

PUGETTIA PRODUCTA, THE OSTENSIBLE EPICUREAN

Ken Hamel

Botany Department, University of Hawaii - Manoa, 3190 Maile Way, Honolulu, HI 96822

ABSTRACT

The kelp crab of the northeastern Pacific coast, *Pugettia producta*, has long been believed to be a facultative herbivore, feeding on macroalgae in the warmer months and on small invertebrates when algae are unavailable. Many claims have been made as to which algae are preferred, information important to determining the ecological role of this small brachyuran, most recently and convincingly *Nereocystis luetkeana*. Here, two non-kelp species are evaluated alongside two kelp species in a standard feeding preference assay. Results indicate that *P. producta* may prefer *Ulva* spp. over kelp species, the algal type to which it is most often ascribed a preference.

INTRODUCTION

Nereocystis luetkeana is an important canopy forming kelp species endemic to the west coast of North America. The distribution of *N. luetkeana* is influenced by a number of factors, among them herbivory and herbivore abundance (Paine 2002, Chenelot and Konar 2007). A number of studies have shown that herbivory can have profound influence over kelp distribution, (Duggins 1981, Vasquez & Buschmann 1997), especially in the absence of species that prey on urchins, (Estes 1974). Evidence indicates that some herbivorous species prefer *N. luetkeana* over other algal species (Vadas 1977).

The kelp crab, *Pugettia producta* (Randall), is considered a facultative herbivore in non-winter months (Knudsen 1964); various investigators have described *P. producta* as having specific preferences for various algae, though offering little to no evidence to

support these claims (Bracken & Stachowitz 2007, Garth & Abbott 1980). Preliminary laboratory experiments suggest that *P. producta* prefer *N. luetkeana* over other kelp species that commonly grow near one another in the environs of Friday Harbor Labs, San Juan Island, WA (Dobkowski 2012). Determining whether *P. producta* prefers to eat *N. luetkeana* over other algal species may help to elucidate how strongly associated these species are and to what extent they exert influence over one another in terms of local and regional distribution and abundance.

In an effort to assess whether *P. producta* prefers *N. luetkeana* over other algal species or if it is simply opportunistic with respect to herbivory, it was offered both whole plant tissue as well as “artificial food” (composed of freeze-dried algae and agar) in separate experiments; this latter preparation was intended to help determine whether the tissue test results are a product of texture preference and may suggest reasons for the food choice (if any).

MATERIALS AND METHODS

Collections

Specimens of *Costaria costata* (J. Agardh) De A. Saunders, *Nereocystis luetkeana* (K. Mertens) Postels & Ruprecht, *Fucus distichus* Linnaeus and *Ulva* spp. were collected from the immediate environs of Friday Harbor Laboratories on several mid-August days in 2012. Crab specimens were collected from the outermost east side of the Friday Harbor Laboratories docks. Crab weight and carapace lengths are recorded in Table 1.

Whole tissue experiment

All samples but those of *F. distichus* were cut into 30 x10 cm strips and weighed prior to being placed in one of 18 flowing seawater tanks. Those of *F. distichus* were separated into approximately equally-sized branches, and also placed in the tanks. Each tank received one sample of each species, for a total of four samples per tank. After 25 hours of starvation, an individual *Pugettia producta* was placed in each of nine tanks; the remaining nine tanks acted as autogenic controls to account for the effects of flowing seawater and associated tissue loss. After 12 hours of feeding, algae were removed and weighed.

Artificial food experiment

Algae were freeze dried in a Labconco lyophilizer at -1° C for 2 days. Material was then ground in a coffee grinder for ca. 2 minutes. Resulting powder was suspended in 2.5% agar + seawater media in 100 x 15 mm plates resulting in gelatinous discs; additional discs were prepared *sans* algal powder to act as autogenic controls. After 25 hours of starvation, an individual *Pugettia producta* was placed in each of nine tanks, followed by one disc each of *Costaria costata*, *Nereocystis luetkeana*, and *Ulva* spp. *F. distichus* discs did not gel sufficiently and were therefore excluded from this experiment. After 12 hours of feeding, artificial food discs were removed and weighed.

Data analyses

Effects of crab feeding on the tissue mass of four algal species was evaluated using two-way analysis of variance (ANOVA). Effects of crab feeding on algal cake mass was evaluated using one-way (ANOVA). Tukey's HSD were conducted post hoc after each ANOVA. All tests conducted using SPSS version 19 (IBM).

RESULTS

Whole tissue experiment

Two-way ANOVA revealed a significant difference in the consumption by crabs in terms of percent consumed of algal species ($p < 0.0001$). *Post hoc* testing showed significantly more *Ulva* spp. was consumed than of the other species ($p = 0.001$), that *P. producta* preferred *N. luetkeana* and *C. costata* equally and *F. distichus* least of all (Fig. 1).

However, when total algal tissue mass consumed is evaluated, no difference is observed between *Ulva* spp. and *N. luetkeana* ($p = 0.412$) or *C. costata* ($p = 0.099$).

Artificial food experiment

P. producta readily consumed some part of most of the algae-agar plates (Fig. 2). One-way ANOVA revealed a significant difference in the consumption by crabs in terms of percent consumed of algal species ($p < 0.016$). However, *post hoc* testing showed a significance difference only between *Ulva* spp. and *C. costata* ($p = 0.018$).

DISCUSSION

This work shows for the first time that *P. producta* not only consumes, but may prefer, green macroalgae to kelp species. *P. producta* appears to favor *Ulva* spp. over *N. luetkeana*, at least in whole food form, and favors it only slightly more to the latter when in disc form. Although in terms of total mass, more bull kelp was eaten than *Ulva* spp., this measure may not be indicative of preference since smaller fragments of *Ulva* tend to drift away rapidly, often out of the reach of the crabs; the story may change if the crabs were offered equal *masses* of algal species rather than equal shapes.

During observation of feeding behavior in the artificial food study, crabs were observed to tentatively (if such a term can be used here) taste morsels at first encounter, which supports Knudsen's (1964) assertion that tactile and visual sensory input play a more important role in crab food search than chemical signaling, and that the *P. producta* must be close to its food source to recognize it as food (Zimmer-Faust & Case 2003). This holds true even for *C. costaria*, which ultimately was avoided by the crabs, but only after one or more attempts to eat portions of cake.

In the first experiment, *Fucus* may have been passed up in favor of other species as a result of positive buoyancy. Crabs were seen to reach for *Fucus* branches, only to have them drift away at first touch, at which the crab would go back to other algae more immediately available. In the future, *Fucus* plants should be secured to avoid this drifting.

A number of authors have suggested algal species for which they believed *P. producta* to have a preference. Early literature on *P. producta* mention brown algae in general as

being food species (Knudsen 1964) and Garth & Abbott (1980) assert specifically that *Sargassum*, *Fucus* and *Nereocystis* are the primary food plants, though neither of these publications offer citations. Leighton (1966) demonstrated that they do consume *Macrocystis pyrifera*, the plant most often associated with the kelp crab. *P. producta* has been found to be an important influence on *Egregia menziensis* biomass (Bracken & Stachowitz 2007), but this does not demonstrate preference for *Costaria* as the authors maintain. Dobkowski (2012) was the first attempt to quantify *P. producta* preference for any algae, rather than simply observing feeding behavior.

P. producta is obviously willing to eat other algal species outside of the Laminariales. Hultgren & Stachowicz (2010) report that the crab has a preference for *Neorhodomela larix* and *Sarcodiotheca gaudichaudii*, the first report to name rhodophyte species as food for this brachyuran species (although Knudsen 1964 reports the presence of rhodophyte tissue in *P. producta* stomach contents). Unfortunately, the methodology used to make these determinations remains unpublished.

It is clear from the results that *P. producta* has no taste for *C. costaria*, and that the reasons go beyond food texture. It may have some chemical defense that deters herbivory, but none has been recorded to date. Van Alstyne et al. 1999 reported that the snail, *Lacuna porrecta*, preferred young *C. costata* to adult tissue, but was still willing to eat the latter. Marine molluscs are often willing to eat algae considered unpalatable to other organisms (Pennings and Paul 1992) and therefore may not be good indicators of a lack of defense against herbivory.

This study demonstrates that kelp crabs do not necessarily prefer kelps to other algae as foodstuffs, though they may have a favorite among kelps in a given region. Observation of feeding behavior suggests that they will at least taste whatever potential food is closest before moving on to something that can hold their interest. Other tests should follow, with the aim of determining to what extent the herbivory of *P. producta* is driven by seasonality, availability or convenience, i.e. whether they are in fact opportunistic omnivores.

ACKNOWLEDGEMENTS

I gratefully acknowledge Ruth McDowell for her advice regarding food preference assay preparation and quantification, Katie Dobkowski for sharing literature, data and her project and J. Robert Waaland for providing assistance in collecting both animal and algal specimens. And to FHL for providing the financial assistance without which this work would not be possible.

REFERENCES

Andrews HL (1945) The Kelp Beds of the Monterey Region. *Ecology* 26: 24-37

Bracken MES & JJ Stachowicz (2007) Top-down modification of bottom-up processes: selective grazing reduces macroalgal nitrogen uptake. *Mar Ecol Prog Ser* 330: 75-82

Chenelot H and B Konar (2007) *Lacuna vincta* (Mollusca, Neotaenioglossa) herbivory on juvenile and adult *Nereocystis luetkeana* (Heterokontophyta, Laminariales). *Hydrobiologia* 583: 107-118

Dobkowski K (2012) Kelp crabs (*Pugettia producta*) eat Kelp Species (*Neoreocystis luetkeana*, *Alaria marginata*, *Saccharina latissima*) found near Friday Harbor, Washington. 26th Annual Northwest Algal Symposium. University of British Columbia, Vancouver, Canada. May 11th-13th, 2012

Estes JA, Palmisano JF (1974) "Sea otters: their role in structuring nearshore communities". *Science* 185: 1058-1060

Garth JS & DP Abbott (1980). *Brachyura: The True Crabs in Intertidal Invertebrates of California*. Morris RH, DP Abbott & EC Haderlie (Eds). Stanford University Press, Stanford, CA. 690 pp.

Hultgren KM & JJ Stachowicz (2010) Size-related habitat shifts facilitated by positive preference induction in a marine kelp crab. *Behavioral Ecol.* 21: 329-336.

Knudsen JW (1964) Observations of Reproductive Cycles & Ecology of Common Brachyura & Crablike Anomura of Puget Sound, WA. *Pac Sci* 18 3-33

Leighton DL (1966) Studies of Food Preference in Algivorous Invertebrates of Southern California Kelp Beds. *Pac Sci* 20 104-113

Paine RT (2002) Trophic control of production in a rocky intertidal community. *Science* 296:736-739

Pennings, SC & VJ Paul (1992) Effect of plant toughness, calcification, and chemistry on herbivory by *Dolabella auricularia*. *Ecology* 73: 1606-1619.

Vadas RL (1977) Preferential Feeding: An Optimization Strategy in Sea Urchins.
Ecological Monographs 47: 337-371

Van Alstyne KL, JM Ehlig & SL Whitman (1999) Feeding preferences for juvenile and adult algae depend on algal stage and herbivore species. Mar Ecol Prog Ser 180: 179-185.

Vasquez JA & AH Buschmann (1997) Herbivore-kelp interactions in Chilean subtidal communities: a review. Revista Chilena de Historia Natural 70:41-52.

Zimmer-Faust RK & JF Case (1982) Organization of food search in the kelp crab, *Pugettia producta* (Randall) J. Exp. Mar. Biol. Ecol 57: 231-255.

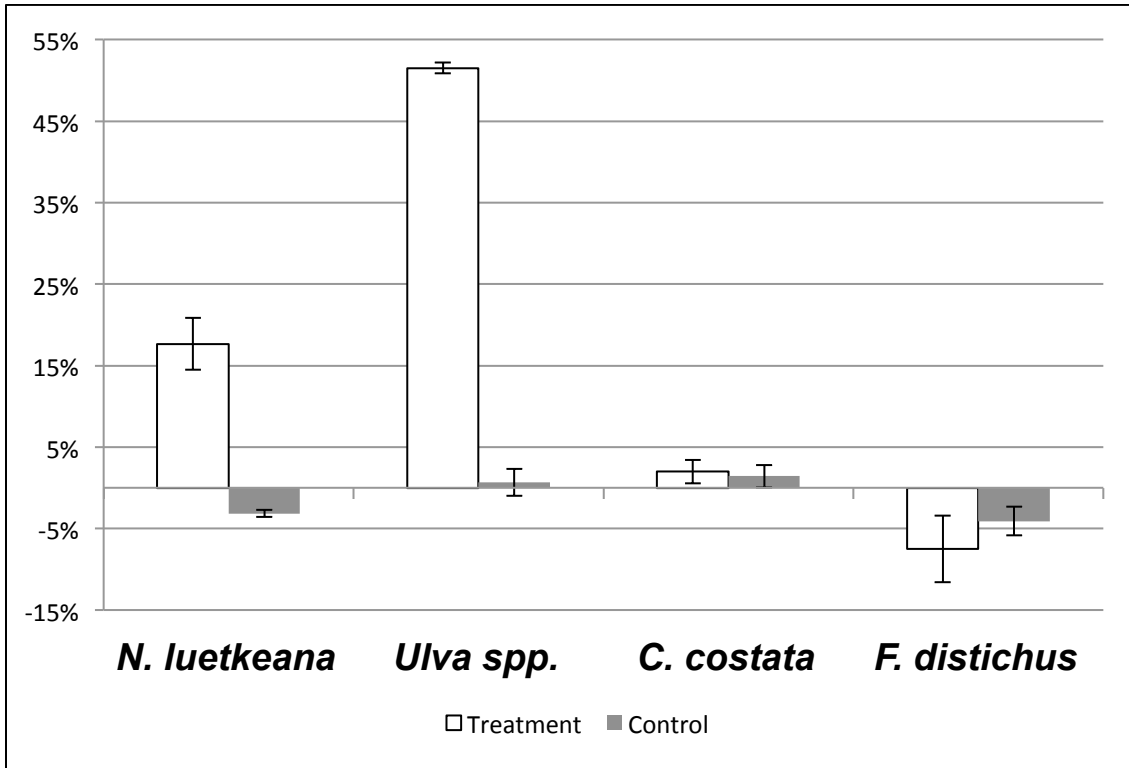


Figure 1: Percent of algal portion consumed. A clear preference for *Ulva spp.* is indicated. *Fucus distichus* appears in the negative as it took on water and was not consumed during the study.

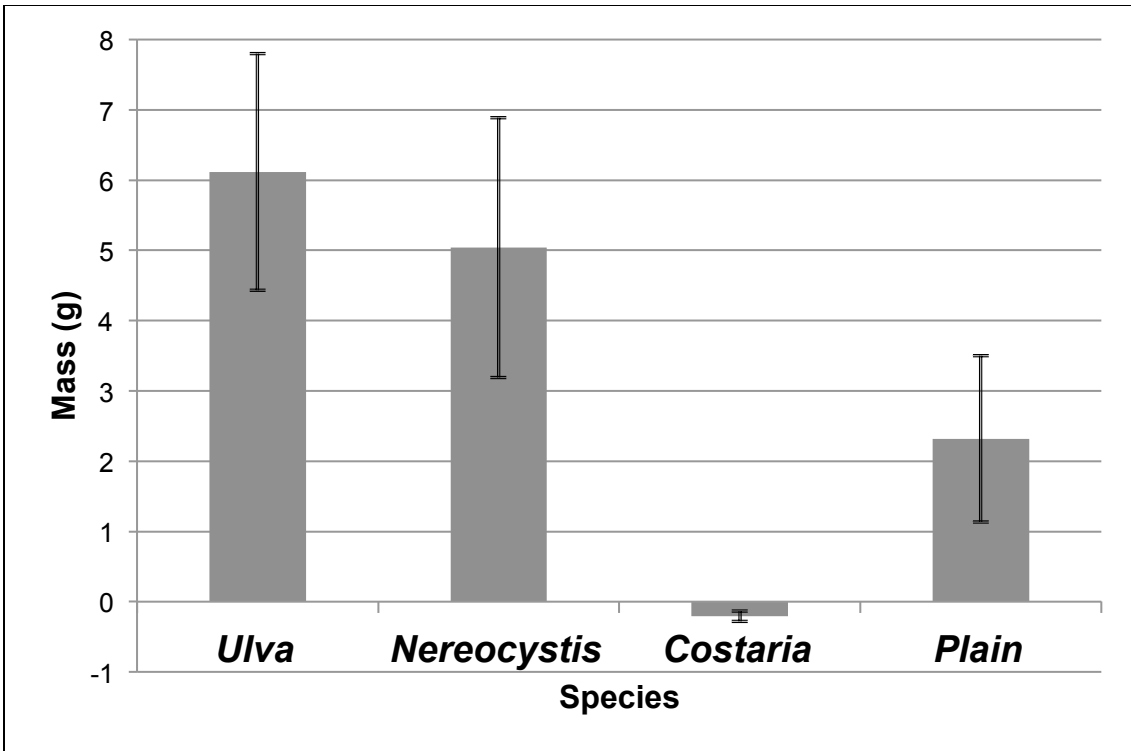


Figure 2: Total artificial food consumed.

Crab ID	Carapace length (mm)	mass (g)
1	57	81.45
3	48	48.53
4	67	112.95
7	68	124.40
8	71	228.30
9	39	27.68
10	38	46.34
11	63	94.40
12	45	48.27

Table 1: *P. producta* carapace lengths and corresponding masses. Crab 3 lacked 3 left-hand walking legs. Crabs 3 and 7 were not used in the artificial food experiment.