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Abstract Approved: ______________________________
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The rocky intertidal is a diverse ecosystem with a variety of species and ecological interactions. Many biotic and abiotic interactions act together to restrict the abundance and distribution of species. Anthropogenic effects can have an important impact on species abundance and distribution as well. This study looks at how human visitation affects community structure in the rocky intertidal along the Oregon coast. Areas of high human visitation were found to have lower species richness than areas of low visitation in the lower vertical zones of the rocky intertidal. However, species richness was found to be higher in high visitation areas in the highest intertidal zone. Abundance of species differed between areas of high and low human visitation, but showed few overall significant trends.

Key Words: anthropogenic affects, human visitation, Oregon coast, rocky intertidal, state parks

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Human Visitation in the Rocky Intertidal and its Effects on Abundance of Algal and Invertebrate Species

by

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I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

Justin J. Silbernagel, Author

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TABLE OF CONTENTS

Page

INTRODUCTION 1

METHODS 3

RESULTS 5

DISCUSSION 6

Species Richness 6
Trends by Taxon or Functional Group 8

CONCLUSIONS 12

BIBLIOGRAPHY 12

LIST OF FIGURES

Page

Figure 1 16

Figure 2 17

Figure 3 18

Figure 4 19

Figure 5 20

Figure 6 21

Figure 7 21

Figure 8 22

HUMAN VISITATION IN THE ROCKY INTERTIDAL AND ITS EFFECTS ON ABUNDANCE OF ALGAL AND INVERTEBRATE SPECIES

Justin Silbernagel

Introduction

The rocky intertidal zone is a diverse ecosystem that is important in the transition between marine and terrestrial ecosystems. Numerous biotic and abiotic factors (predation, competition, recruitment, desiccation, temperature, etc.) act together to control species distributions and community structure in the intertidal (Dayton, 1971; Paine, 1974; Menge, 1976; Lubchenco, 1980; Menge et al., 1994; Petes et al., 2007). Many of these natural controls have been extensively studied, and their effects on intertidal organisms are well known. Less well known are the impacts of humans on intertidal communities.

Several workers have studied the effects of human visitation in the rocky intertidal (Beauchamp and Gowing, 1982; Castilla and Duran, 1985; Addessi, 1994; Brosnan & Crumrine, 1994; Fletcher and Frid, 1996). The three major disturbances human visitors have on the intertidal zone include collection of organisms, disruption of habitat (e.g., overturning rocks), and crushing of organisms simply by walking on the rocks (Addessi, 1994). Collection of invertebrate and algal specimens by humans for food, fishing bait, and home aquariums can have significant impacts on rocky intertidal communities as selected species are removed from the area (Castilla and Duran, 1985; Keough et al., 1993; Addessi, 1994).

Human trampling has been shown to change the structure of intertidal communities as well (Povey and Keough, 1991; Fletcher and Frid, 1996; Schiel and Taylor, 1999). Povey and Keough (1991) and Schiel and Taylor (1999) showed that higher intensities of trampling have greater effects on rocky intertidal organisms. They showed how trampling immediately decreases cover of fleshy algae as the blades are torn and the holdfasts removed from the substratum. Invertebrates and algae in the understory were shown to decline in response to increased desiccation from the removal of fleshy algae (Schiel and Taylor, 1999). Declines in fleshy algae have also been shown to contribute to declines in many species of invertebrates that use the algae for food or habitat (Brown and Taylor, 1999).

Recovery times of impacted species are affected by the intensity of trampling (Povey and Keough, 1991; Fletcher and Frid, 1996; Schiel and Taylor, 1999). Under high intensities of trampling, recovery can take anywhere from months to years to reach pre-disturbance levels (Brosnan and Crumrine, 1994; Schiel and Taylor, 1999). Increases in herbivorous molluscs and turf algae increase recovery time for fleshy algae, which must compete for space with these species (Povey and Keough, 1991; Keough and Quinn, 1998). Recovery is also limited by settlement, which tends to peak at certain times during the year (Brosnan and Crumrine, 1994; Schiel and Taylor, 1999).

The rocky intertidal along the Oregon coast is a prime area to study the affects of human visitation due to its popularity as a tourist destination. Oregon is known for its public beaches and numerous state parks and recreation areas along the coast. These state parks are the perfect location to look at the impacts of human visitation because they act as access points to the rocky intertidal for human visitors (Addessi, 1994).

In this study, we asked whether human visitation has an effect on the species richness and abundance of intertidal organisms. We hypothesize that most intertidal communities will have lower species richness and differing species abundances in high visitation areas of state parks compared to low visitation areas. We further hypothesize that these areas will show lower abundances of fleshy algal species and greater abundances of turf algal species.

Methods

The sites for this study were located within three state parks on the central Oregon coast. The parks included Otter Crest (44^{o}45'N, 124^{o}03'W), Seal Rock (44^{o}29'N, 124^{o}05'W), and Strawberry Hill (44^{o}15'N, 124^{o}06'W) (Figure 1). All of these parks are frequented by tourists throughout the year, but especially in the summer. A high and low visitation area was identified at each park using previous knowledge of visitor densities along the shore. Within each site, the shore was divided into four intertidal zones according to shore height above mean lower low water (low, 0 m; low-mid, 0.61 m; mid, 1.52 m; and high, 2.74 m). Biological vertical zonation was taken into account when identifying intertidal zones (e.g., mussel bed was designated as the mid intertidal zone).

Each site had slightly different physical characteristics. The lower intertidal zones of the high visitation area at Otter Crest were located partially on a rocky bench that extended westward into the ocean and partially on large boulders in a small bay with a high retention of sand. The upper intertidal zones were located on a slightly sloping rock slab that faced the ocean. The lower intertidal zones of the low visitation area at Otter Crest had been highly excavated by urchins and were located behind a channel running along the shore. The rock was pit-marked with small hollows and crevices from the urchins. The upper intertidal zones were located on flat rock behind a small ridge that protected them from heavy wave action.

The high intertidal zone at Seal Rock was not sampled because it consisted mostly of sand. Large rocks located less than 100m offshore broke up waves and sheltered the intertidal from heavy wave action. The high visitation area was located at the end of an access path from the state park, and the low visitation area was located farther down the beach. The lower intertidal zones at Seal Rock were located around the western facing edges of small rocky outcroppings surrounded by sand in both visitation areas. The mid intertidal zones were located on top of these rocky outcroppings.

The high visitation area at Strawberry Hill was located in a small, southern facing channel. The southerly direction of the channel reduced wave action during the summer because waves had to curl around to the north to enter the channel. The low visitation area was located away from the most frequently visited areas on one of many rocky benches that extend into the ocean at Strawberry Hill.

Community structure was sampled using transect surveys of each intertidal zone. Fifteen 55cm x 36cm quadrats were distributed randomly along a 50m transect in each zone. Stainless steel lags and washers were used to mark and identify diagonal corners of each quadrat in order to ensure sampling of the same quadrat in following years. Percent cover of all algal and sessile invertebrate species were recorded along with number of individuals of mobile invertebrate species within each quadrat. Some species were only identified to the genus level or higher if field identification was not possible. Photographs of each quadrat were taken. Sampling took place between June 29th and July 16, 2007.

Species richness was compared between sites, visitation level, and intertidal zone. Two sample t-tests were used to compare high visitation and low visitation abundances of species in each zone of the three parks in order to see how species react to high levels of visitation. Two sample t-tests were used because differences between the parks were deemed to be too great to allow an analysis of variance between the sites.

Results

Species richness varied dramatically between intertidal heights and visitation levels (Figure 2). Unlike the three lower zones, the high intertidal zone showed higher species richness in the high visitation areas compared to the low visitation areas. The three lower zones had fewer species in the high visitation areas.

By comparing the percent difference in high visitation species richness and low visitation species richness, a pattern emerges with respect to which intertidal zones had the greatest difference. The low intertidal zone had the smallest difference between high and low visitation areas (16.66%). The difference in species richness in the mid (24.00%) and low-mid (22.54%) intertidal zones were very similar. The high intertidal zone had the greatest difference between high and low visitation areas (28.00%).

Figures 3 through 8 show average abundances of species in intertidal zones where the species had high abundance. Two sample t-tests showed that abundance of most species differed between high and low visitation areas in the different intertidal zones of the state parks (Table 1).

Invertebrate species that were more abundant in high visitation areas include amphipods, the isopod *Idotea* sp., *Littorina* snails, and the anemone *Anthopleura elegantissima* (Figure 3). Invertebrate species that were less abundant in areas of high human visitation include the anemone *Anthopleura xanthogrammica*, the barnacle species

Pollicipes polymerus, the limpet *Lottia* sp., the whelk *Nucella emarginata*, the sea star *Pisaster ochraceus*, sandy tube worms, and sponges (Figure 4). Other invertebrates of interest included the barnacles *Balanus glandula* and *Semibalanus cariosus*, chitons, and the mussel *Mytilus californianus* (Figure 5). This last group of species varied in abundance with human visitation, but the relationship was inconsistent over multiple sites or intertidal zones.

Algal species that were more abundant in high visitation areas included *Neorhodomela* sp. and *Ulva* sp. (Figure 6). Algal species that were less abundant in areas of high human visitation included *Saccharina sessile* and *Laminaria* sp (Figure 7). Other algal species of interest included coralline algal species, *Mastocarpus* sp., *Mazzaella* sp*lendens*, and *Odonthalia* sp. (Figure 8). This last group of species varied in abundance with human visitation, but was inconsistent over multiple sites or intertidal zones.

Discussion

Species Richness

The results of this study suggest that human visitation in the rocky intertidal has an impact on species richness and abundance. At all three state parks sampled, species richness was different in high visitation areas of the park compared to areas of low visitation (Figure 2). The lower species richness in the lower intertidal zones suggests that human visitation has a negative impact on species diversity there, and acts to exclude species that would normally be found in these areas. The higher species richness in the high intertidal zone suggests that human visitation has a different affect on communities in the high shore.

The lower species richness in the high visitation areas of the lower intertidal zones was most likely due to the amount of time visitors spend in these zones. Visitors are more likely to spend their time in the lower intertidal zones than in the high intertidal zone because most of the charismatic organisms (e.g., sea stars, anemones, urchins, crabs, etc.) are located in the lower intertidal zones. Visitors will focus their time in these areas, increasing their impacts in these zones. However, time spent in the intertidal is limited by the tides, and the low intertidal zone is exposed for less time than the high intertidal zone. It is suggested that the time spent under water only acts to protect the low intertidal zone because visitors tend to time their visits with the tides in mind. Most visitors arrive a few hours before low tide, and begin to leave as the tide begins to rise. This focuses their visit during times when the high, mid, and low-mid intertidal zones are exposed. The low intertidal zone is suggested to be protected by the tides because it is only exposed on very low tides, and stays submerged during most low tides.

The association of high species richness in areas of high visitation in the high intertidal zone is suggested to be due to an increase in disturbance caused by visitors. Visitors are not likely to spend time in the high zone due to its lack of diversity, and visitors may pass through the zone quickly on their way to the lower intertidal zones. While traveling through the high zone, visitors are more likely to step on or crush organisms in their rush to get to the lower intertidal zones. This increased disturbance may free space for other species to colonize, increasing diversity in the area by opening space for subordinate competitors.

The association in the high intertidal zone may be due to increased protection from waves instead of intensity of human disturbances. The high visitation area at Otter

Crest was located behind a bay that may slow waves before they break on the bench where the high intertidal zone is located. The high visitation area at Strawberry Hill was located in a south facing channel which greatly reduced waves. Unlike these protected areas, the high intertidal zones at the low visitation areas at Otter Crest and Strawberry Hill were more exposed to waves.

Trends by taxon or functional group

Our hypothesis that intertidal organisms are affected by human visitation was supported by the results of this study. Seven invertebrate species and two algal species had lower abundances in areas of high human visitation (Figures 4 and 7), while four invertebrate species and two algal species had higher abundances in areas of high human visitation (Figures 3 and 6). Other invertebrate and algal species had different abundances at the two levels of visitation, but did not show a consistent trend over all intertidal zones and sites (Figures 5 and 8).

Chitons are a good example of a species that showed an inconsistent trend to human visitation at different sites. Chitons had lower abundance in high visitation areas at both Otter Crest and Strawberry Hill in the low-mid and low intertidal zones, but had higher abundance in the high visitation at Seal Rock in the same zones. It is unclear whether this difference is caused by differing levels of visitation at the different state parks, or some other factor that was not measured in this study.

Seal Rock differed from the other two sites in *Balanus glandula* abundance as well. The abundance of *B. glandula* was high in high visitation areas at both Otter Crest and Strawberry Hill. However, *B. glandula* were abundant in the mid intertidal zone at Seal Rock in the low visitation area and were sparse at the high visitation area.

This variation between parks was not restricted to differences between Otter Crest/Strawberry Hill and Seal Rock. Coralline algae had a difference between Otter Crest and Seal Rock/Strawberry Hill. Coralline algae were sparse in areas of high visitation at Seal Rock and Strawberry Hill, but were abundant in the high visitation area at Otter Crest in both the low-mid and low intertidal zones. The variability of responses to human visitation does not seem to be confined to any one state park or intertidal zone, and instead seems to suggest that human visitation may not be the limiting factor for species abundance in some areas.

Mytilus californianus had an interesting pattern in relation to human visitation. These mussels were scarce with high visitation in the high and mid intertidal zones at Strawberry Hill. However, *M. californianus* was abundant with high visitation in the mid intertidal zones at Otter Crest and Seal Rock. Once again, it is unclear why this pattern is present. The location of the high visitation area in a channel at Strawberry Hill may have an impact on *M. californianus* abundance in the mid intertidal zone there. The configuration of the site may force visitors to walk through the mid intertidal zone, instead of around it as at the other two sites, to reach the low intertidal. This may increase the number of people who trample mussels and increase their loss (Brosnan and Crumrine, 1994).

Our hypothesis that fleshy algae would have lower abundances at high visitation areas was not clearly supported by the results. Abundances of fleshy algae were higher in areas of low visitation, but not at all sites and intertidal zones. *Saccharina sessile* and

Laminaria sp. were the only species of fleshy algae that had consistently lower abundances in areas of high visitation. *Mastocarpus* sp. was sparse in high visitation areas in the low-mid intertidal zone, but was more abundant in high visitation areas than in low visitation areas in the high intertidal zone. This inconsistency in response to visitation at different intertidal zones and sites was observed for *Mazzaella* sp*lendens* and *Odonthalia* sp., and suggests that abundance of fleshy algae is affected by more than just human visitation. However, there is evidence that human visitation does negatively affect abundance of these algal species as most had lower abundances in areas of high visitation.

Ulva sp. had a consistent pattern with visitation at all sites, but had an opposite trend than the other species of fleshy algae. *Ulva* sp. was more abundant in areas of high visitation. This pattern went against our prediction that fleshy algae would be less abundant with higher human visitation, but can be explained by the fast colonization of bare space by *Ulva* sp. If the abundance of *Ulva* sp. is used as an indicator of disturbance due to its ability to colonize bare space faster than other species, the results suggest that higher levels of human visitation have higher levels of disturbance in rocky intertidal communities.

The patterns of abundance of fleshy algae in the rocky intertidal along the Oregon coast may limit the ability to compare the effects of human visitation to experiments done in other intertidal areas around the world. Povey and Keough (1991), Keough and Quinn (1998), and Schiel and Taylor (1999) conducted experiments on areas with little or no visitation by humans. Their study sites were described as being covered in fleshy algae (up to 100%) and being far away or isolated from normal areas of visitation. The areas used in their experiments differed greatly from the low visitation areas used in this study, which were inside the main area of each state park and simply located a few hundred meters up or down the coast from the high visitation areas. The low visitation areas still experienced human visitation throughout the year, just at a lower intensity than the high visitation areas. Addessi (1994) showed that intensity of visitation is negatively correlated with species abundance, and even low intensity visitation can affect the abundance of fleshy algal species (Povey and Keough, 1991; Keough and Quinn, 1998; Schiel and Taylor, 1999).

Our prediction that turf algae would be more abundant in high visitation areas was supported by the results. This pattern is suggested to be due to the resistance of *Neorhodomela* sp. to trampling. It is also suggested that the higher abundance of *Neorhodomela* sp. in high visitation areas is related to decreased competition with fleshy algae. The decreased abundance of fleshy algae in high visitation areas may allow *Neorhodomela* sp. grow faster in these areas as it is released from competition with fleshy algal species.

The higher abundance of amphipods and the isopod *Idotea* sp. in areas of high human visitation is suggested to be directly related to the abundance of *Neorhodomela* sp. The abundance of these three species is very similar, with higher abundance in the high visitation areas of the low-mid intertidal zone. During sampling, most amphipods and isopods were found within beds of *Neorhodomela* sp. We suggest that increased cover of *Neorhodomela* sp. increases amphipod and isopod abundances in the area due to increased habitat for them to occupy.

Conclusions

While the small sample size and lack of experimental manipulation of this study has provided more questions than answers, striking patterns have emerged in species richness and abundance between high and low visitation areas in state parks along the Oregon coast. High intensities of human visitation do affect both species richness and abundance in rocky intertidal communities. As human populations continue to grow globally, human use of the intertidal will increase. It is therefore necessary to determine how human visitation affects community structure in the rocky intertidal in order to inform resource managers and the public for use in decisions about management practices for this ecosystem. It is important to continue community surveys at these and other intertidal sites along the coast in order to measure long term changes due to natural and anthropogenic phenomena.

References

Addessi, L. 1994. Human disturbance and long-term changes on a rocky intertidal community. Ecological Applications, 4: 786-797.

Beauchamp, KA, Gowing, MM. 1982. A quantitative assessment of human trampling effects on a rocky intertidal community. Marine Environmental Research, 7: 279-293.

Brosnan, DM, Crumrine, LL. 1994. Effects of human trampling on marine rocky shore communities. Journal of Experimental Marine Biology and Ecology, 177: 79-97.

Brown, PJ, Taylor, RB. 1999. Effects of trampling by humans on animals inhabiting coralline algal turf in the rocky intertidal. Journal of Experimental Marine Biology and Ecology, 235: 45-53.

Castilla, JC, Duran, LR. 1985. Human exclusion from the rocky intertidal zone of central Chile: the effects on *Concholepas concholepas* (Gastropoda). Oikos, 45: 391-399.

Dayton, PK. 1971. Competition, disturbance, and community organization: the provision and subsequent utilization of space in a rocky intertidal community. Ecological Monographs, 41: 351-389.

Fletcher, H, Frid, CLJ. 1996. Impact and management of visitor pressure on rocky intertidal algal communities. Aquatic Conservation: Marine and Freshwater Ecosystems, 6: 287-297.

Lubchenco, J. 1980. Algal zonation in the New England rocky intertidal community: an experimental analysis. Ecology, 61: 333-344.

Keough, MJ, Quinn, GP, King, A. 1993. Correlations between human collecting and intertidal mollusk populations on rocky shores. Conservation Biology, 7: 378-390.

Keough, MJ, Quinn, GP. 1998. Effects of periodic disturbances from trampling on rocky intertidal algal beds. Ecological Applications, 8: 141-161.

Menge, BA. 1976. Organization of the New England rocky intertidal community: role of predation, competition, and environmental heterogeneity. Ecological Monographs, 46: 355-395.

Menge, BA, Berlow, EL, Blanchette, CA, Navarrete, SA, Yamada, SB. 1994. The keystone species concept: variation in interaction strength in a rocky intertidal habitat. Ecological Monographs, 64: 249-286.

Paine, RT. 1974. Intertidal community structure: experimental studies on the relationship between a dominant competitor and its principal predator. Oecologia, 15: 93-120.

Petes, LE, Menge, BA, Murphy, GD. 2007. Environmental stress decreases survival, growth, and reproduction in New Zealand mussels. Journal of Experimental Marine Biology and Ecology, 351: 83-91.

Povey, A, Keough, MJ. 1991. Effects of trampling on plant and animal populations on rocky shores. Oikos, 61: 355-368.

Schiel, DR, Taylor, DI. 1999. Effects of trampling on a rocky intertidal algal assemblage in southern New Zealand. Journal of Experimental Marine Biology and Ecology, 235: 213-235.

Species	Zone	Otter Crest	Seal Rock	Strawberry Hill
Amphipods	Low-Mid	x	0.00000	0.00000
	Low	x	0.00001	0.00084
Anthopleura elegantissima	Mid	0.00005	0.27658	0.00000
	Low-Mid	0.00000	0.00000	0.10657
Anthopleura xanthogrammica	Mid	0.00010	0.00000	0.00027
	Low-Mid	0.00000	0.00000	0.00000
	Low	0.00084	0.00001	0.00000
Balanus glandula	High	0.00000	x	0.00000
	Mid	0.50000	0.00000	0.00000
Chthamalus sp.	High	0.00001	x	0.00003
	Mid	0.05328	0.00003	0.00152
	Low-Mid	0.00005	0.10779	0.00000
	Low	x	0.03221	0.10507
Coralline Algae	Low-Mid	0.00000	0.00000	0.00000
	Low	0.00000	0.00001	0.01866
Encrusting Algae	Low-Mid	0.13133	0.00089	0.00000
	Low	0.00385	0.07803	0.00000
Saccharina sessile	Low-Mid	0.00000	0.07242	0.00000
	Low	0.00000	x	0.19519
Idotea sp.	Low-Mid	x	0.00031	0.00000
	Low	0.00084	0.00181	0.00000
Chitons	Low-Mid	x	0.00555	0.00000
	Low	0.00480	0.00002	0.00001
Laminaria sp.	Low-Mid	0.00002	0.00000	0.00542
	Low	0.31732	0.00002	0.00001
Littorina sp.	High	0.00000	x	0.00011
	Mid	0.00002	0.00000	0.00000

Species	Zone	Otter Crest	Seal Rock	Strawberry Hill
Lottia sp.	High	0.00010	x	0.00000
	Mid	x	0.00000	0.00028
	Low-Mid	0.00394	0.00000	0.00122
	Low	0.00006	0.00008	0.00002
Mastocarpus sp.	High	0.00016	x	0.00014
	Low-Mid	0.00011	0.23265	0.00000
Mazzaella splendens	Low-Mid	0.00000	0.00000	0.00000
	Low	0.47601	0.00014	0.00141
Mytilus californianus	High	0.00003	x	0.00000
	Mid	0.00385	0.00000	0.00000
Neorhodomela sp.	Low-Mid	0.00000	0.00000	0.00000
	Low	0.00051	0.00000	0.00086
Nucella emarginata	Mid	0.00090	0.00001	0.00001
Odonthalia sp.	Low-Mid	0.00000	0.24805	0.00000
	Low	0.00000	0.00032	0.00006
Pisaster ochraceus	Low-Mid	x	0.00006	0.00000
	Low	0.00002	0.00001	0.00000
Pollicipes polymerus	High	0.00000	x	0.00003
	Mid	0.00000	0.00000	0.00000
Sandy Tube Worms	Low-Mid	x	0.00000	0.00035
	Low	x	0.00281	0.00003
Semibalanus cariosus	High	0.00001	x	0.00000
	Mid	0.00000	0.00295	0.01392
Sponges	Low-Mid	0.00000	0.00003	0.00010
	Low	0.00086	0.01163	0.00000
Ulva sp.	Low-Mid	0.00001	0.00000	0.00069
	Low	0.00000	0.00000	0.00017

Table 1: Results from two-sample t-test testing whether abundance in high visitation areas equaled abundance in low visitation areas for each species at each site in each zone. Highlighted cells are not significant at the 0.05 level. Cells containing (x) represent no species found in that zone of the state park.

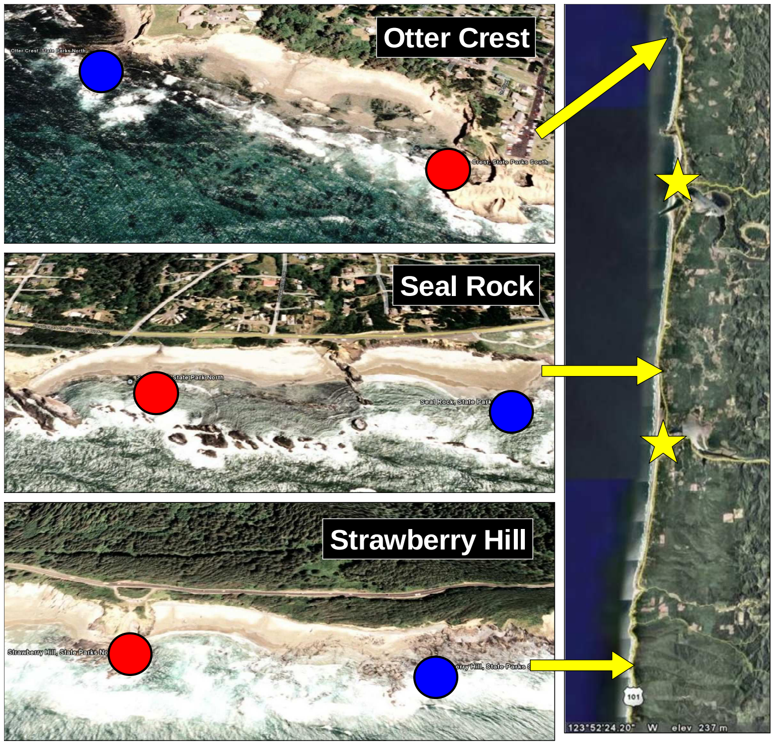


Figure 1: Map of study site locations along the Oregon coast. Red dots represent high visitation areas. Blue dots represent low visitation areas. Yellow stars represent the cities of Newport and Waldport.

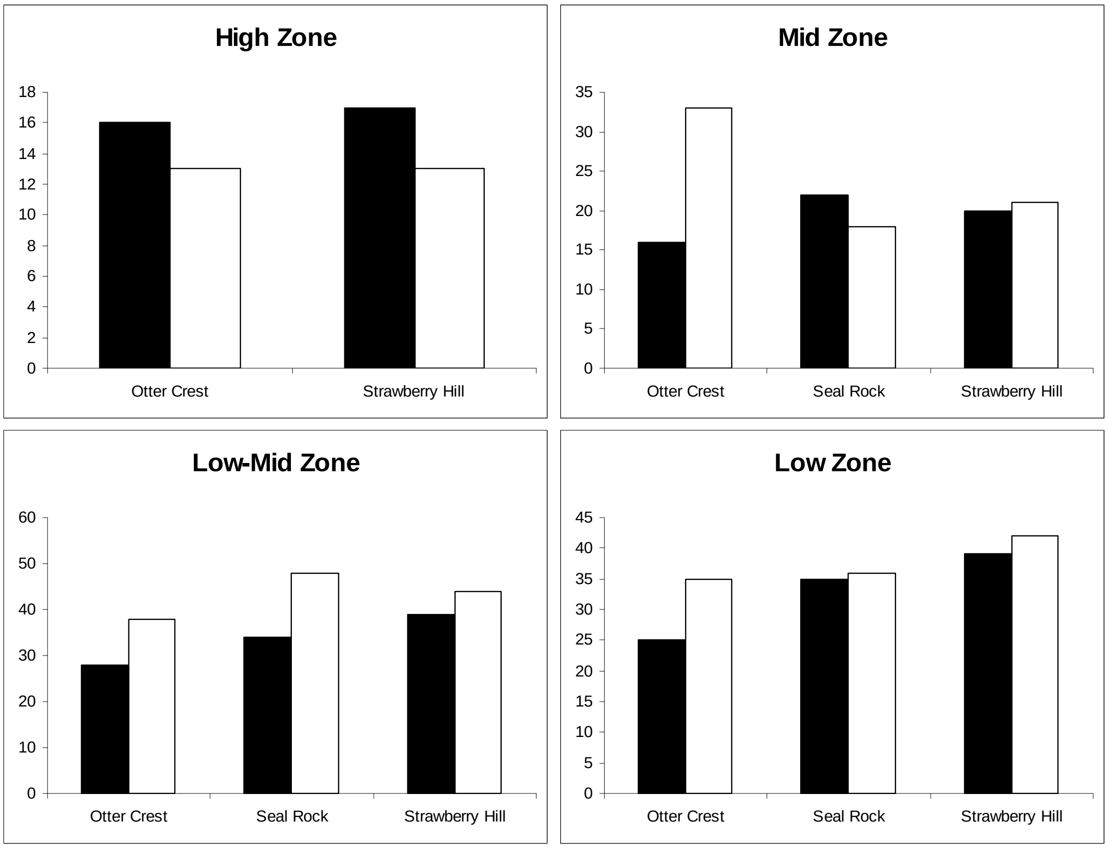


Figure 2: Total species richness of each transect. Dark bars represent high visitation areas. Light bars represent low visitation areas. High visitation areas had more species than low visitation areas in the highest zone at each site. All other zones had more species in low visitation areas.

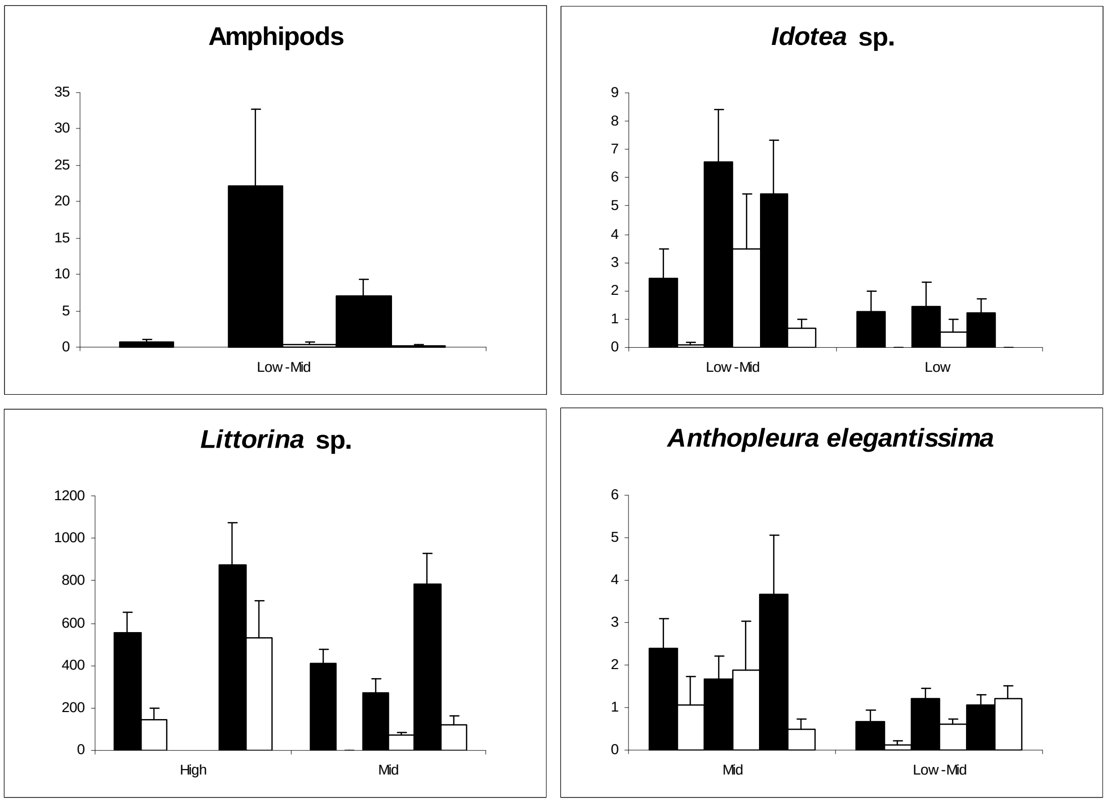
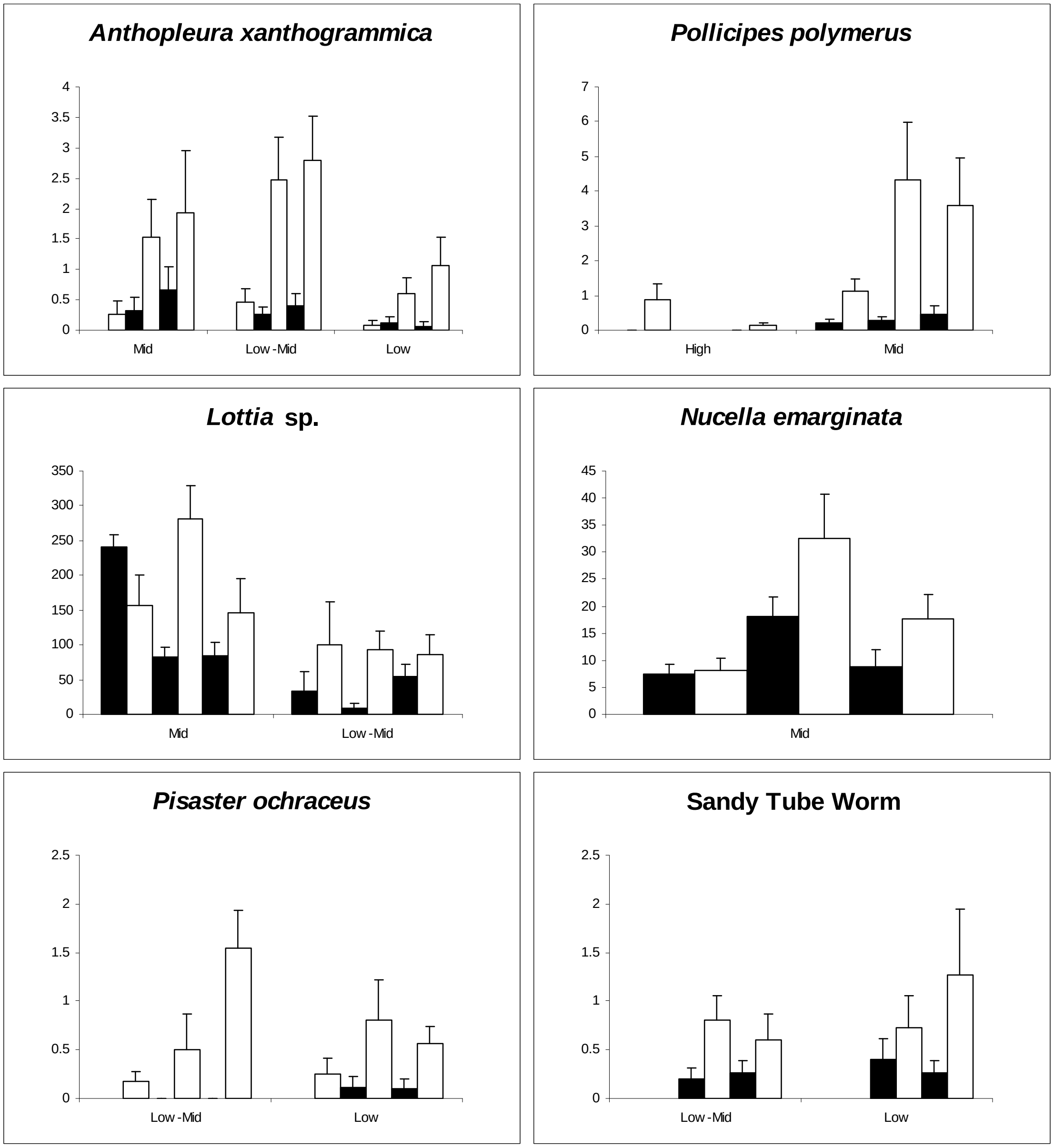


Figure 3: Average abundance of invertebrate species with higher abundances in high visitation areas. Dark bars represent high visitation areas. Light bars represent low visitation areas. Sites are arranged north to south (Otter Crest, Seal Rock, Strawberry Hill).



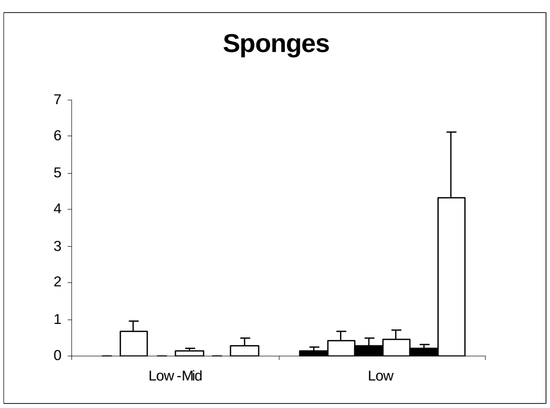


Figure 4: Average abundance of invertebrate species with lower abundances in high visitation areas. Dark bars represent high visitation areas. Light bars represent low visitation areas. Sites are arranged north to south (Otter Crest, Seal Rock, Strawberry Hill).

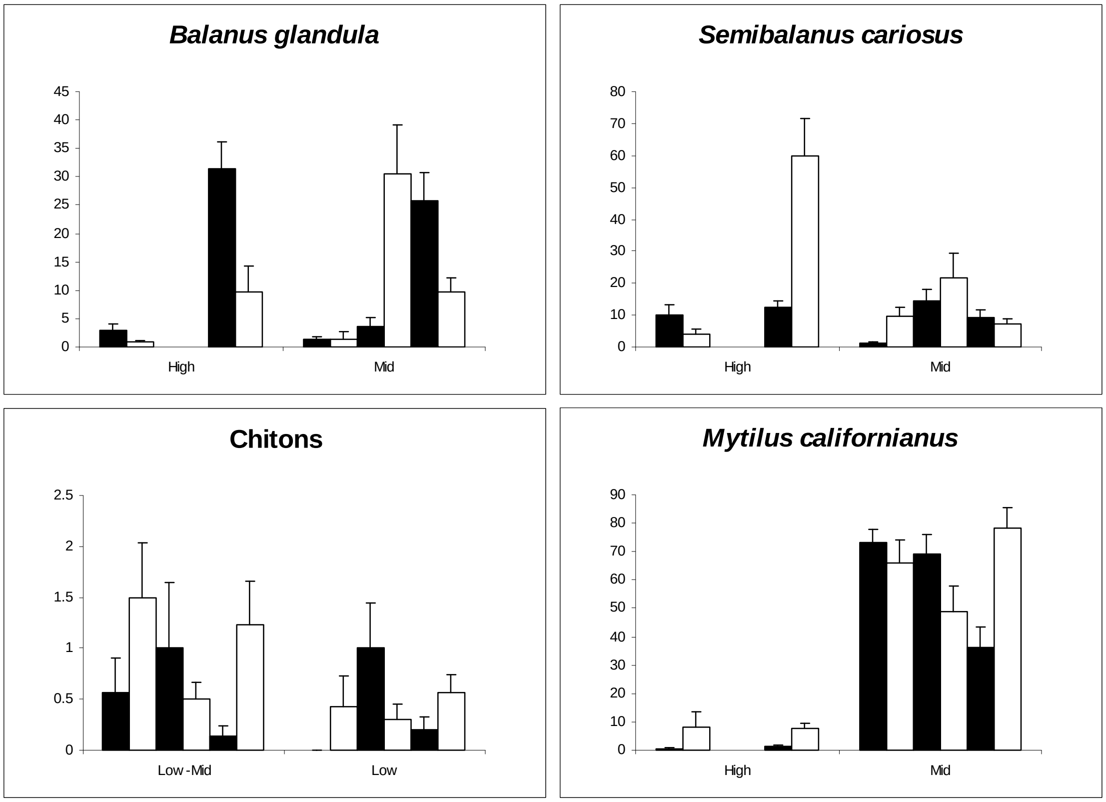


Figure 5: Average abundance of invertebrate species with inconsistent associations to human visitation. Dark bars represent high visitation areas. Light bars represent low visitation areas. Sites are arranged north to south (Otter Crest, Seal Rock, Strawberry Hill).

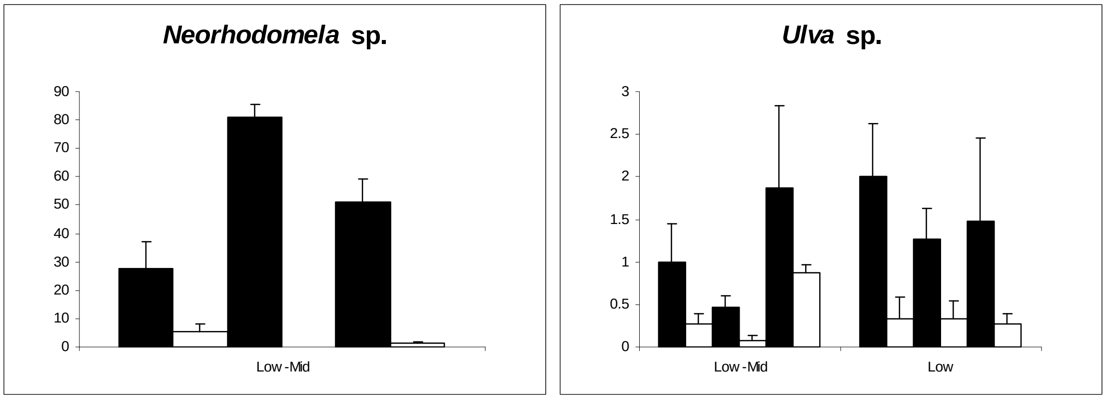


Figure 6: Average abundance of algal species with higher abundances in high visitation areas. Dark bars represent high visitation areas. Light bars represent low visitation areas. Sites are arranged north to south (Otter Crest, Seal Rock, Strawberry Hill).

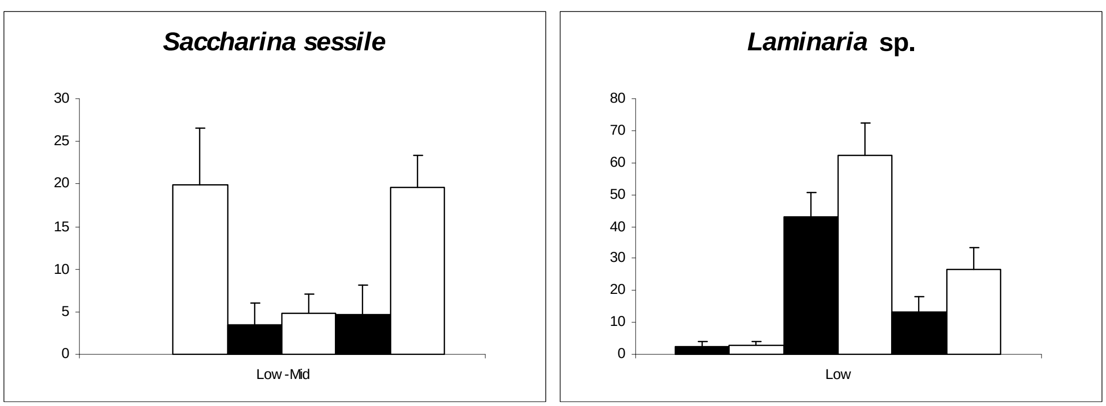


Figure 7: Average abundance of algal species with lower abundances in high visitation areas. Dark bars represent high visitation areas. Light bars represent low visitation areas. Sites are arranged north to south (Otter Crest, Seal Rock, Strawberry Hill).

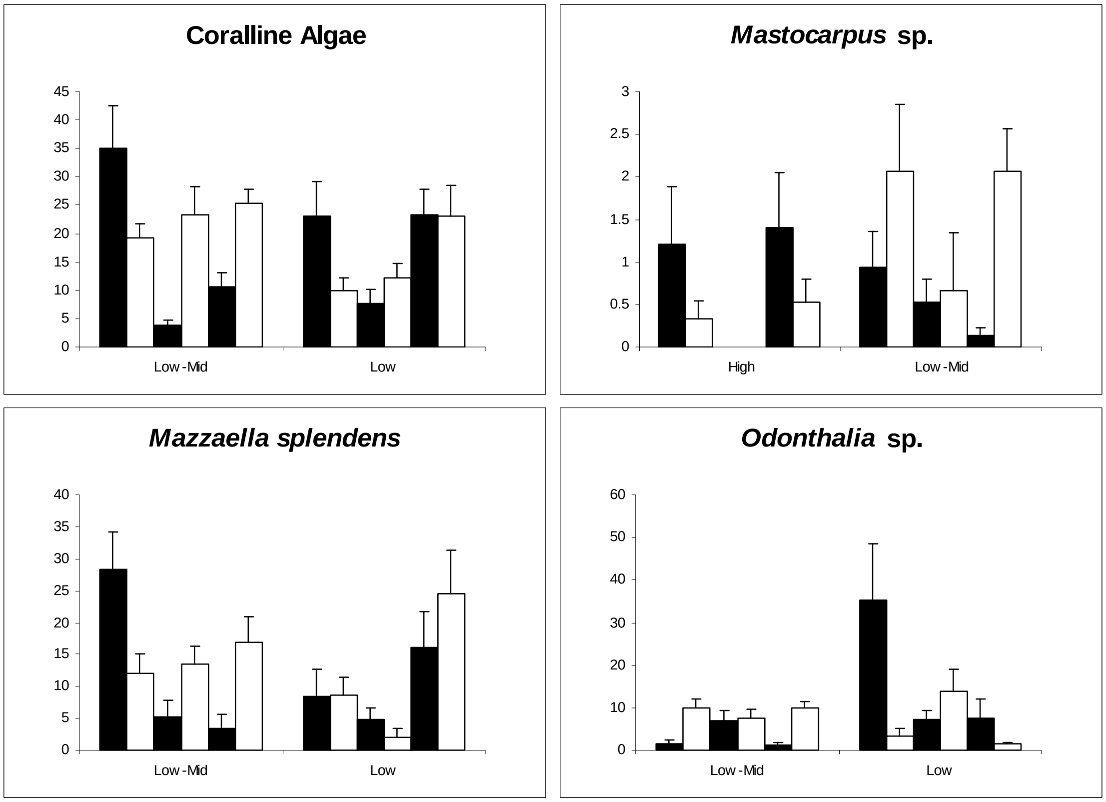


Figure 8: Average abundance of algal species with inconsistent associations to human visitation. Dark bars represent high visitation areas. Light bars represent low visitation areas. Sites are arranged north to south (Otter Crest, Seal Rock, Strawberry Hill).