Detecting changes in whelk abundance using hermit crab shell utilization in Oregon's rocky marine intertidal

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Abstract:

Utilization and preference of whelk shells by the hairy hermit crab are examined in the following to further define the ecology of Oregon's mid to low intertidal ecosystems. The study was conducted at Tokatee Kloochman State Natural Area (TK) where I made observations before collecting data. My observations were of two whelk species, the channeled dogwinkle (*Nucella canaliculata*), and the northern striped dogwinkle (*Nucella ostrina*). Observing an apparent decreased abundance of the channeled dogwinkle and an unchanging abundance of the northern striped dogwinkle initiated the preliminary research of this study. Cause for such a shift in species abundance is a topic of interest, however we must first establish that this shift has indeed occurred and discover how it may be influencing the current ecosystem at TK. The goal of this study is to determine if channeled dogwinkle survival had changed in the early spring of 2016 at the TK site.

Searching for empty shells of the two species, as evidence that many individuals from one species have died in recent months, was largely unsuccessful. There were not enough empty shells at TK to determine if channeled shells are more abundant than striped. Investigating why there would be so few empty whelk shells I found a potential explanation. Hermit crabs use vacant snail shells and there are many hermit crabs at the TK site. I shifted my focus and proposed that if there was a decrease in channeled dogwinkle abundance it may be observed in the shell utilization by hermit crabs. The hairy hermit crab (*Pagurus hirsutiusculus*) uses empty snail and whelk shells, but has expressed a preference for shells of certain species in similar ecosystems. I have observed these hermit crabs at TK using shells from both species so I needed to determine whether a shell preference could account for differential utilization of shells by the hermit crabs. I also needed to assess whelk abundances for the same reason. If the hermit crab does not have a shell preference between the channeled and the striped species then a higher utilization of shells from one whelk species would be evidence for greater numbers of vacant shells from this species available to the hermit crabs. The shell preference experiments did not show a significant shell preference between the two species of whelk. Also, I found no statistical evidence that the channeled species and the striped species are at different abundances. Finally, I could confidently use the shell utilization of hairy hermit crab at TK to determine whether more

channeled dogwinkle shells were recently available than northern striped dogwinkle. The shell utilization study did reveal a statistically higher number of channeled dogwinkle shells being used by the hairy hermit crab than the northern striped dogwinkle.

Introduction:

The Oregon coast is a very dynamic environment because it is influenced by several macroscale systems. The Pacific Decadal Oscillation and El Nino-Southern Oscillation largely dictate this region's climate, but fluctuations in these systems and the climate they produce remain to be fully understood. What is understood is that the climate fluctuations from year to year cause rises and falls in primary productivity on the Oregon coast. With unprecedented climate fluctuations being observed on a global scale, it is important to understand how ecosystems currently function for better predictions of how they may change. Previously, keystone predators have been the focus of many studies in the Oregon rocky intertidal. Though keystone species are highly influential in sustaining diversity here, we must still investigate fluctuations in relative abundances of this diversity of species to track the effects of large scale climate change. For this reason, I will investigate whelk species abundance and how it effects interspecies interactions with a common hermit crab species.

My research was conducted in the rocky intertidal zone of Tokatee Klootchman State Natural Site (TK) on the central Oregon coast. Since my research was conducted on the population of hermit crabs and whelks at this site, I begin by researching the influences of the Pacific Ocean on this region of coastline. Primary productivity of coastal marine environments is driven largely by nutrient inputs. At TK the main source of nutrients is cold deep water. In the Winter, southerly winds drive surface water towards Oregon's shoreline keeping the nutrient water at the bottom. Northerly winds in the summer push surface waters offshore, bringing the deep water to the surface near the shoreline causing productivity to elevate (Small and Menzies 1981). The movement of this water is due to Ekman transport, and the process of deep water being brought to the surface is called upwelling. Upwelling in Oregon is described as intermittent because it is inconstant due to fluctuations in wind speed and direction with each season (Menge and Menge

2013). Along with the delivery of nutrients, the reproduction and larval recruitment of many species is dependent upon intermittent upwelling too (Wing et al. 1995). The coastal environment found here has been described as a bottom-up and a top-down ecosystem because of its dependence on nutrient provisions from upwelling and habitat zonation from keystone predators (Menge 2000). Revisiting my research in particular, there is more that must be discussed about the organisms I chose to study.

The two species of whelk I examined are the northern striped dogwinkle and the channeled dogwinkle. The hairy hermit crab was also a focus of this research because it uses vacant whelk shells. All three species are found in the mid to low rocky intertidal zones of this location, and their North American distribution is from California to Alaska (Harvey and Colasurdo 1993). The whelk species are similar in size and structure, but their feeding preference is still partly unresolved (Sanford 2002, Dahlhoff et al. 2001). What is known, is that the channeled dogwinkle has a preference for the bay mussel, but will prey on some barnacle species if the mussel isn't available. The bay mussel is small with an annual life history which involves planktonic development and downwelling dependent recruitment to the rocky intertidal (Wing et al. 1995). The northern striped dogwinkle is a more generalist predator, preying on multiple species of mussels and barnacles, possibly even having a preference for one of the barnacle species. Also, the ability of each species of whelk to feed on its prey varies spatially. For example, a population of channeled dogwinkle at one location may be more efficient at feeding on the bay mussel and less efficient at feeding on barnacles than a population in an area with consistently less bay mussel recruitment. Since the preferred prey item of the channeled dogwinkle has an annual life history, a higher level of uncertainty exists for the channeled dogwinkle which the northern striped dogwinkle does not encounter. A low recruitment year for the bay mussel could reveal a fitness advantage for the more generalist northern striped dogwinkle.

In the spring of 2016 when I observed the decreased abundance of the bay mussel at TK I began this study to investigate whether the abundance of the channeled dogwinkle had decreased. Since I was unable to assess mussel or whelk abundances in previous years I am unable to determine if mussel recruitment caused a decrease in channeled dogwinkle abundance. Instead I studied the hairy hermit crab to determine if its observed shell utilization at the TK site is an objective record of whelk deaths in recent months. There are two major question I needed answered to prove that their utilization of shells accurately represents whelk death in recent months. Does the hairy hermit crab exhibit a shell preference between the two whelk species, and are the abundances of the two whelk species at the location the same? If one species is in higher abundance than the other than that could be a confounding explanation for differing shell utilization of the hermit crab.

The findings of Hernandez and Sanford revealed that the hairy hermit crab has a significant shell preference. Given the choice between shells from three gastropod species, a preference toward the northern striped dogwinkle was found (Hernandez and Sanford 2005). But, this study did not include the channeled dogwinkle. At the TK site, I have observed the hairy hermit crab using many different species of gastropod shells including both species of dogwinkle in question. The two dogwinkle shells are very similar in structure and size, which may be enough to eliminate a preference between them. Thus, I hypothesize that:

1) The species abundance of the channeled dogwinkle and the northern striped dogwinkle are the same at the TK site.
2) The hairy hermit crab does not exhibit a shell preference between the two species of whelk, the channeled dogwinkle and the northern striped dogwinkle.
3) There will be a greater number of channeled dogwinkle shells being utilized by the hairy hermit crab than shells from the northern striped dogwinkle at TK, because of a greater availability of vacant shells from that species.

Methods:

The whelk species abundance data was analyzed using a two sample t-test on Excel assuming unequal variance. Unequal variance was determined by running an F-test in Excel as well. The Binomial Formula was used to analyze.

a. Field Surveys:

I surveyed and sampled species abundance, vacant shell abundance, and shell utilization at TK. At this site I have observed a rocky intertidal ecosystem with a gradual wave exposure gradient that produces noticeable zonation with respect to the intertidal species. I used the Transect-Quadrat method in the mid to low rocky intertidal zone of Tokatee-Kloochman State Natural Site to determine the abundance of the two whelk species, and the abundance of all vacant gastropod shells. Four, 30 meter transect lines were placed during each of the two field sampling days. Six, 0.25 m^2 quadrats were placed on the west side of six randomly generated meter marks. I randomly generated 6 meter marks for each transect sampled. In each quadrat I record every whelk of the two being studied including, the species and aperture opening length using a ruler. I also record the species, and aperture opening length of every empty gastropod shell for all species, and the shell species and aperture opening length of any shell being utilized by the hermit crab. Any hermit crab without a shell had their date, time, weather, tidal phase, and location documented too. All shell aperture lengths have been measured in millimeters. To determine the shell utilization at TK I conducted peripatetic data collection, recording the shell species and aperture opening length of every hairy hermit crab I found as *Nucella ostrina*, *Nucella canaliculata*, or other. In order to conduct the shell preference studies I collected 20 hermit crabs with their shells both sampling days.

b. Laboratory Trial

Laboratory trials were conducted at the Hatfield Marine Science Center in Newport Oregon, and were done to determine if the hermit crab has a shell preference between the two whelk species. For the laboratory trials, the original shell of each hermit crab was documented and each hermit crab received its own 10 cm^3 container. The edges of these containers will be below the water level of the larger tank that they will be contained in. This assures that they receive the same water temperature, pH, and oxygenation. After an 48 hr recovery period from capture, each hermit crab will be anesthetized using proper amounts of the compound Tricaine Methanesulfonate, which is commonly known as ms-222. The ms-222 used was produced by Western Chemical Inc. and was massed out using a TR-403 lab scale by Denver Instrument Company which allows for accuracy to one-thousandth of a gram. In order to anesthetize the hermit crabs quickly while having a rapid recovery time the ms-222 was mixed to concentration of 1400.0000 mg/L.

The hermit crabs were carefully removed from their shells once anesthetized and placed back into their original containers to recover over a 24 hr period. During the 24 hr period the 20 shells of the northern striped dogwinkle and 20 shells of the channeled dogwinkle were boiled and sorted according to damage and size. Fifteen shells from each species were found to be undamaged and of equal size. A caliper was used to measure the aperture opening of each shell to greater precision. Each northern striped dogwinkle shell was paired with a channeled dogwinkle shell using the aperture measurements to find the closest match. At the end of the first 24 hr recovery period a set of paired shells was placed into the containers of the first 15 hermit crabs to be tested and left over a 24hr period. The specific set of paired shells being used was recorded for each individual preference trial. The species of shell utilized was recorded after the 24 hr trial period. Hermit crabs that do not utilize either shell will be noted as No Shell (NS). The shells remained paired after being removed from the first 15 hermit crabs through anesthetization. They were boiled again and shell preference trials were conducted on the next 15 hermit crabs. The same methods for data collection, shell removal, and shell sterilization were used for the third and final set of trials. The final set of trials was run and the data was collected. All hermit crabs were given a shell and returned to the Oregon rocky intertidal.

Results:

The data collected on vacant shells found a total of seven vacant shells in all 48 quadrats. Interestingly, six of the seven shells that were found were channeled dogwinkles. Still, since the total number of shells found was so few, I am unable to find significance in the results.

The whelk abundance study resulted in a count of 82 northern striped dogwinkles and 119 channeled dogwinkles. I analyzed the populations with a Two-Sample *t*-Test for Equal Means. The *t*-Test was two-tailed and assumed unequal variance. The p-value from this method determines the probability of observing these average counts if the populations are the same. This means, the higher the p-value the more likely the populations are equal in abundance. When analyzed on Excel I found no significant evidence that the populations are different (p =

0.2177). My hypothesis that the abundance of channeled dogwinkle and northern striped dogwinkles at TK is supported. The counts are displayed in the following table to help visualize the variability I observed in the abundances for each species (Figure 1).

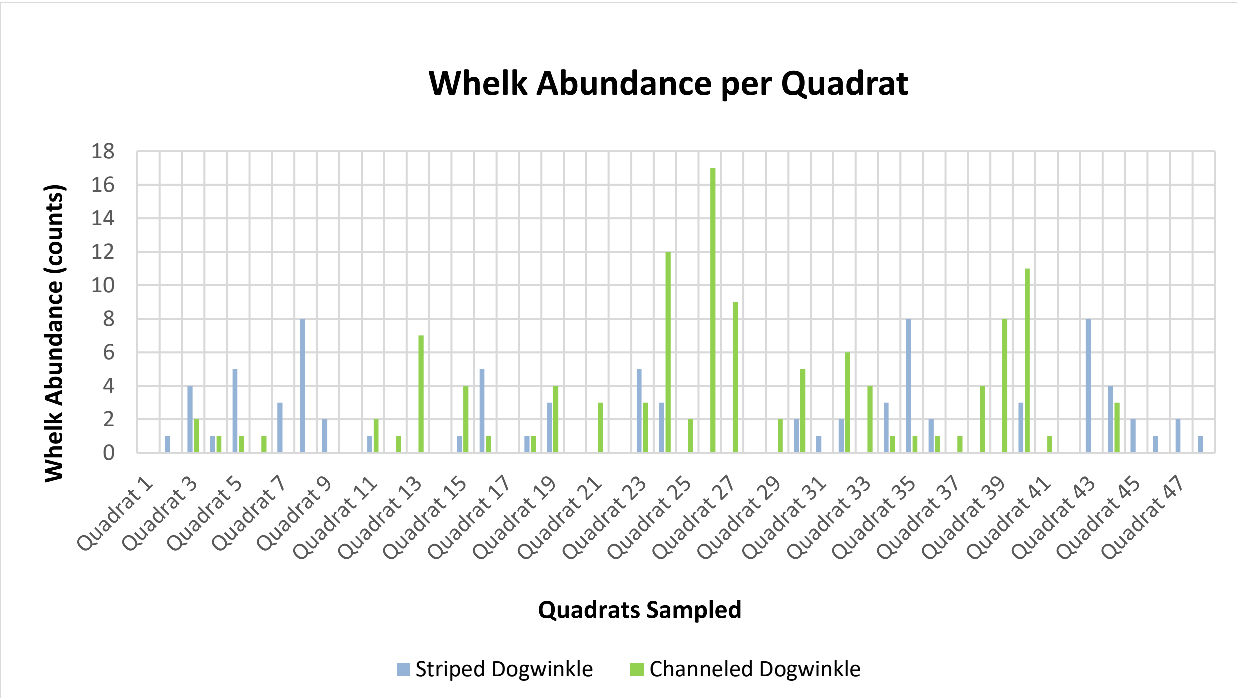

Figure 1: The abundance of the two whelk species for each quadrat from the 8 transects sampled at Tokatee Klootchman State Natural Site.

The 40 trials conducted to determine if the hairy hermit crab has a shell preference produced 18 hermit crabs choosing northern striped dogwinkle, and 22 choosing channeled dogwinkle. I used a binomial probability table to determine the probability of seeing these values if there is no preference. The resulting p-value is large which indicates that the greater number of channeled dogwinkle shells chosen is likely due to chance ($p = 0.3179$). My hypothesis that the channeled dogwinkle does not have a preference between the two whelk species is supported.

Data recorded on shell utilization revealed 35 hairy hermit crabs using northern striped dogwinkle shells and 52 using channeled dogwinkle shells (Figure 2). Since this data could be analyzed as a binomial relationship too, I used the binomial formula and found that the difference I recorded in shell utilization was not due to chance with greater than 95% confidence (p=0.0428). My hypothesis that more hairy hermit crabs were using channeled dogwinkle shells than northern striped dogwinkle shells at TK because of a greater number of vacant channeled dogwinkle shells is supported.

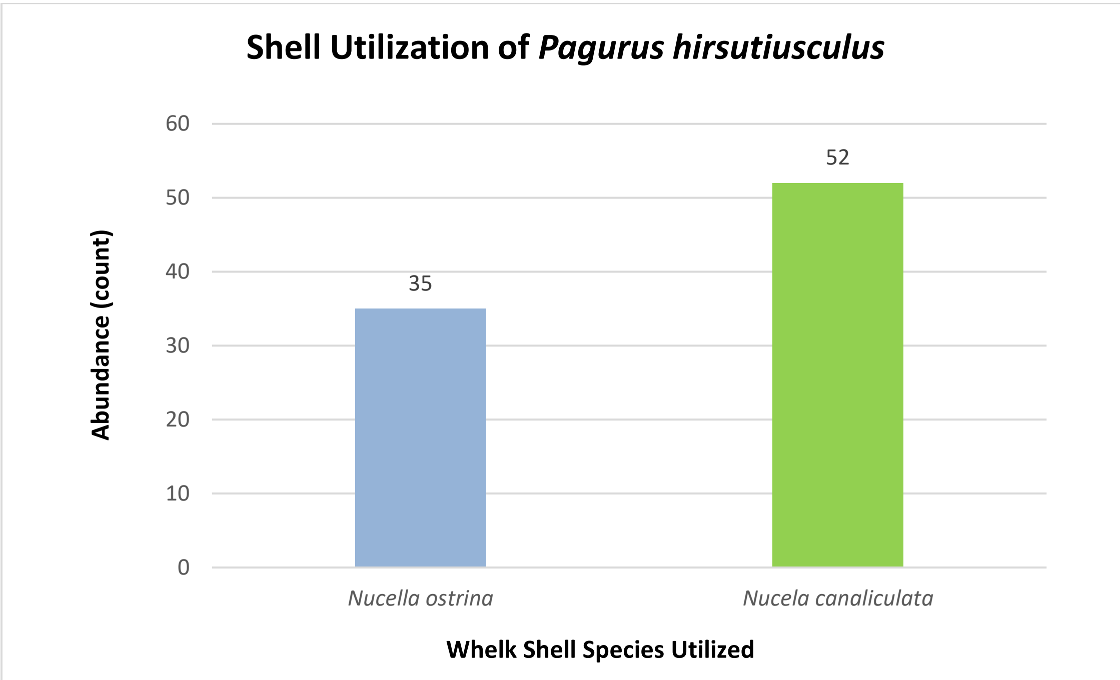

Figure 2: The shell utilization of the two whelk species by the hairy hermit crab at Tokateee Klootchman State Natural Site on June 24th and 25th of 2016.

Discussion:

The vacant whelk shell abundance results found little significance at TK which is why I developed an alternate method for investigating the apparent decrease in channeled dogwinkle abundance. But, the results are still worth noting. With six out of the seven shells collected being channeled dogwinkle, a larger scale study may be able to find significance. A confounding variable for future research on this subject would be collecting the whelk shells. For hermit crabs, the removal of vacant shells from their habitat would influence their shell utilization, especially in environments where vacant shells appear to be limiting. However, for long term studies, leaving shells after they have been counted may lead to them being counted multiple times.

Moving forward to whelk abundances, the evidence that their abundances are the same allows me to then investigate shell preference by the hermit crab. However, the somewhat low p-value allows for chance to play a smaller role which weakens confidence. There is a good chance that the higher count of channeled dogwinkle I recorded was due to chance, but since the abundances were not an even split there is a degree of uncertainty. Still, the evidence I found allows me to say that shell utilization by the hairy hermit crab is due to the number of shells available to them if the hermit crab does not show a preference.

The shell preference experiments, indicated that the hairy hermit crab does not have a significant shell preference between the striped and the channeled dogwinkle. This is not consistent with the findings of Hernandez and Sanford but their study was slightly different. Their study compared relatively unrelated and dissimilar species in morphology, while the species I compared are very similar. Because the hermit crab did not show a preference among the two whelk species shells, preference cannot explain any differential utilization of shells by the hairy hermit crab at TK either.

Finally, the greater utilization of channeled dogwinkle shells by hairy the hermit crab reveals a greater availability of these vacant shells compared to the northern striped dogwinkle. Since each vacant shell indicates a whelk which has died, I am confident in stating that in the spring of 2016 the survival of the channeled dogwinkle was lower than that of the northern striped dogwinkle. Why this was the case brings about a completely new line of questions and unknowns.

Abundances of these whelks in previous months or years is unavailable, so I am not able to conclude whether this was a decrease in channeled dogwinkle survival, an increase in northern striped dogwinkle survival, or both. I am also unable to determine the cause of this event. From observations in the field by local marine ecological scientists and myself we propose a likely explanation which may be a focus for future studies. Along with the channeled dogwinkle, the bay mussel was unofficially observed to be in lower abundance in the spring of 2016. Since the bay mussel is often the primary and preferred prey of the channeled dogwinkle, their recruitment may significantly dictate the abundance of the channeled dogwinkle. Furthermore, the ability of the channeled dogwinkle to compete with the northern striped dogwinkle may be an indirect product of yearly fluctuations in productivity because of its prey's dependence on productivity. The survival of the bay mussel is highly dependent upon productivity and the northern striped dogwinkle is not as reliant on the bay mussel for prey. Though it's a plausible ecological explanation, non-biological factors like temperature, ocean acidification, and even disease may be the cause too.

As our understanding of large scale environmental factors becomes more understood the level at which we can resolve fluctuations within an ecosystem rises. Conservation and species extinction will always be a focus in biology, especially as human development continues to alter the world. With many more studies into behavioral ecology like this we can better predict how human development affects ecosystems, giving us the best opportunity to limit our impact.

Literature Cited:

NOAA National Center for Environmental Information. 2016. State of the climate: global analysis for April 2016. U.S. Department of Commerce, Silver Spring, MD.

McPhaden, M., J. Picaut. 1990. El Nino southern oscillation displacements of the western equatorial Pacific warm pool. Science **250:** 1386-1388.

Menge, B. 2000. Top-down and bottom-up community regulation in marine rocky intertidal habitats. Journal of Experimental Marine Biology and Ecology **250:**257-289.

Small, L., D. Menzies. 1989. Patterns of primary productivity and biomass in a coastal upwelling region. Deep Sea Research Part A. Oceanic Research Papers **28:** 123-149.

Wing, S., J. Largier, L. Botsford, J. Quinn. 1995. Settlemetn and transport of benthic invertebrates in an intermittent upwelling region. Limnology and Oceanography **40:** 316-329.

Menge, B., D. Menge. 2013. Dynamics of coastal meta-ecosystems: the intermittent upwelling hypothesis and a test in rocky intertidal regions. Ecological Monographs **83:** 283-310.

Harvey, A., E. Colasurdo. 1993. Effects of shell and food availability on metamorphosis in the hermit crabs *Pagurus hirsutiusculus* (Dana) and *Pagurus granosimanus* (Stimpson). Journal of Experimental Marine Biology and Ecology **165:** 239-247.

Sanford, E. 2002. The feeding, growth and energetics of two rocky intertidal predators (*Pisaster ochraceus* and *Nucella canaliculata*) under water temperatures simulating episodic upwelling. Journal of Experimental Marine Biology and Ecology **273:** 199-218.

Dahlhoff, E., B. Buckley, B. Menge. 2001. Physiology of the rocky intertidal predator *Nucella ostrina* along an environmental stress gradient. Ecological Society of America **82:** 2816-2829.

Hernandez, J., E. Sanford. 2006. The scent of a predator: the effects of chemical threats on shell selection in the hermit crabs, *Pagurus samuelis* and *Pagurus hirsutiusculus*. Department of Biology: University of California, Davis, California.