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Abstract

Predation within the intertidal zone, specifically regarding the predator-prey interaction between sea stars in Class Asteroidea and their food source, contributes to a large biodiversity of organisms. In this experiment, we compared the percent coverage of algae and shelled organisms within a quadrat surrounding three types of predatory sea stars (Pisaster ochraceus, Dermasterias imbricata, and Lepasterias hexactis) to determine their habitat based on predatory behavior. Our data showed a significant difference in algae and shelled organism coverage between different species of sea star; shelled organism percent coverage was less than algae percent coverage in all species of sea stars. The niche, or role and position a species plays in its environment, of each star ultimately influenced the frequency and diversity of other recorded organisms.

Keywords: asteroids, algae coverage, gastropod, arthropod, intertidal, Pisaster ochraceus

Introduction

The beaches in Northern California consist of rocky intertidal shores, which are inhabited by various marine invertebrates and a wide selection of algae (Foster et al. 1988). The intertidal zone can be broken up into four smaller zones, described by the species that inhabit those zones (Foster et al. 1988). The two lowest zones, the Splash Zone and the Barnacle Zone, are mostly comprised of kelp, sea stars, mussels, and barnacles. One of the most common inhabitants in Northern California is the ochre star *Pisaster ochraceus*, accompanied by the leather star (*Dermasterias imbricata*) and six-rayed star (*Lepasterias hexactis*). Asteroids are carnivorous, and their diet consists mostly of shelled organisms, such as mussels (Paine 1976, Penchaszadeh and Lera 1983, Monteiro and Pardo 1994). These sea stars are often found near areas of dense mussel beds or other food sources (Paine 1976).

Table 1. Summary of F test comparing the variance between the different groups (F = f distribution factor, df = degrees of freedom).

Comparison Groups	F	Num df	Denom df	P-value
Algae: Pisaster v Other	1.2661	49	37	0.458
Shelled: Pisaster v Other	5.1344	33	22	0.0001675
Pisaster: Algae v Shelled	284.7	49	33	< 2.2e-16
Other: Algae v Shelled	1154.6	37	22	< 2.2e-16

Sea stars play an important role in the intertidal zone, they are described as a keystone species based on how their presence increases biodiversity due to their predation on mussels (Manzur et al 2009). Biodiversity is crucial to keeping an ecosystem functioning, as each species has their own role in the productivity of that ecosystem. In this study, we looked at different species of sea stars and the habitats immediately surrounding them by measuring algae coverage and animal coverage in that area. Animals that were observed in this area included gastropods such as marine snails and limpets, and arthropods such as hermit crabs. With the impending threat of climate change, intertidal species are at a greater risk of desiccation, or drying out, which can threaten the species survival. Tracking sea star's prey selection can help scientists to measure the health of this keystone species. We hypothesize that shelled organisms should be more abundant than algae near sea stars because sea stars are more likely to be found in dense areas of food sources, such as mussel beds.

Methods

We measured algae and shelled percentage coverage among 51 *P. ochraceus* and a combined 31 *D. imbricata* and *L. hexactis*. We collected data three separate times at Patrick's Point State Park (41.1298° N, 124.1651° W) and Baker Beach (41.0477° N, 124.1236° W) at low tide during the week of November 10th-17th, 2019 (Fig 1). The low tide levels ranged from -0.3 ft to 2.6 ft. Percent coverage was determined using a 0.50 x 0.50 meter quadrat with 100 squares, each square representing 1% coverage. We centered the quadrat on the sea star and counted squares occupied by algae or shelled organisms. Percent coverage of algae and shelled organisms between *P. ochraceus* and other stars was analysed using the statistical program R. Three tests were run: the Shapiro-Wilk normality test to determine data normalcy, an F-test to compare variances, and a Wilcoxon rank sum test with continuity correction for determining significance of differences seen in the data.

Results

The average quadrat makeup differed between the groups of sea stars we compared. Results from F- and the Shapiro-Wilk test indicated that most data sets did not meet statistical standards for equal variance and normality (Table 1, Table 2); this led us to run a Mann-Whitney test to determine significance (Table 3).

Algae was the most abundant group throughout the duration of the experiment, no matter the asteroid we measured (Fig 2). Even with this, the Mann-Whitney test showed significant differences between algae percent coverage of *P. ochraceus* compared to other sea stars in the intertidal zone; there is significantly more algae surrounding *D. imbricata* and *L. hexactis* than *P. ochraceus* (p-value 2.47e-05, Table 4). When comparing shelled organisms, we see a different pattern arise. The mean percent coverage of shelled organisms is significantly different, but with a majority of shelled organisms surrounding *P. ochraceus* (p-value 0.0004525).

By looking at the data, it is apparent that there was a difference in shelled and algae coverage within each sea star group. There is significantly more algae in both groups compared to shelled organisms (p-value < 2.2e-16, Table 4).

Discussion

Our data and measurements provided our research group with indications that did not support our hypothesis, namely, that if sea stars predominantly feed on shelled organisms, then the percent coverage of shelled organisms would surpass that of algae within each quadrat sample. We recognized that the opposite was true; the percent coverage of algae actually exceeded that of all sea stars and shelled organisms in almost every quadrat that was sampled. Although the experiment we conducted did not cater to our initial hypothesis, the frequency of our measurements provided us with a better understanding regarding the differences, similarities, and patterns between percent coverage of shelled organisms and algae in relation to the different sea stars.

Average percent coverage of algae was greater among *L. hexactis* and *D. imbricata* than that of *P. ochraceus*. However, the average percent coverage of shelled organisms was greater among *P. ochraceus*. This is most likely due to the protection that the algae may provide for smaller sea stars, such as *L. hexactis*; *Leptasterias* spp., which are noted to

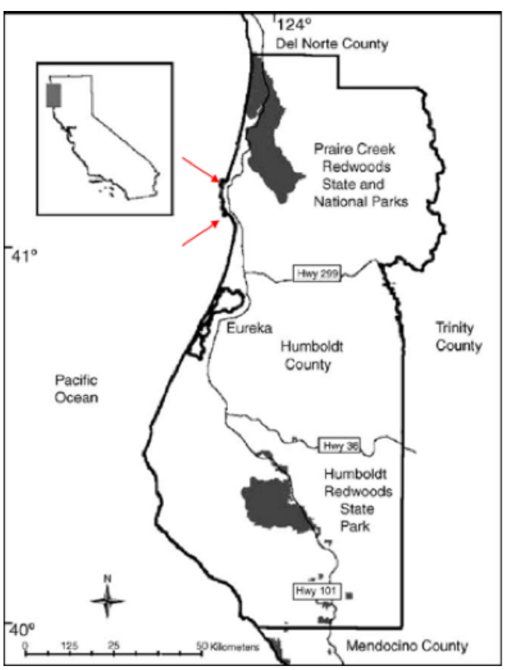

Fig 1. Map of Humboldt County showing the locations of data collection (Baker Beach and Patrick's Point State Park). Adapted from Ashton et al. 2006

reside in mussel beds or in nearby pools, usually in contact with sea grass or algae (Jaffe et al. 2019) We observed that *P. ochraceous* were found more often attached to bare rock, while other sea stars were found more submerged in water. Our data also shows that a variety of other organisms such as anemones, urchins, and nudibranchs were recorded within *L. hexactis* and *D. imbricata* quadrat samples, while *P. ochraceus* was often seen only in the presence of algae or some shelled organisms. The niche of each star ultimately influenced the frequency and diversity of other recorded organisms.

Identifying diet according to each individual species would strengthen this study and may provide more conclusive results in the future, as well as recording data in control quadrats that did not contain sea stars. Understanding the prey selection of sea stars and their location within the intertidal zone drives the understanding of the ecosystem as a whole; a change in sea star behavior would cause catastrophic change in the structure of the intertidal zone. This was observed during the seastar wasting disease outbreak in 2014, when the population of sea stars on the West Coast, specifically *P. ochraceus*, was impacted by the disease. This caused a significant reduction in predation rates of mussel beds (Menge et al. 2016), which results in decreased biodiversity and community structure (Paine 1976). Studying the habitat selection of different sea stars provides future scientists with a basic understanding that is necessary to protect these keystone species in our intertidal zone. With

Table 2. Summary of Shapiro-Wilk test for normality in each data set (W = W-value).

Data sets	W	P-value
Algae (Pisaster)	0.86301	3.549e-05
Algae (Other)	0.93393	0.02672
Shelled (Pisaster)	0.86395	0.0005831
Shelled (Other)	0.81916	0.0007892

Table 3. Summary of Wilcoxon rank sum test comparing differences within the two groups of sea stars and between the two groups of sea star (W= rank totals)

Comparison Groups	W	P-value
Algae: Pisaster v Other	449.5	2.47e-05
Shelled: Pisaster v Other	605	0.0004525
Pisaster: Algae v Shelled	1662	1.255e-13
Other: Algae v Shelled	874	7.621e-11

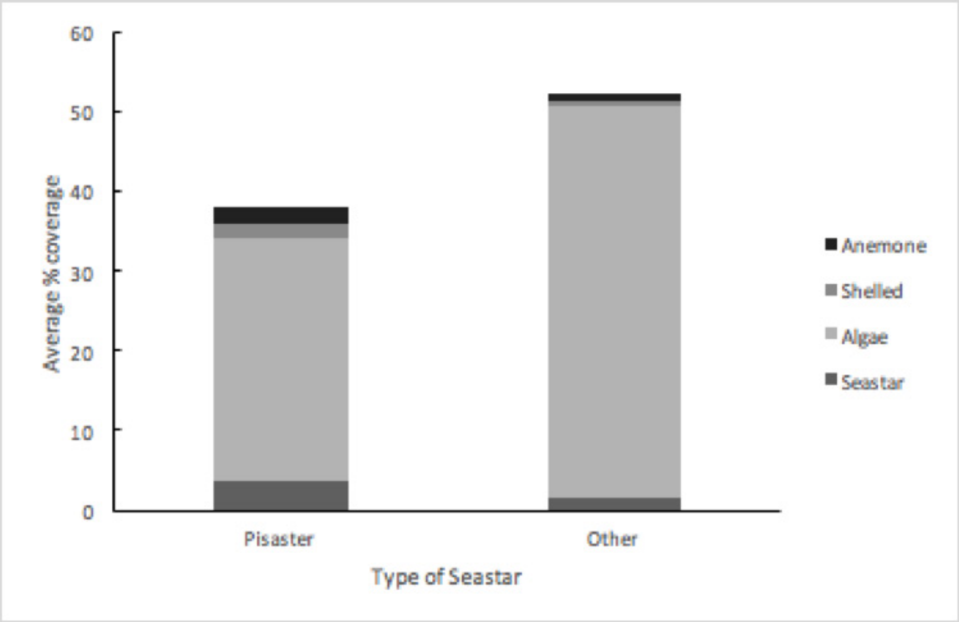

Fig 2. Comparison of mean percent cover of sea star, algae, shelled organisms, and anemones between Ochre stars (*P. ochraceus*) and the Other group (*L. hexactis* and *D. imbricata*)

Table 4. Summary of the averages of algae coverage and shelled organisms organized by type of sea star it was surrounding; group "Other" is a combination of six rayed stars (*L. hexactis)* and leather stars (*D. imbricata*).

Group	*Pisaster ochraceus* **Mean**	*Pisaster ochraceus* **STD**	**Other Mean**	**Other STD**
Mean % Algae coverage	31	24	49	21
Mean % Shelled organisms	1.9	1.4	0.74	0.62
Mean % Anemone	2.1	1.7	0.80	0.40
Mean % Nudibranch	0	N/A	0.31	0.19
Mean % Chiton	0	N/A	8.0	2.8
Mean % Sea Urchin	0	N/A	6	0

the impending threat of climate change, species higher in the intertidal zone, such as the ones we observed, are at a greater risk of desiccation. The temperatures the sea stars experience determine where in the intertidal zone they are located, which in turn could affect their foraging abilities (Helmuth and Wethey 2009). This stress causes shelled organisms to grow slower, and moving through the food chain would result in less nutrients for the sea stars. The risks of climate change are only growing; knowing how sea stars rely on their prey can help us track the survival of this keystone species.

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