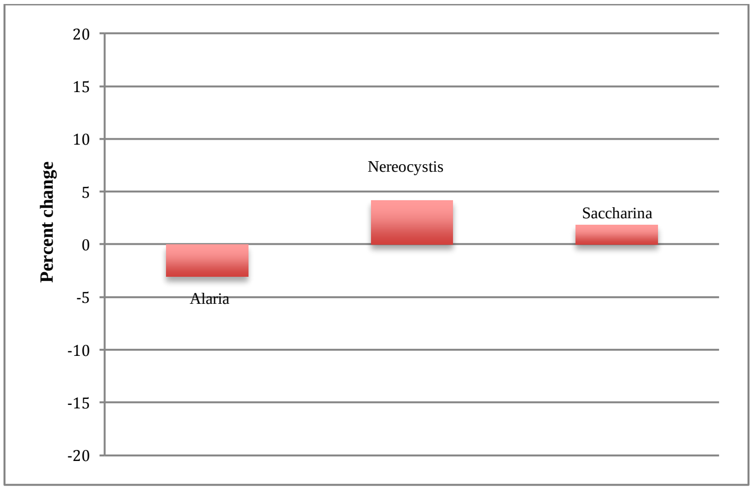

Figure 2: Percent change of *Alaria, Nereocystis,* and *Saccharina* in algal tissue control trials. *Alaria* showed a percent change of -3.049%, *Nereocystis* showed a percent change of 4.191%, and *Saccharina* showed a percent change of 1.876%.

6. Tables:

Combined treatments	p value
Nereocystis-Alaria	0.0015137
Saccharina-Alaria	0.982862
Saccharina-Nereocystis	0.0008697

Table 1: P values for combined trial data

Choice		p value
Nereocystis	*Alaria*	0.2772186
Nereocystis	*Saccharina*	0.0574922
Saccharina	*Alaria*	0.9750547

Table 2: P values for choice treatment data

No Choice		p value
Nereocystis	*Alaria*	0.0381849
Nereocystis	*Saccharina*	0.123893
Saccharina	*Alaria*	0.9961301

Table 3: Percent change of *Alaria*, *Nereocystis*, and *Saccharina* in algal tissue control trials