# The Long-term Effect of Trampling on Rocky Intertidal Zone Communities: A Comparison of Urchin Rocks and Northwest Island, WA.

A Class Project for BIOL 475, Marine Invertebrates

Rosario Beach Marine Laboratory, summer 2020

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**ABSTRACT**

In the summer of 2020 the Rosario Beach Marine Laboratory Marine Invertebrates class studied the intertidal community of Urchin Rocks (UR), part of Deception Pass State Park. The intertidal zone at Urchin Rocks is mainly bedrock, is easily reached, and is a very popular place for visitors to enjoy seeing the intertidal life. Visits to the Location have become so intense that Deception Pass State Park has established a walking trail and docent guides in the area in order to minimize trampling of the marine life while still allowing visitors. No documentation exists for the state of the marine community before visits became common, but an analogous Location with similar substrate exists just offshore on Northwest Island (NWI). Using a belt transect divided into 1 $m^2$ quadrats, the class quantified the algae, barnacle, and other invertebrate components of the communities at the two locations and compared them. Algal cover at both sites increased at lower tide levels but while the cover consisted of macroalgae at NWI, at Urchin Rocks the lower intertidal algae were dominated by diatom mats instead. Barnacles were abundant at both sites but at Urchin Rocks they were even more abundant but mostly of the smallest size classes. Small barnacles were especially abundant at Urchin Rocks near where the walking trail crosses the transect. Barnacles may be benefitting from areas cleared of macroalgae by trampling but in turn not be able to grow to large size at Urchin Rocks. Other invertebrates commonly found on the transects included *Anthopleura elegantissima* anemones, limpets, chitons, amphipods, and isopods at both Locations. *Mytilus trossulus* mussels, predatory *Nucella* snails, and larger anemone species were only found at NWI. The lack of *Nucella* spp. At UR may also explain the abundant barnacles there because small barnacles are one of their main prey items. Seastars were present at both locations but lower down and less abundant at UR. Species richness was 45 at NWI and 31 at UR. Overall, these results are similar to those of a similar study 18 years ago in 2002 and suggest that even though the marine community at UR shows likely impacts of human use the Location does not appear to be becoming more degraded and maintains a moderate level of diversity. The most obvious difference between the Locations is the heavy diatom mat at low intertidal levels. This mat is persisting but it is not clear whether it is due to human trampling or some other cause.

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## INTRODUCTION

Marine intertidal zones, with their easy access and abundant marine life, are a favorite destination for many both for recreation and education. However, with the spatial extent of intertidal zones being so limited there is danger of “loving them to death”, especially in diverse, easily accessible zones near dense urban populations. In many places it has proven necessary to institute some limits to access to avoid destruction of the intertidal community. In public parks, this leads to a question of how to achieve an appropriate balance between access by the human community and enough protection of the marine community so that the intertidal can continue to flourish.

Urchin Rocks, a popular rocky intertidal site in Deception Pass State Park, WA, is an area that is faced with this dilemma. The park is less than 2 hours’ drive from the Seattle urban area. Urchin Rocks is next to the Rosario picnic area and is popular over much of the year, especially in summer. The rocks are not steep and are easily accessible from the picnic area. They are a favorite site for leisurely or educational enjoyment of the tide pools. This enjoyment became a special concern in the late 1990’s when hundreds of school children visited and trampled the area during field trips over a period of not more than a few days. Shortly thereafter, Washington State Parks instituted a system designed to allow access to the site while restricting negative impact. A U-shaped path through the intertidal zone, marked by an anchored rope, was established on Urchin Rocks. Signs were posted asking visitors to remain on the path while exploring the intertidal zone. Park personnel or community volunteers watched over the area during low tides, educated the public about intertidal life, and encouraged them to remain on the path.

Multiple studies have looked into how human trampling affects the coastal environment and the species that live within it. A study on the similarly rocky coast of Brazil found that some species were more vulnerable to trampling than others. Interestingly, the study found that turnover, richness, and diversity had all increased in just four months after trampling was stopped (Ferreira and Rosso, 2009). These results show an impressive resilience of intertidal fauna, considering that four months is an incredibly short time to recover. The process of recovering from trampling may be similar to secondary succession, in which at least during the initial phases, r-strategist species move in and become established quickly. It would be interesting to see if these factors continue over a longer period of time. Another study looked into similar trampling on California's rocky coast focusing on two different species of mussels and how they were affected not just by trampling, but by the presence of marine reserves (MRs) (Smith et al., 2008). In their analysis they also found that human interference negatively affected mussel populations, and further that that this effect did not differ between MRs and non-MRs. Their results suggested that California's MRs were not strict enough to help avoid the negative effects of trampling. A third study, on coastal dunes, confirmed that trampling affects the habitat as well (Santoro et al., 2012). Santoro et al. (2012) compared an unfenced area to a fenced area and found that once a dune was fenced off it began to recover from the detrimental effects of human trampling. These make it clear that trampling can have a negative impact on habitats, but these impacts can be reversed with strict implementation of careful restrictions.

To our knowledge, no detailed studies of the diversity and composition of marine life were made at Urchin Rocks before the trampling or establishment of restricted access so there is no direct way to compare the present community with its former state. However, the geography of the area provides an opportunity for addressing this question indirectly. Northwest Island is just offshore in Rosario Bay, less than 1 km from Urchin Rocks (Figure 1). Both Urchin Rocks and a site on Northwest Island are composed of gently sloping bedrock with a similar northern exposure, with few boulders and only a few small tide pools. Northwest Island, however, is only lightly visited by people. Therefore, it can serve as a valuable comparison of what a site such as Urchin Rocks would likely be like if it were relatively untouched.

In 2002, a few years after protection of the Urchin Rocks area began, a college-level marine invertebrates class at Walla Walla University's Rosario Beach Marine Laboratory (RBML) , which is adjacent to the park next to Urchin Rocks, compared a transect of the intertidal community at Urchin Rocks with a similar transect on Northwest Island (Cowles, 2002). The class found that overall diversity between the sites was not significantly different. However, certain groups, such as macroalgae and motile invertebrates, were less common at Urchin Rocks where they were  largely replaced by a thick mat of diatoms. The expected increase in diversity and percent cover of macroalgae and invertebrates in the lower intertidal was also muted or absent at Urchin Rocks.

In this study, the summer 2020 RBML marine invertebrates class carried out a second study of the same two transects to see what changes have occurred over the intervening 18 years of partial protection with continued limited trampling. We could not make a direct comparison with the 2002 study because students were not able to gather as a class to visit the intertidal zone directly due to the COVID-19 pandemic. Instead, a detailed photographic record of each transect was taken and students analyzed the photos remotely. This approach allowed a direct comparison between the current status of Northwest Island and Urchin Rocks, and could also be compared with some aspects of the previous study made in 2002.

## MATERIALS AND METHODS

Siting and subdividing the Transects:

Each transect was sited at the same place as the 2002 transect (Table 1), based on the GPS coordinates, descriptions, and photographs recorded in 2002. Both belt transects started in the high intertidal zone and ran just west of north toward the ocean (Figure 1). The transect at Urchin Rocks crossed the low-intertidal branch of the marked U-shaped visitors' path at an elevation of +0.6 feet above zero tide at the 10-11 m mark but did not cross the high-intertidal branch of the path. The area near the path out to the 15 m mark also appeared to be at least lightly trampled. Surveys along the transects were taken at low minus tides so that a broad tidal range could be sampled. A 50 m measuring tape was stretched straight along each transect and each meter along the tape was numbered as a quadrat, starting at 0 in the high intertidal. The height above zero tide level at the center of each meter, referenced to the height at the water's edge at low tide as specified in NOAA tide tables, was measured using a Porter Cable laser level and recorded as the characteristic elevation for that meter.

Table 1: Geographic placement of the transects in this study

| Location | Starting coordinate UTM 10U, WGS84 | Direction (degrees from magnetic north) | Length |
|---|---|---|---|
| Urchin Rocks | 0524814, 5362712<br>48° 25.024'N<br>122° 39.879'W | 316° | 21 m |
| Northwest Island | 0524392, 5362990<br>48° 25.172'N<br>122° 40.220'W | 332° | 23 m |


Figure 1: Location of the two transects in this study

Each square meter quadrat, centered on the transect line, was subdivided into four 0.5m$^2$ quadrants. A 0.5 m$^2$ PVC quadrant frame subdivided internally into 5 x 5 1-dm$^2$ grids was placed over each quadrant. The quadrant was then photographed before any disturbance using a Nikon D5500 12-megapixel camera at right angles to the substrate from a height of approximately 1 meter to avoid parallax error. The photo was framed to include just the 0.5m$^2$ quadrant along with the transect line and a quadrant marker. These photos were used to calculate percent algal cover. As much algae as possible was then removed from the quadrant to expose the substrate and invertebrates below, and the quadrant was photographed again to document the invertebrates present. At Urchin Rocks, however, the algae was not removed from sites with rich algal growth in order to minimize disturbance to the already heavily used area. Instead, barnacle and other invertebrate counts were made only in exposed areas on these quadrats and the counts were later extrapolated to represent the entire 1 $m^2$ quadrat area based on the algal percent cover. All four quadrants were photographed with and without algae for each square meter quadrat along the transect, except for this adjustment made for some quadrats at Urchin Rocks. At both sites, extra close-up photographs of hard-to-see invertebrates present in the quadrant were also taken to supplement counts made from the whole-quadrant photos. The animals present in these close-ups were documented and the information was provided to the students analyzing each animal group.

Analysis of the Photographs:

Students were divided into three groups, each one focusing on one aspect of the community structure. The first group documented the percent cover of algae and bare rock. Percent cover was calculated by documenting the topmost algal type or bare rock which appeared under each of 25 fixed points in each quadrant (100 points total per 1 $m^2$ quadrat). The algae were identified to phylum, including diatoms, plus a few of the most recognizable species. Photographs used by this group were the photos taken before disturbing any of the algae. The next student group used the photographs taken after removing the algae and focused on barnacles, which were abundant at the sites. Barnacle measurements included percent cover, number count, mortality, and barnacle species (although features distinguishing barnacle species are not readily apparent in photographs so barnacle species identification should be regarded as tentative). In quadrants with more than 200 barnacles, at least 5 but enough 1 $dm^2$ squares of the quadrant were randomly sampled to contain 200 or more barnacles, then this value was adjusted to the 25 squares present in each quadrant to estimate the total count in the quadrant. Dead barnacles, as indicated by empty plates, were counted to determine whether trampling in some regions such as near the path at Urchin Rocks increases barnacle mortality. Finally, the third student group counted the presence of other invertebrates such as bivalves, snails, chitons, limpets, anemones, sponges, seastars, and motile crustaceans using the photos of the quadrants after the algae was cleared. This group also kept a total of the number of different invertebrate species observed along each transect.

Statistical Analysis:

Each student group made their measurements or counts in duplicate and re-counted quadrants in which the two counts did not agree. They then recorded their data in Excel spreadsheets and exported the data as .csv files for statistical analysis in R. Since ecological counts such as these frequently include groups with non-normal distribution or inhomogeneity of variance, the nonparametric multivariate PERMANOVA method was used to compare the quadrats. The metric used to express differences was the Bray-Curtis dissimilarity index, which is useful for distinguishing groups based on the relative numbers of different taxa present. For algae the independent variables used were percent cover of Brown, Red, Green, Diatom, and Bare rock. For barnacles the independent variables counted were individuals of *Chthamalus* sp., *Balanus glandula*, *Semibalanus cariosus*, *Balanus nubilus*, and dead barnacles. Average barnacle size was also estimated by dividing the calculated area the barnacles covered by barnacle count. For other invertebrates the variables counted were anemones, mollusks, motile crustaceans, and seastars. The Zones compared were the high and low intertidal quadrats (divided by the + 3 feet elevation above zero tide) at each Location, plus a comparison of the two Locations to one another. The 0.05 confidence level was considered statistically significant, and the Bonferroni correction was used when assessing the significance of multiple comparisons.

**RESULTS:**

Besides being both on similar bedrock substrates and oriented in similar directions (Table 1), the two transects were of similar length and slope and covered a similar range of intertidal heights (Figure 2). Note that all future transect plots will have elevation (feet above 0 tide) instead of meter number as the X-axis to allow direct comparisons between the transects.

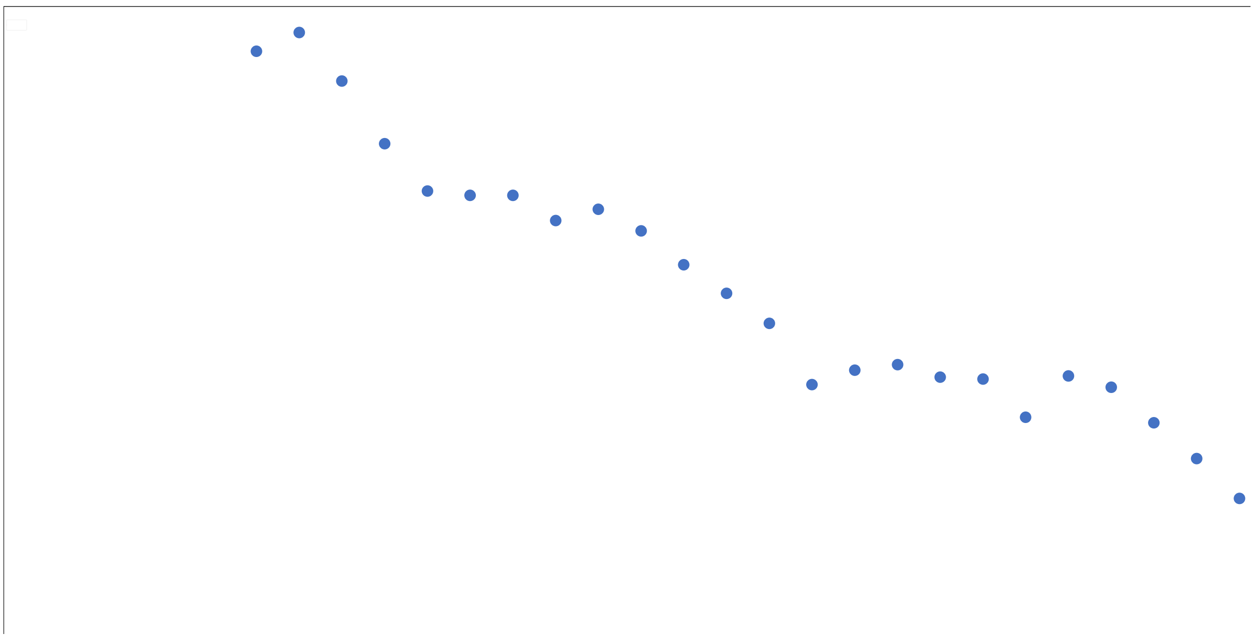

Figure 2: Slopes and elevations of the two transects. The gray rectangle on the Urchin Rocks transect shows where the trampled trail crosses the transect, at about 0.6 feet elevation, although limited trampling was evident out to the 15 m quadrat. The dividing line between "high" and "low" intertidal for this study is the +3 foot mark.

Comparison of the Algal Communities:

The change in percent cover of the different types of algae with intertidal elevation at Urchin Rocks is shown in Figure 3 and at Northwest Island in Figure 4. Algae generally increased in percent cover at both locations at lower elevations though in different patterns. At Urchin Rocks macroalgae increased from high to middle tidal elevations but decreased sharply at elevations near the trail, then began increasing again at the lowest elevations. Diatoms, on the other hand, were very abundant and even dominant at the trail's elevation and lower. At Northwest Island,

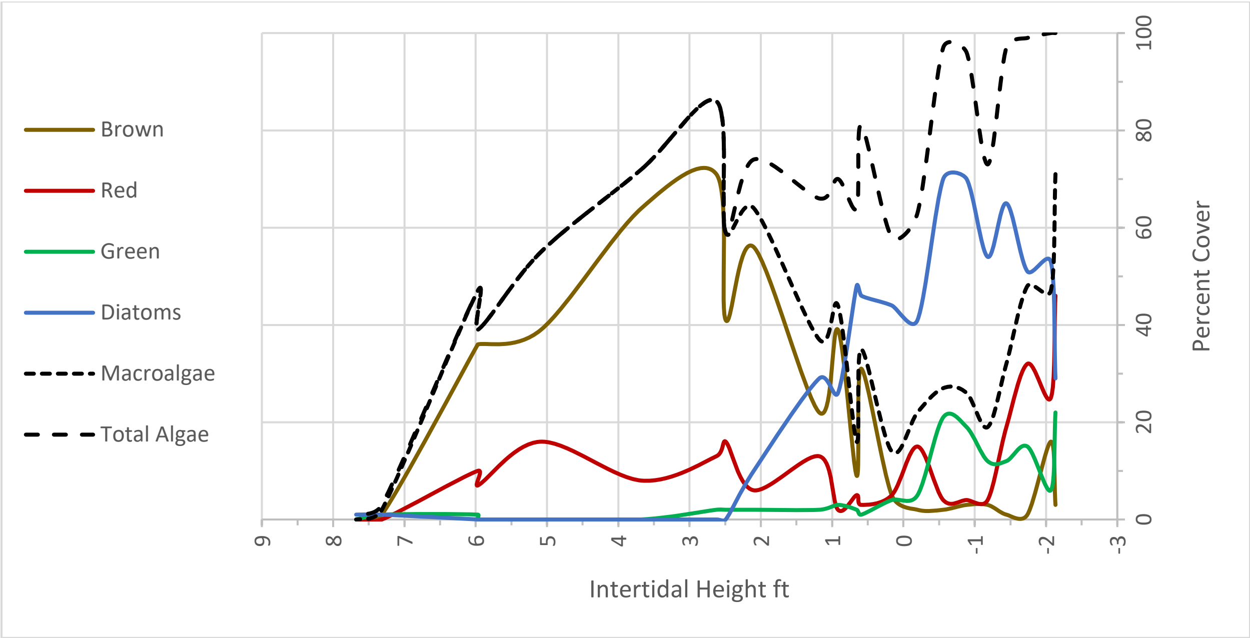


Figure 3: Changes in percent cover of algal groups with intertidal height at Urchin Rocks. Macroalgae are the total of (brown + red + green)

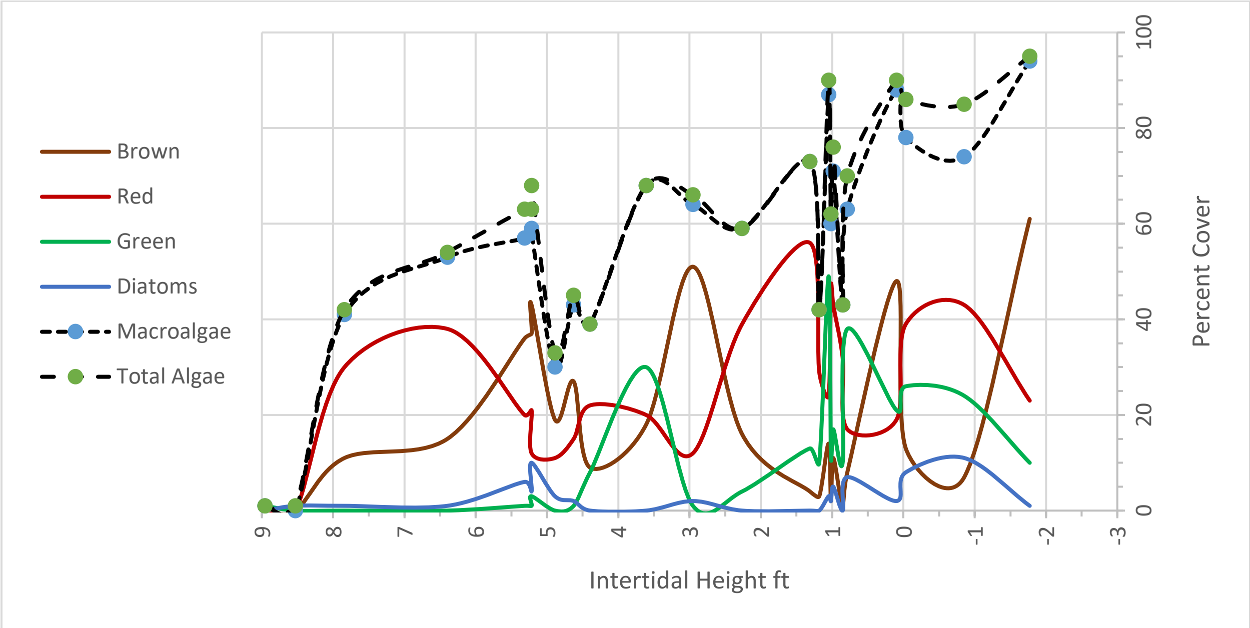


Figure 4: Changes in percent cover of algal groups with intertidal height at Northwest Island. Macroalgae are the total of (brown + red + green)

in contrast, the macroalgae increased steadily from the high to low tide levels and diatoms were never a major component of the intertidal algal community. Figure 5 directly compares the change in cover of total macroalgae and diatoms at different elevations for the two locations.

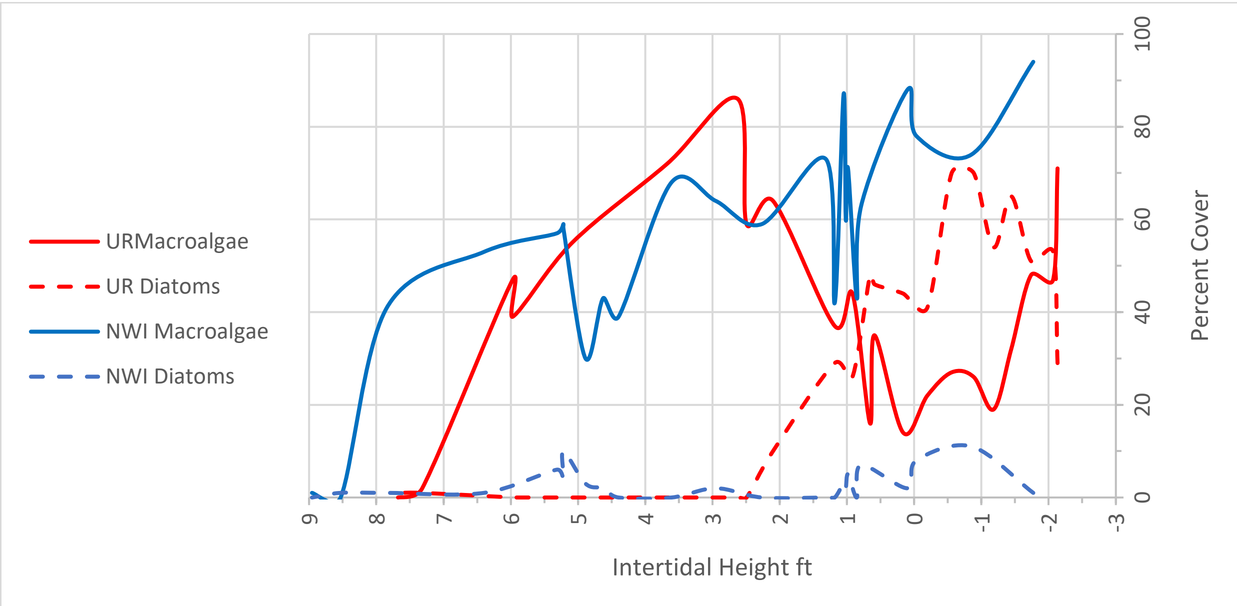


Figure 5: Comparison of the total percent cover of macroalgae and diatoms at Urchin Rocks and Northwest Island

Permanova analysis revealed that there was a highly significant dissimilarity in algal community composition between Urchin Rocks and Northwest Island (F = 4.13, df = 1, P = 0.002) and between the high and low intertidal Zones (F = 6.86, df = 1, P = 0.001). There was also a highly significant interaction between Location and Zone (F = 3.19, df = 1, P = 0.007), which indicates that the dissimilarity between the algal community in the high and low intertidal zones was different at Urchin Rocks than it was at Northwest Island. Four Permanova post-tests revealed that there were highly significant dissimilarities between the high and low algal communities at both Urchin Rocks (F = 7.22, df = 1, P = 0.002) and Northwest Island (F = 2.80, df = 1, P = 0.002). The high intertidal Zones at the two Locations were not significantly dissimilar from each other (F = 0.108, df = 1, P = 0.952), but the dissimilarity between low tide Zones at the two

Locations was highly significant (F = 23.67, df = 1, P = 0.001). Table 2 shows the average percent cover of the different types of algae in high and low tide Zones at the two Locations.

Table 2: Average (mean/median) percent cover of the different algal types at High and Low tide elevations at Urchin Rocks (UR) and Northwest Island (NWI). Macroalgae is the total of Brown + Red + Green algal percent cover.

| | Brown | Red | Green | Macroalgae | Diatoms |
|---|---|---|---|---|---|
| UR High | 36/37.5 | 8.75/9 | 0.75/0.5 | 45/51 | 0.25/0 |
| UR Low | 13.8/4 | 13.1/5.5 | 9.0/5.5 | 35.9/33.5 | 45.4/47 |
| NWI High | 19.5/18 | 17.2/20 | 4.1/1 | 40.8/43 | 2.5/1 |
| NWI Low | 18.4/11 | 32.5/32 | 18.0/13 | 68.9/71 | 3.2/2 |

Comparison of the Barnacle Assemblages:

As expected, *Balanus glandula* dominated the barnacle community at both sites. *Chthamalus* sp. was found only in the highest zones and *Semibalanus cariosus* and *Balanus nubilus* in lower zones (Figures 6,7). Barnacles tended to be more abundant at Urchin Rocks and *B. glandula* was common lower in the intertidal there than at Northwest Island. Live barnacles predominated at both locations (Figures 8, 9). Dead barnacles predominated at the highest intertidal heights at Urchin rocks and at the lowest tide levels at Northwest Island (Figure 10), although barnacles were relatively scarce at those heights at both locations (Figures 8, 9). However, barnacles averaged quite large at Northwest Island, especially in the low intertidal, while at Urchin Rocks they were mostly less than 1 $cm^2$ in size (Figure 11). Limited numbers of barnacles and heavy algal cover prevented reliable calculations of average barnacle sizes in some quadrats.

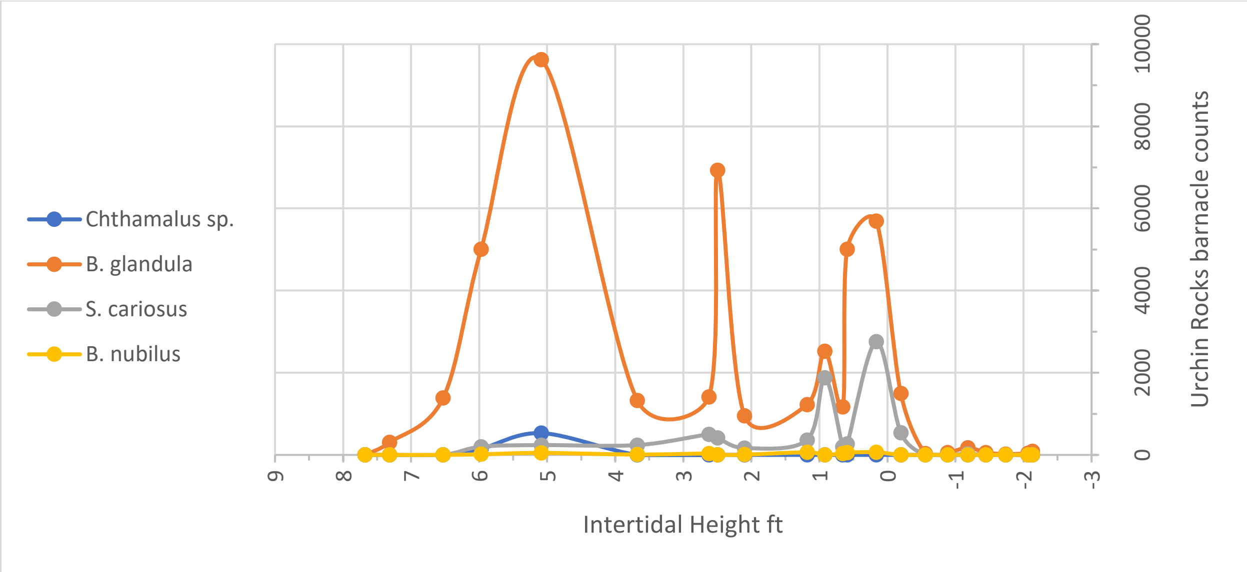


Figure 6: Barnacle abundance by tentative species and elevation at Urchin Rocks

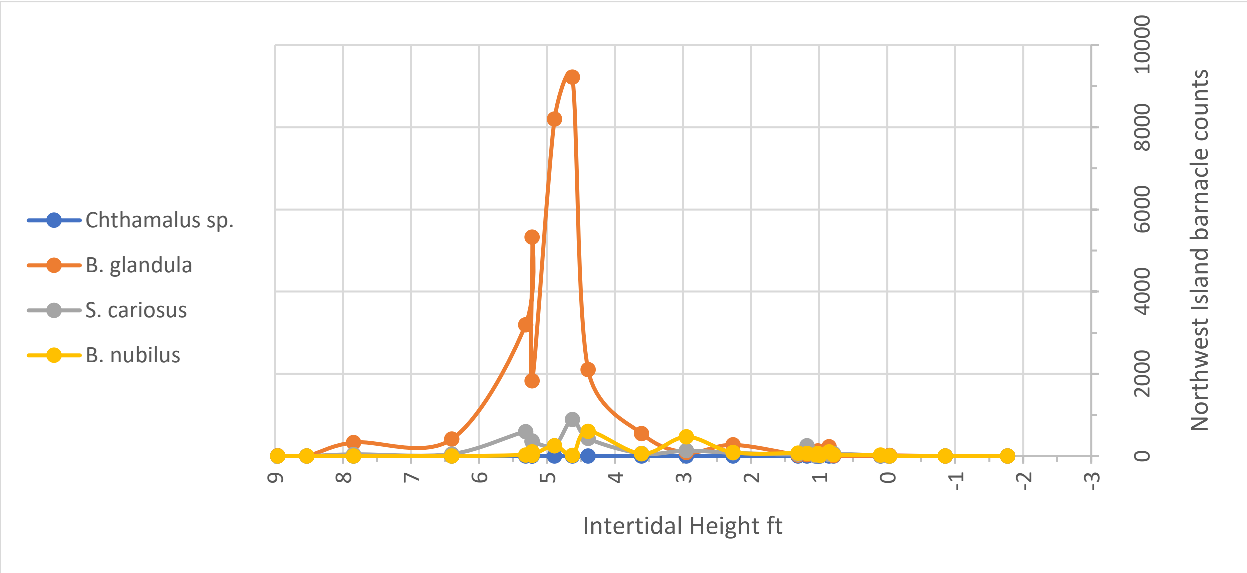


Figure 7: Barnacle abundance by tentative species and elevation at Northwest Island

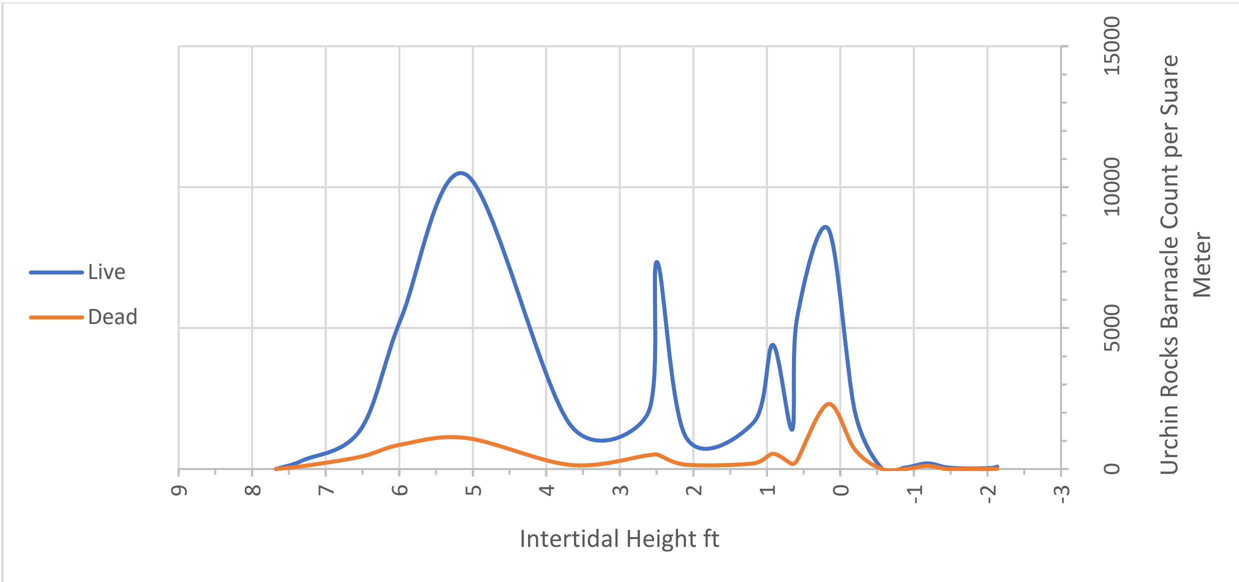


Figure 8: Abundance of live versus dead barnacles at Urchin Rocks

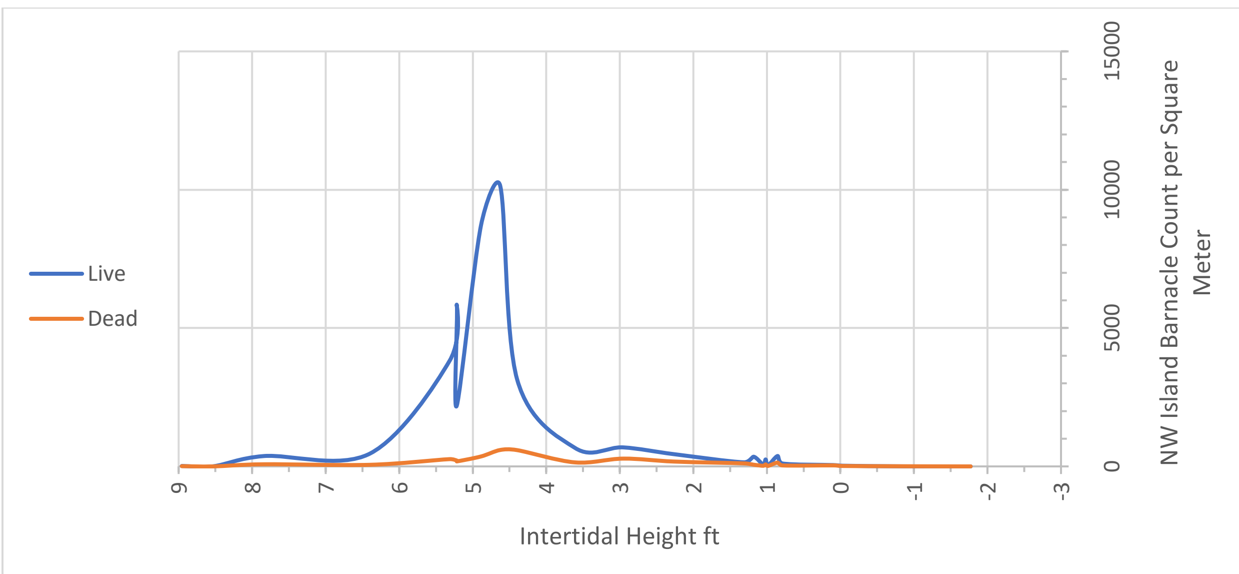


Figure 9: Abundance of live versus dead barnacles at Northwest Island

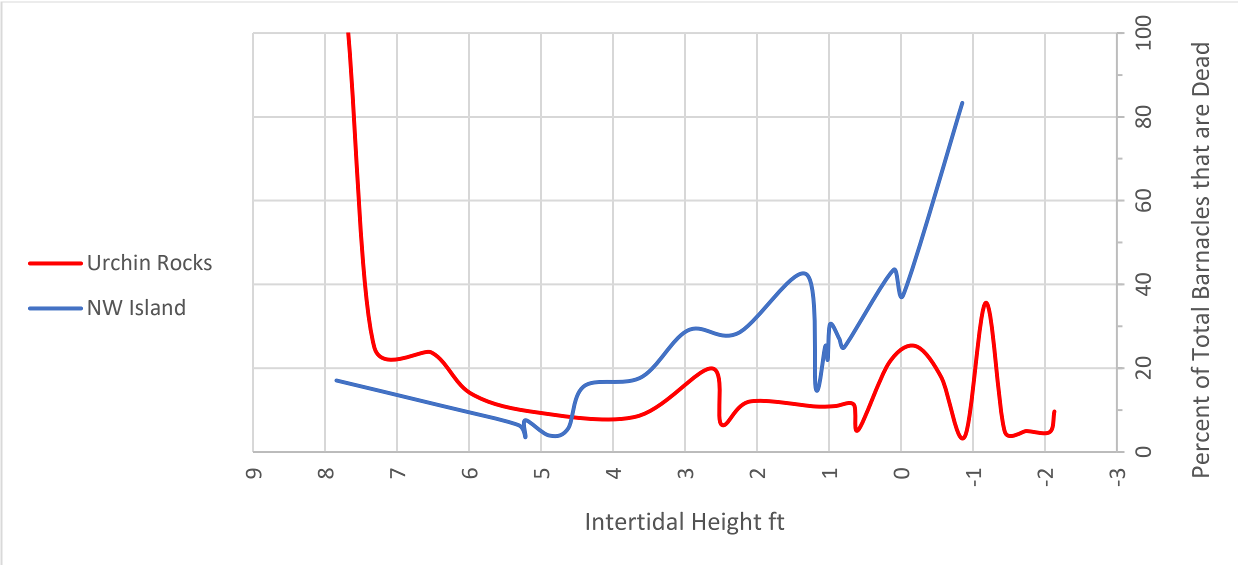


Figure 10: Percent of barnacles that were dead at Urchin Rocks and Northwest Island

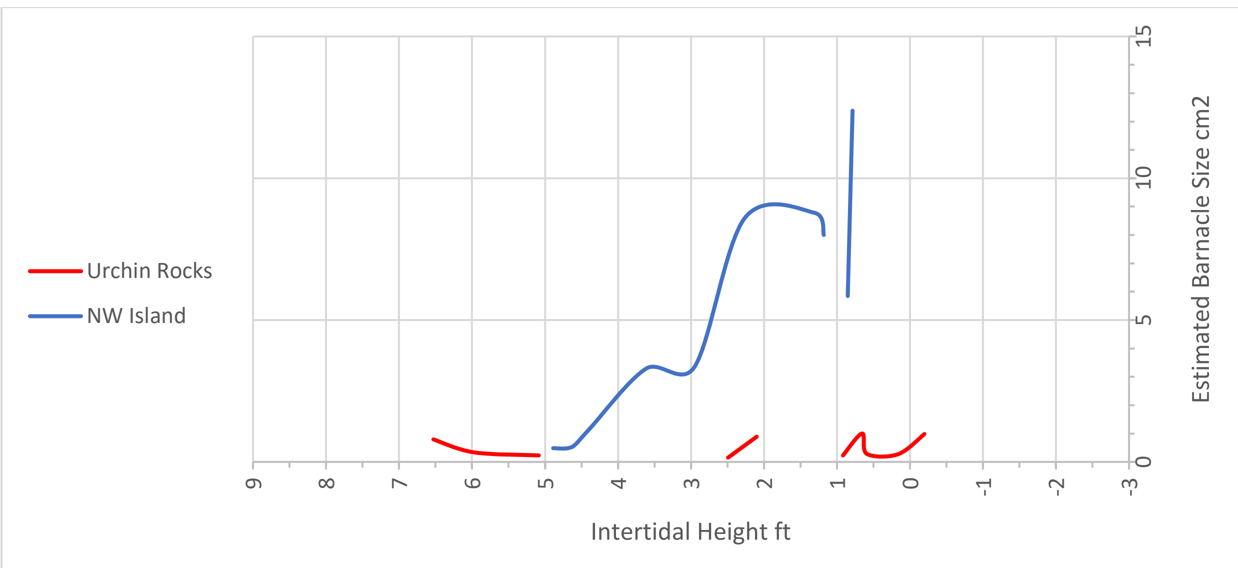


Figure 11: Calculated mean barnacle size at Urchin Rocks and Northwest Island

Permanova analysis revealed that the barnacle assemblages differed by both Location ($F = 3.08$, $df = 1$, $P = 0.027$) and Zone ($F = 3.90$, $df = 1$, $P = 0.027$). There was no significant interaction between Location and Zone, indicating that the overall trends by intertidal elevation were comparable between the two Locations. The high intertidal Zones at the two locations were not significantly dissimilar from one another ($F = 0.04$, $df = 1$, $P = 0.66$) but the dissimilarity of the two low Zones from each other was highly significant (F = 4.89, df = 1, P = 0.005). Interestingly, although the dissimilarity of the barnacle assemblages between high and low Zones on Northwest Island was highly significant (F = 4.61, df = 1, P = 0.003), the high and low zones at Urchin Rocks were not significantly dissimilar (F = 0.94, df = 1, P = 0.34). This was likely due to the dominant *B. glandula* populations found in both the high and low intertidal Zones there (Figure 6). Table 3 shows the average counts of the different barnacle species (tentatively identified) in high and low tide Zones at the two Locations.

| Table 3: Average (mean/median) counts of the different live barnacle species and dead barnacles per square meter at High and Low tide elevations at Urchin Rocks (UR) and Northwest Island (NWI). Species identifications should be regarded as tentative. | | | | | |
|---|---|---|---|---|---|
| | *Chthamalus sp.* | *Balanus glandula* | *Semibalanus cariosus* | *Balanus nubilus* | Dead barnacles |
| UR High | 113.3/0 | 2939.7/1355 | 113/100 | 118.4/4.5 | 441.5/289 |
| UR Low | 0/0 | 1679.4/1060 | 444.2/183 | 16.5/0 | 344.1/289 |
| NWI High | 0/0 | 2835.5/1832 | 277.1/253 | 98.7/19 | 225.8/181 |
| NWI Low | 0/0 | 65.3/24 | 54.8/44 | 75.5/37 | 74.7/37 |

Comparisons of the Assemblages of Other Invertebrates:

Of the other major groups of invertebrates at the two sites, mollusks and anemones were the most common (Figures 12, 13). Note that the y (count) axis is logarithmic in these figures so a small vertical difference represents a large difference in counts. The anemones were mostly *Anthopleura elegantissima*, with a few *Urticina crassicornis* and *Epiactis prolifera* in the low intertidal. Gastropods such as periwinkles (*Littorina*) and limpets were the main mollusks at Urchin Rocks and periwinkles, limpets, mussels, and chitons were common at Northwest Island. Motile crustaceans, especially amphipods and isopods, were sporadically found at all tidal elevations. Seastars were not abundant and were only found in the low intertidal, especially at Urchin Rocks.

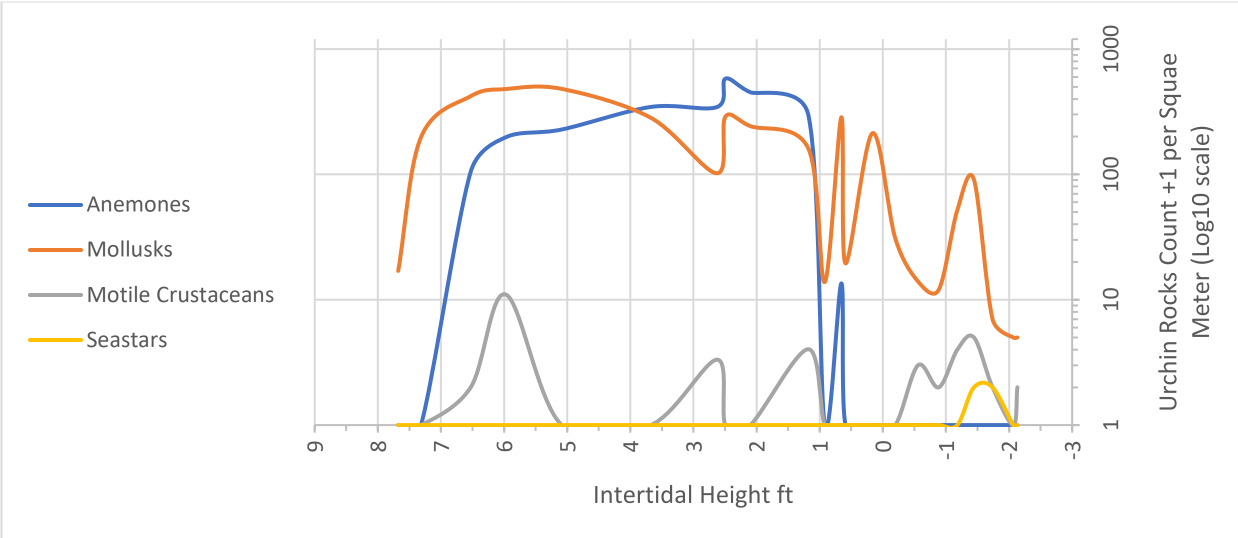


Figure 12: Counts of several important types of invertebrates at Urchin Rocks. Note that the vertical (count) axis is logarithmic.

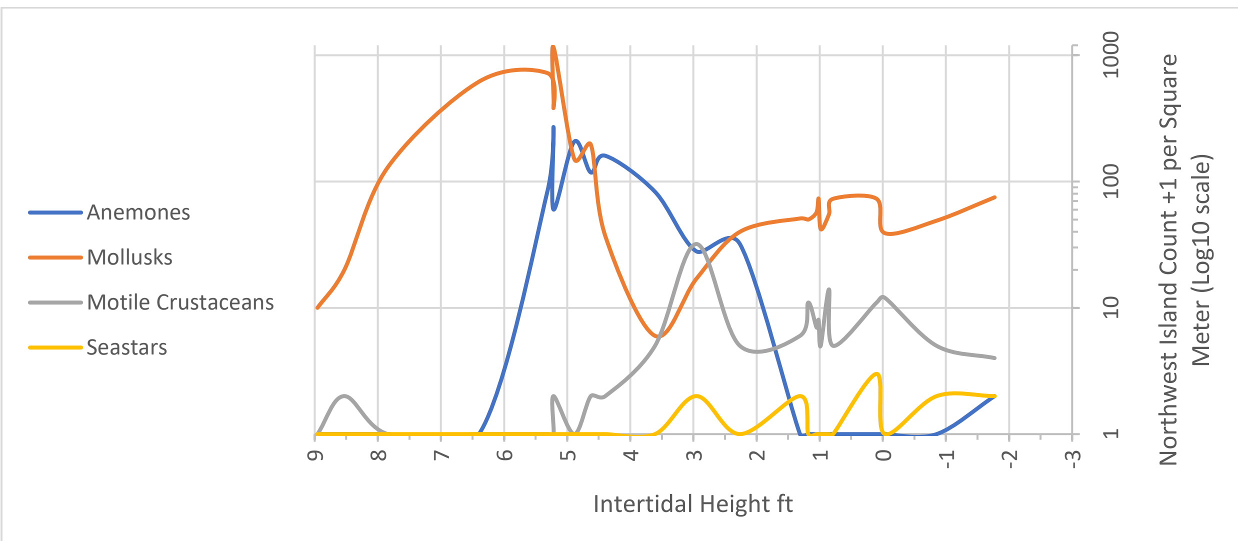


Figure 13: Counts of several important types of invertebrates at Northwest Island. Note that the vertical (count) axis is logarithmic.

Permanova analysis of invertebrate counts found no significant dissimilarity between Locations overall ($F = 2.06$, $df = 1$, $P = 0.118$) but a highly significant dissimilarity between intertidal Zones ($F = 9.88$, $df = 1$, $P = 0.001$). The high intertidal Zones were not dissimilar at the two Locations ($F = 0.21$, $df = 1$, $P = 0.83$) but the low intertidal Zones were moderately dissimilar ($F = 4.66$, $df = 1$, $P = 0.011$ but barely significant after Bonferroni correction). As with the barnacle assemblage, the dissimilarity between the high and low intertidal Zones at Urchin Rocks was not significant (F = 2.83, df = 1, P = 0.063) but the high versus low intertidal dissimilarity was highly significant at Northwest Island (F = 10.59, df = 1, P = 0.001). Table 4 lists the average counts per square meter of the different invertebrate groups, and Table 5 lists all the species identified at the two Locations. Invertebrate species richness was 31 at Urchin Rocks and 45 at Northwest Island (Table 5).

Table 4: Average (mean/median) counts of several different invertebrate groups per square meter at High and Low tide elevations at Urchin Rocks (UR) and Northwest Island (NWI).

| | Anemones | Mollusks | Motile Crustaceans | Seastars |
|---|---|---|---|---|
| UR High | 145.3/50.5 | 312.3/351 | 1.8/0 | 0/0 |
| UR Low | 105.4/0 | 95.5/40.5 | 1.1/0.5 | 0.1/0 |
| NWI High | 88.5/82 | 310.9/150 | 0.7/0 | 0/0 |
| NWI Low | 4.5/0 | 52.4/50 | 8.6/6 | 0.5/0 |

Table 5: Invertebrate species found in the transects at Urchin Rocks and Northwest Island

| Group | Species | Urchin Rocks | Northwest Island |
|---|---|---|---|
| Porifera-Sponges | | | |
| | *Haliclona ecbasis* | | X |
| Cnidaria-Anemones | | | |
| | *Anthopleura elegantissima* | X | X |
| | *Urticina crassicornis* | | X |
| | *Epiactis prolifera* | | X |
| Nemertea-Ribbon Worms | | | |
| | *Paranemertes peregrina* | X | X |
| | *Baseodiscus princeps* | X | |
| | Unknown nemertean | | X |
| Annelida-Polychaetes | | | |
| | *Eudistylia vancouveri* | | X |
| | Motile polychaete | X | X |
| Mollusks-Polyplacophorans-Chitons | | | |
| | *Lepidochitona dentiens* | X | |
| | *Tonicella lineata* | X | X |
| | *Mopalia muscosa* | X | X |

| | | |
|---|---|---|
| *Cryptochiton stelleri* | X | X |
| *Katharina tunicata* | | X |
| *Stenoplax heathiana* | | X |
| Mollusks-Gastropods-Limpets | | |
| *Tectura persona* | X | X |
| *Tectura scutum* | X | X |
| *Lottia digitalis* | X | X |
| *Lottia pelta* | X | X |
| *Diodora aspera* | | X |
| Mollusks-Gastropods-Snails | | |
| *Littorina scutulata* | X | X |
| *Littorina sitkana* | X | X |
| *Calliostoma ligatum* | X | X |
| *Searlesia dira* | | X |
| *Nucella lamellosa* | | X |
| *Nucella canaliculata* | | X |
| *Ceratostoma foliatum* | | X |
| *Ocenebra lurida* | | X |
| *Amphissa columbiana* | | X |
| *Bittium exchrichtii* | | X |
| Mollusks-Gastropods-Nudibranchs | | |
| *Doris montereyensis* | X | |
| Mollusks-Bivalves-Mussels | | |
| *Mytilus trossulus* | | X |
| Arthropods-Chelicerates-Annelids | | |
| Red mite | | X |
| Arthropods-Crustaceans-Barnacles | | |
| *Chthamalus* sp. | X | |
| *Balanus glandula* | X | X |
| *Semibalanus cariosus* | X | X |
| *Balanus nubilus* | X | X |
| Arthropods-Crustaceans-Amphipods | X | X |
| Arthropods-Crustaceans-Isopods | | |
| *Pentidotea wosnessenskii* | X | X |
| Arthropods-Crustaceans-Hermit crabs | | |
| *Pagurus granosimanus* | X | X |
| Arthropods-Crustaceans-Crabs | | |
| *Placetron wosnessenskii* | X | X |
| *Hemigrapsus nudus* | X | X |
| *Hemigrapsus oregonensis* | X | |
| *Pugettia producta* | X | X |
| *Pugettia oregonensis* | X | X |
| Decorator crab | X | X |
| *Glebocarcinus oregonensis* | | X |
| Echinoderms-Seastars | | |
| *Leptasterias hexactis* | X | X |

| | | |
|---|---|---|
| *Leptasterias pusilla*<br>*Henricia pumila* | X | <br>X |
| Echinoderms-Urchins<br>*Strongylocentrotus droebachiensis* | | <br>X |
| | | |
| Invertebrate Species Richness: | 31 | 45 |

**DISCUSSION**

Clear differences continue to exist between the Urchin Rocks and Northwest Island sites, in all three aspects of community structure (algae, barnacles, other invertebrates) that we studied. Visual examination of the two sites suggests that, although the prominent diatom algal mat seen in 2002 is still present, it may be less extensive. Nevertheless, it still is the dominant type of algae in the lower intertidal at Urchin Rocks but plays only a minor role at Northwest Island (Figure 5). This difference may be due to trampling at Urchin Rocks, although this study could not verify why it persists. Barnacles are abundant at both sites, but consist of mostly small, young individuals at Urchin Rocks while the Northwest Island site has abundant large, mature barnacles (Figure 11) but fewer individuals overall (Figure 7). Dead barnacles appear to be especially abundant near the lower intertidal path at Urchin Rocks (Figure 8), although their presence might simply be due to the fact that live barnacles were also especially abundant in that area. Indeed, the actual percent of barnacles that were dead was higher in the 0-1 foot elevation area of Northwest Island than it was at Urchin Rocks (Figure 10), although with the fewer, larger barnacles characteristic of Northwest Island the actual number of dead barnacles there was much less than at Urchin Rocks.

The extensive abundance of small barnacles, primarily *Balanus glandula*, well down into the lower intertidal zone and around the trail at Urchin Rocks contrasted with the relatively fewer, larger barnacles at similar heights at Northwest Island suggests different ecological pressures may be present at the two sites. It may be that the trampling occurring at Urchin Rocks limits the growth of macroalgae (but not diatoms) in the lower intertidal region. This in turn may provide plenty of bare rock substrate for barnacles to settle and grow. The abundant macroalgae at Northwest Island may also limit barnacle growth by limiting the barnacles' access to their plankton food. So although trampling may cause some mortality in barnacles its overall effect may promote increase in the barnacle population. However, the largest barnacle sizes are mostly missing from the Urchin Rocks assemblage. Could it be that trampling promotes settlement of barnacles by exposing bare rock surfaces but prevents growth to the larger sizes? The barnacles present at Urchin Rocks may then be following an r-strategist pattern in which many individuals can settle but few can continue to live and grow there long-term, while at Northwest Island fewer successfully settle due to the heavy macroalgal growth but a number of individuals persist to large size. It should also be noted that predatory snails such as *Nucella* spp. are major predators of small intertidal barnacles. However, large predatory snails, which can be easily seen, are mostly absent from Urchin Rocks and were not observed within our transects (Table 5). Their absence could also be a factor in allowing the large population of small barnacles at Urchin Rocks. [Side note: For some reason, *Nucella* snails seemed to be at unusually low abundance at a number of rocky sites near Rosario in summer 2020, but were definitely present on Northwest Island].

A caution should also be given about the barnacle species identifications in Figures 6 and 7 and in Table 3. Reviews were made of the anatomy of the different barnacle species before the survey but it can be difficult to distinguish species reliably, especially based simply on photographs. The counts showed *Semibalanus cariosus* extending higher in the intertidal zone than I would expect, and some of these individuals may have been *Balanus glandula*. I would also expect *Balanus nubilus*, a mostly subtidal species, to be rarely found above zero tide level and most of the counts of this species above that point are probably *Semibalanus cariosus*.

This study had the most difficulty accurately quantifying the number of invertebrates other than barnacles at the two sites. While the overall count of invertebrates at the two sites was similar (Figures 12, 13) the diversity (species richness) was considerably higher at Northwest Island (Table 5). Motile invertebrates, especially crabs, were no doubt strongly undercounted at both Locations because once the algae were cleared most of them ran for cover. My subjective observations were that invertebrate counts generally increased with increasing macroalgal cover but the motile ones quickly found other cover once the algae was removed. Amphipods and isopods often left but many of them stayed behind and tried to hide in crevices. The most accurate counts, of course, were of less motile or fixed species such as anemones, snails, chitons, and mussels. Of these, *Anthopleura elegantissima* anemones were quite common at both sites. Northwest Island had a number of chitons and mussels, though, that were seldom found at Urchin Rocks. That may imply that *A. elegantissima* is fairly resistant to trampling (they tend to live in crevices or small tide pools) but that *Mytilus trossulus* mussels, which were not found at all on the Urchin Rocks transect, is a more vulnerable species, which is a similar result as that found by Smith et al., (2008). Seastars also, though found at both Locations, was less common and found lower at Urchin Rocks. Some pleasant surprises turned up at Urchin Rocks, however, such as the large *Doris montereyensis* nudibranch which was found in a small tidepool directly in the most trampled area. Also, though most motile macroinvertebrates seemed scarce in the diatom-overgrown areas, a few decorator crabs, heavily encrusted with diatoms, were found there. And though macroinvertebrates were scarce, examination of the diatom scum through a dissecting microscope showed that it was a vibrant, teeming community of small and larval invertebrates such as ostracods, amphipods, and polychaete worms. It therefore may serve as an important nursery and food source for surrounding communities.

In summary, most of the differences between Urchin Rocks and Northwest Island seem to have persisted over the past 18 years. Urchin Rocks has lower diversity (species richness), more but smaller barnacles, and the usual rich algal growth at low intertidal levels seems to be largely replaced by diatoms. These are likely largely due to the impact of human visits, but even if the area shows impact and is not improving in diversity it does maintain a substantial amount of diversity while hosting large numbers of human visitors. Some segments of the community, especially in the higher intertidal areas, remain statistically indistinguishable from that of the little-disturbed Northwest Island.

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