

Scavenging Rates and Community Composition at Different Habitats along a Shallow Water Depth Gradient

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Deep Sea Biodiversity, Connectivity & Ecosystem Function
Summer 2014

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Keywords: scavengers, community, subtidal, intertidal, habitat, composition, rate

Abstract

As fisheries grow and the amount of bycatch being thrown back into the oceans rises, studies on the effects of interferences in natural food chain processes that occur throughout the ocean become increasingly important. This study aims to look at scavenging rates at different depths and make preliminary observations about how quickly carrion will be consumed and affect the food chain. Three identical traps were deployed at three different habitats: intertidal, shallow subtidal, and deep subtidal. The first was pulled up after 6 hours, the second after 12 hours, and the third after 24 hours. All of the species within each trap were counted, identified, recorded, and entered into Primer and Excel to determine the differences between the habitats, the species richness and diversity for each depth, and the percent bait consumption to determine scavenging rates. The results showed that scavenger species varied noticeably at different depths. The shallow subtidal had the highest scavenger diversity and fastest consumption rates. It also seems apparent that scavenging rates in the intertidal are slowest. Therefore, the habitat would probably be most affected by large carrion debris due to slow decomposition, but it would affect upper trophic levels more slowly than in the other habitats. Future studies should be completed at deeper depths, with more replication, and using controls to find more conclusive results.

Introduction

As animals move through the ocean, they experience many changes in habitat types. Whether they move from a rocky intertidal beach to a sandy subtidal, or from the steep continental slope to the dark and flat abyss, many abiotic changes occur along a depth gradient. With a changing environment comes a variety of organisms adapted to live best in the different conditions. The rocky intertidal is full of many species adapted to avoid desiccation, predation, and competition (Bertness and Leonard, 1997), while the deep sea contains species adapted to

low energy availability (Ramirez et al, 2010). As factors like the climate and human interference are changing, it is important to try and understand the way animals in all habitats will or can react.

While fisheries grow, the amount of bycatch being thrown back into the waters has risen to an estimated 27 million tons each year (Britton and Morton, 1994). The affects this amount of carrion have may be beneficial or detrimental, but with that amount of extra food being placed in the water, there will be affects. The carrion may feed many organisms, but in turn it will then be affecting all trophic levels by disturbing the bottom of the food chain. By studying the scavengers and how quickly they appear and consume bait, it may eventually be possible to determine how long the discarded bycatch will take to be completely consumed at different depths, and how rapidly the food chain may be affected.

Previous studies on scavenging rates at different depths have led to multiple conclusions. A study completed by Ramsay et al. completed off the coast of Red Wharf Bay found that while scavenger species were similar at different depths and habitats, there was a noticeable difference between consumption rates. They also found that the number of animals recovered was partially a simple reflection on the background population densities at each habitat (Ramsay et al, 1997). A different study concluded that in general, the time it takes for scavengers to find food is similar in deep and shallow waters, a discovery that contradicts Ramsay et al (Gage, 1991). A third experiment analyzed the scavenging rates of two species, a gastropod and hermit crab, in an intertidal habitat. The paper found that the hermit crab could not detect the bait at distances that the gastropod could, took longer to find the bait, and took longer to consume the bait than the gastropod did. (Morton and Yuen, 2000). This does not support the idea that the animals

recovered are a reflection of the background population, but that competition plays a significant role as well.

This study aims to look at scavenger rates and composition in the intertidal, shallow subtidal, and deeper subtidal off of San Juan Island in the Puget Sound. By analyzing the species retrieved in modified crab traps, each with three different trial times in each habitat, scavenger composition, species richness, diversity, and rate of bait consumption will be calculated. The results may determine if there are different community structures at different depths, and if habitat has an effect on how quickly scavengers can find bait. This study hypothesizes that scavengers will find the bait more quickly in the subtidal, because while deeper waters may have many species, they are known to have lower biomass (Rex et al, 2006), and getting to the traps in the intertidal where there is not always water may present more of a challenge than the other two habitats. It is also hypothesized that more species will be present in the deep subtidal trial, because with increased depth biodiversity and evenness are known to be very high (Ramirez—Llodra et al 2010). Lastly, I hypothesize that the intertidal scavengers will be noticeably different than those found in either the subtidal or the deeper subtidal, because of the markedly different habitat make up.

Materials and Methods

Preparing the Traps

The first step toward completing this experiment required making three identical crab traps. Three 23”x23”x11” traps were found, and covered in fiber glass window screening (Figure 1B). One door of the each trap was wrapped separately to allow easy access into the cages on site, and the trap doors were wrapped individually to try and prevent any holes in the netting. A 6” diameter filter was zip tied down on the top to allow for smaller animals to enter. Two bricks

were zip tied down into the middle of each cage, and extra mesh was added behind the removable door to cover any holes. Zip ties were used to close the door during a trial. A stabilizing rope was added to the top of the cage by attaching it to three points on the cage and creating a loop for the long rope. 100 ft long rope were then tied to the stabilizing rope, and all loose rope ends were either zip tied down or taped down with black tape.

Approximately 12 hours before the traps were being deployed, six 6"-7" herring that were being stored in a freezer were placed into a tupperware container in the fridge to thaw. Come the morning, the fish were divided into groups of two and weighed. Being sure to keep each weighed pair of fish together and to record what cage each pair goes into, each cage was loaded with two fish. They were hung by one zip tie that ran through both of the fish's operculum and out their mouth. The zip tie was then hung through one of the original cage rungs near the center of the trap. After each trap was pulled out of their given location, the pair of fish would be weighed again together in order to determine the percent of bait eaten.

The goal for every deployment was to get all three crab traps down in either the intertidal, shallow subtidal, or deep subtidal, and leave them there for 6, 12, and 24 hours respectively. They were all aimed to be deployed between 7 am and 9 am.

Intertidal

The intertidal traps were deployed in False Bay, approximately 25 meters in from the top of the rocky intertidal (Figure 1A, Figure 1C). For the first trial run in the intertidal, only two of the three traps were deployed around 8:00 am. The third would not have been retrievable due to the tides. The first cage was retrieved around the 12 hours mark, and the second was retrieved the next morning 24 hours later. For the first run, the cages were placed on a large rock, and

every item inside the trap was counted, recorded, and a picture was taken. The pictures allowed for species identification back in the lab.

During the second intertidal trial, all three traps were put out, but two of them were retrieved at the 24 hour mark, again due to tides. The first trap was still recovered after 6 hours of being in the intertidal. For this trial, the cage was carried to a sea table, where it was placed face down on the side of the removable door. The door was removed, and water was washed only the cage to get all the animals into the sea table. The sea table was then poured off into a bucket. The bait was eventually weighed to determine percent of the fish that was eaten for each cage. Everything was carried back to the lab, where the bucket was emptied into an active sea table to keep the organisms alive until sorting and identification were complete.

Shallow and deep subtidal

The subtidal was the only location to have all three traps deployed and retrieved at the proper times with a complete replicate. They were all deployed off the Friday Harbor Laboratories dock (Figure 1C), and retrieved at 6, 12, and 24 hours. A sea table was taken to the end of the dock, so pulling the organisms from the cage happened immediately when the cages were recovered. The two trial days were back to back, so the 24 hour cage of the first trial was emptied, bait removed, new bait placed in the cage, and was almost immediately redeployed.

In order to get a deeper subtidal trial, the Auklet was used to carry the traps to the other side of Brown Island (Figure 1C). They were deployed in waters between 22 and 23 meters deep, and labeled with buoys. The Auklet was used for the 6, 12, and 24 hour marks, and had the sea table and bucket on it directly. The trial was only completed one time due to time constraint.

Data analysis

Once all animals were in the sea tables, they were counted and identified using dichotomous keys and photos. The pictures from the first intertidal trial were not enough to identify many species, which are labeled by a species number in the data. Once all animals were recorded, they were put back into the ocean.

The species lists were put into excel, and Primer 6 was used to find the species richness, diversity, and cluster graphs. The before and after bait weights were turned into percents and graphed as well.

Results

Community Structure

Each habitat, the intertidal, shallow subtidal, and deep subtidal, had different scavenger species present with little overlap. The intertidal was dominated by *Hemigrapsus oregonensis*, or the Green Shore Crab. By the 12 hour trap there were 4 species present, and by the 24 hour trap, there were 8 species present (Figure 2). The subtidal also had a dominant species throughout each trap, *Pandalus danae*, the Coonstripe shrimp. The 12 hour trap had 17 species present, and by 24 hours there were 14 species counted. With each time lapse, the *Pandalus danae* became less prominent, but always remained the most dominant species. (Figure 3). The deep subtidal traps did not have a dominant species (Figure 4). The 6 hour trap, containing three species, was dominated by *Alia tuberosa*, a type of snail known as the Variegate Dovesnail. The 12 hour trap also contained *Alia tuberosa*, but was highly dominated by *Acila castrensis*, the Divaricate Nutclam, of which there were 108 specimens. The 24 hour trap had no *Alia tuberosa* or *Acila castrensis*, and was not highly dominated by any one species. The two most prominent organisms were *Amphissa versicolor*, The Variegate Amphissa, and *Pandalus danae*, the same dominant shrimp that occurred in the shallow subtidal trial.

Species richness and diversity

Primer was used to analyze the habitat diversity of the intertidal, shallow subtidal, and deep subtidal. A Bray-Curtis similarity dendrogram was made (Figure 5), and showed that the intertidal was completely separate from the shallow subtidal and deep subtidal, which were separate except for the 24 hour trap in the deep subtidal, which was the outgroup on the shallow subtidal grouping. The Bray Curtis MDS plot (Figure 6) showed in a 2 dimensional figure how different the three habitats were based on diversity. Each habitat was grouped separately, except for the 24 hour deep subtidal trap, which was again found closest to the shallow subtidal group.

Scavenger diversity (Figure 7) was highest in the shallow subtidal. It was followed by the deep subtidal, and then the intertidal with a very low diversity. A rarefaction plot of scavenger richness (Figure 8) shows that the most species rich trap was the 24 hour deep subtidal trap, but that within the 12 hour traps, the shallow subtidal had the highest species richness. Species richness generally increased throughout time in the deep and shallow subtidal traps, but decreased between the 12 and 24 hour traps in the intertidal.

Bait consumption

The weight of the bait—two herring per trap—was taken before each trap was released and again after each trap was pulled. The percent of bait eaten was calculated for each trap, excluding the 12 hour intertidal trap which was completed before bait weights were being taken, to determine how quickly scavengers can find and consume carrion in each habitat (Figure 9). In both trials, the intertidal 24 hour trap always had bait remaining; the 24 hour trap in the second trial had 20% of the fish consumed. In both 12 hour traps of the subtidal habitats, the bait was completely gone. For both replicates of the subtidal trial, the 24 hour traps had no fish remaining. The deep subtidal 24 hour trap had most of the bait remaining.

Discussion

Generally, all three hypotheses presented in this experiment were supported, but for each other factors or possible skewed results in the experiments should be discussed. The hypothesis predicting that the subtidal depth will have the highest scavenging rates was supported, because it was the only location at which all of the bait was gone in both the 12 hour and 24 hour traps. These results may not be complete though, since the 24 hour trap for the deep subtidal does not appear to be consistent with all the other data. Shown in both the Bray-Curtis dendrogram and MDS plots as the only trap not grouped within its own habitat, the 24 hour deep subtidal trap also had all the bait gone by 12 hours, but the bait was almost completely present in the 24 hour trap. The deep subtidal 12 hour trap had no bait and had five large Dungeness crabs, while the 24 hour trap still had most of its bait and no Dungeness crabs. The 24 hour trap was hard to pull up, and had sponge and crabs on top of the cage, which may imply that the trap sunk into the sediment, allowing animals to crawl on top instead of inside, or perhaps the trap doors were blocked. Another replication of this trial would have been helpful to understand if the 24 hour trap was underproductive in this experiment, or if the 12 hour trap was over productive.

The species richness graph (Figure 8) shows that generally there were higher species counts in the deep subtidal at 24 hours than in the shallow subtidal or intertidal, supporting the second hypothesis. However, the 24 hour trap may have been an outlier in the data, and if the 12 hour point were being considered, the subtidal had higher species richness. Again, a replication in the deep subtidal would be helpful in understanding what is due to chance and what is significant.

The hypothesis stating that the intertidal community will differ greatly from the subtidal habitats was supported, but additionally there were different community structures in each of the

habitats, including shallow and deep subtidal. The pie charts showing species composition in each habitat show clearly that there was a difference in species community between all habitats, not just intertidal and subtidal.

Since these hypotheses are supported but really need more data, further studies should be completed to continue to understand more about scavenging rates at different depths. More replications of the same experiment, as stated, would be useful in data analysis, and completing the experiment at deeper habitats would also broaden the scope of the experiment. Using a control, or an empty trap in with the other three, would also explain what animals arrive in the baited traps simply because they are a background species and which are actually scavengers. Lastly, an analysis on microfauna in addition to large scavengers should be completed, since amphipods were seen at all sites, but they were not able to be quantitatively counted. Microfauna would make a difference in bait consumption rates, in how carrion would affect the food chain starting with a lower trophic level, and understanding their community structure and scavenger rates at different depths would create more well-rounded conclusions. This study may be viewed as a preliminary study that, along with other studies, may find significant conclusions.

A look at other studies helps put the results found during this experiment into a context. Morton and Chan found that two species of snails, one subtidal and one intertidal, while being starved each had thresholds at which they begin risking being predated upon for finding bait. The threshold began about two times faster in the subtidal than in the intertidal. The paper concludes that the results are probably due to larger species being present in the subtidal than intertidal, and that intertidal animals maybe expend less energy than those in the subtidal (Morton and Chan, 1999). This would explain why there were more scavengers in both the shallow and deep subtidal: they are generally more desperate for food. Along the same lines, the

crabs found in the intertidal were only about an inch long, while the crabs found in the subtidal were much larger species that would require more food. Another paper discusses how carrion is a more important food source at greater depths, and so there is a wider variety of scavengers in deeper waters (Yeh and Drazen, 2011). This supports our results in that the highest species richness was found in the deeper subtidal, but the difference in this experiment between habitats was much less. This may support the idea that this experiment should be repeated at deeper depths, or that there were skewed or biased results in some of the deep subtidal data.

After analyzing community structure, bait consumption, and species richness and diversity at different depths, many conclusions can be made. The scavenger species vary noticeably at different depths or habitats, shown in the fact that there was little overlap in species between habitats and that each had different dominant scavengers. It also seems apparent that scavenging rates in the intertidal are slowest and therefore would probably be most affected by large carrion debris, but it would affect the food chain the slowest. This would occur because it would take longer for scavengers to find and consume it, slowing the effect on the food chain, but it would also take them the longest to remove all of the carrion, creating the largest affect. The intertidal also had the lowest scavenger diversity by far, implying that large food deposits would severely affect only a narrow range of species.

Scavenging rates and species composition do overall tend to change quickly at different depths. Between the intertidal and about 22 meters depth, all around the San Juan Island, the habitats were already very different. The scavengers don't appear to be completely the same in any two places, and for any changes, biotic or abiotic, occurring in the ocean, this is an important idea to consider.

Acknowledgements

I would like to acknowledge the Deep Sea professors, Ken Halanych and Craig Smith, for their guidance throughout the project, and Craig for letting me use his car. I would like to thank Collin Gross for sharing his abundant knowledge throughout our work together, and of course a big thank you to Erica Sampaga, Ben Pelle, Gabby Kurz, Rachel Rillera, and Jeff Lou, for their help in the field and their support!

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Figures

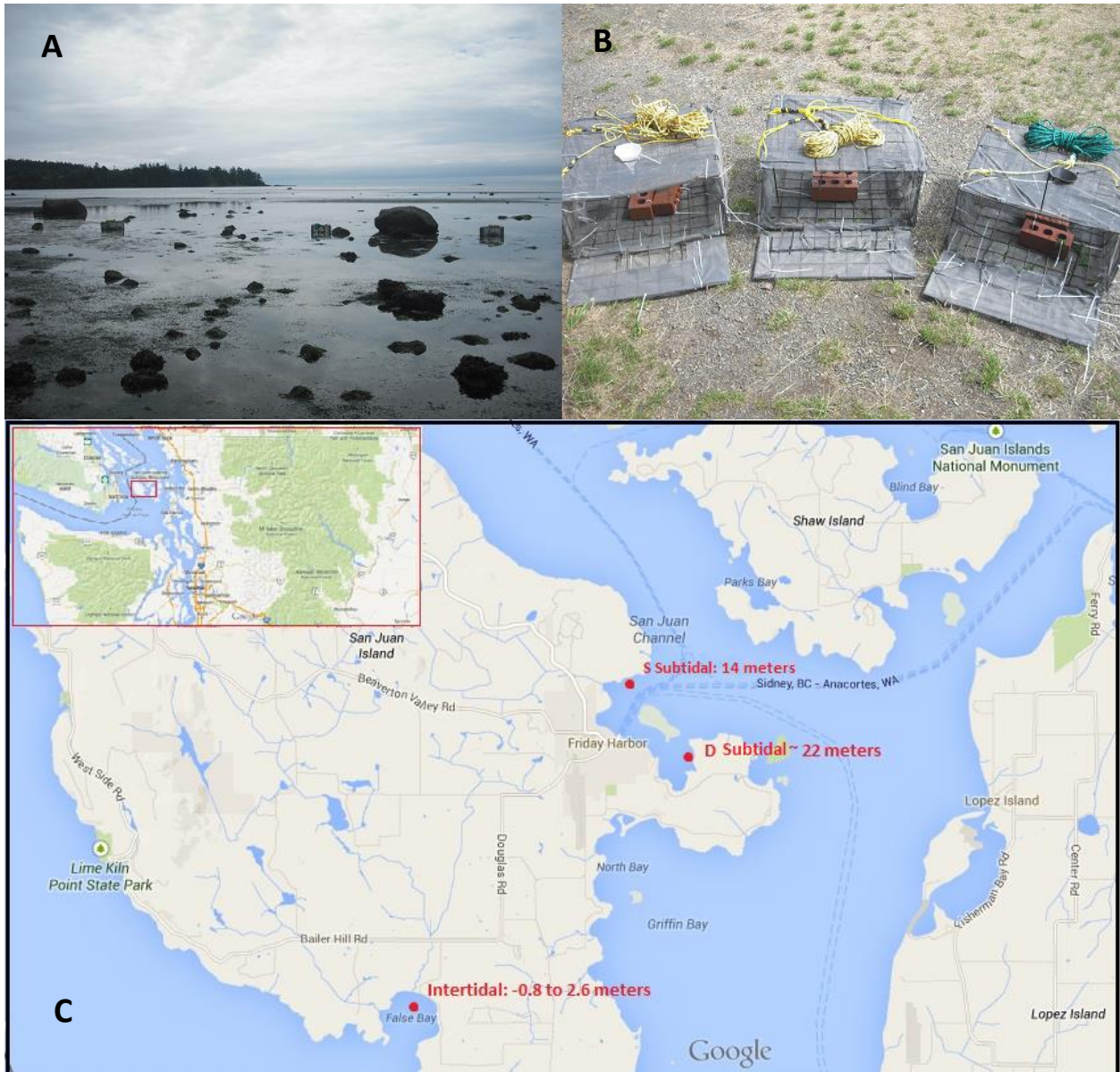


Figure 1. A) A picture of the three traps deployed in the intertidal at False Bay. B) The three identical traps used throughout the project. Crab traps wrapped in mesh with bricks inside, filters on top, and rope. C) Map of the three habitats and depths, where the traps were deployed. [Google Maps]

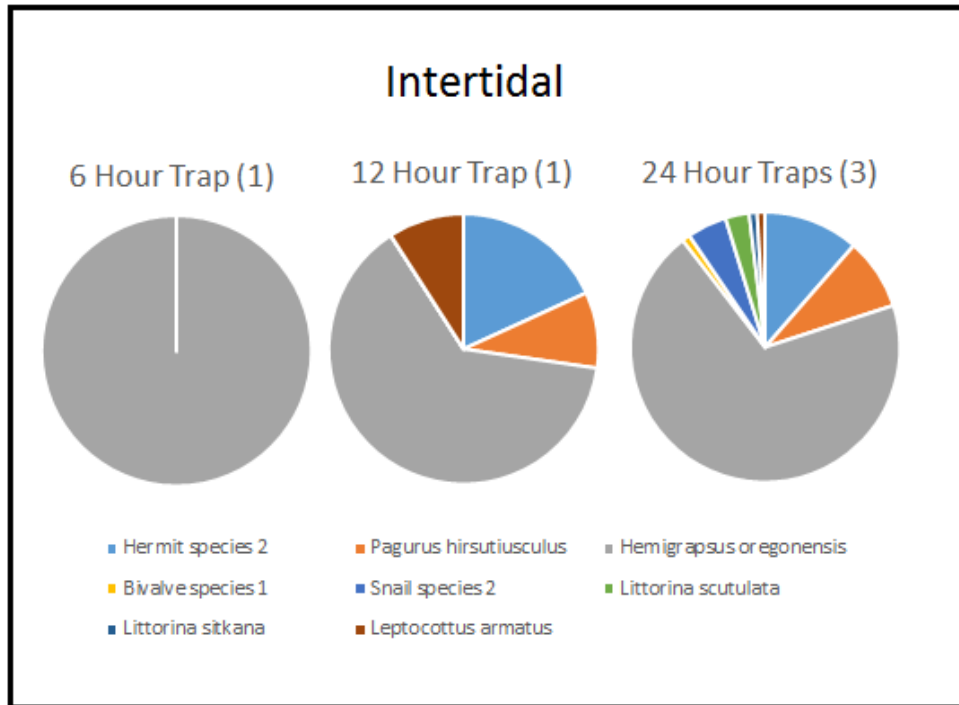


Figure 2. The scavenger compositions in the intertidal habitat at False Bay (-0.8-2.6 m) for the 6, 12, and 24 hour traps. The number beside the trap in parenthesis represents how many replicates there were of that trap included in the pie chart.

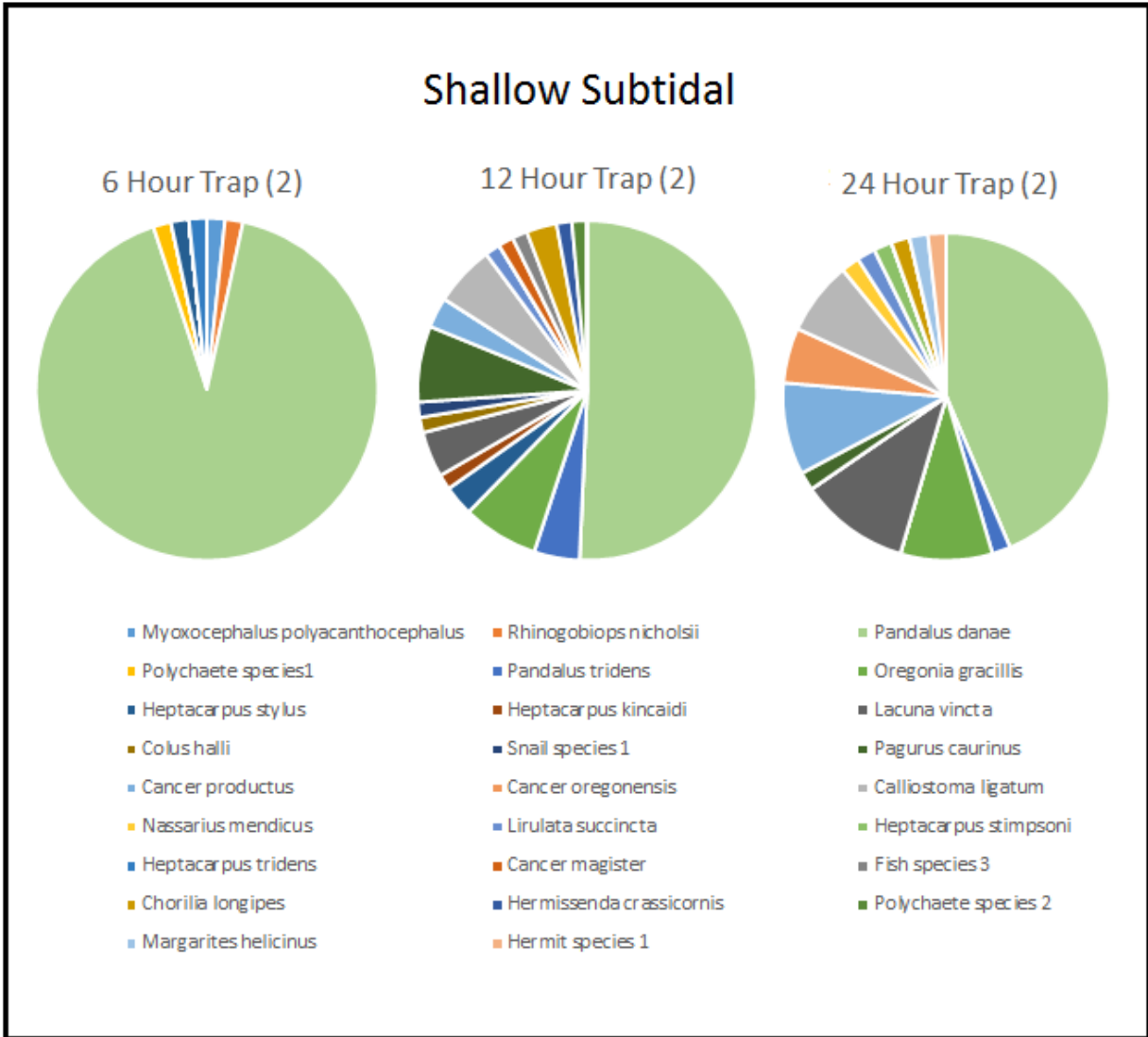


Figure 3. The scavenger compositions in the shallow subtidal habitat deployed off the Friday Harbor Labs dock (14 m) for the 6, 12, and 24 hour traps. The 2 in parenthesis explains that there were two replications of each trap, and the data from both trials is included in the pie chart.

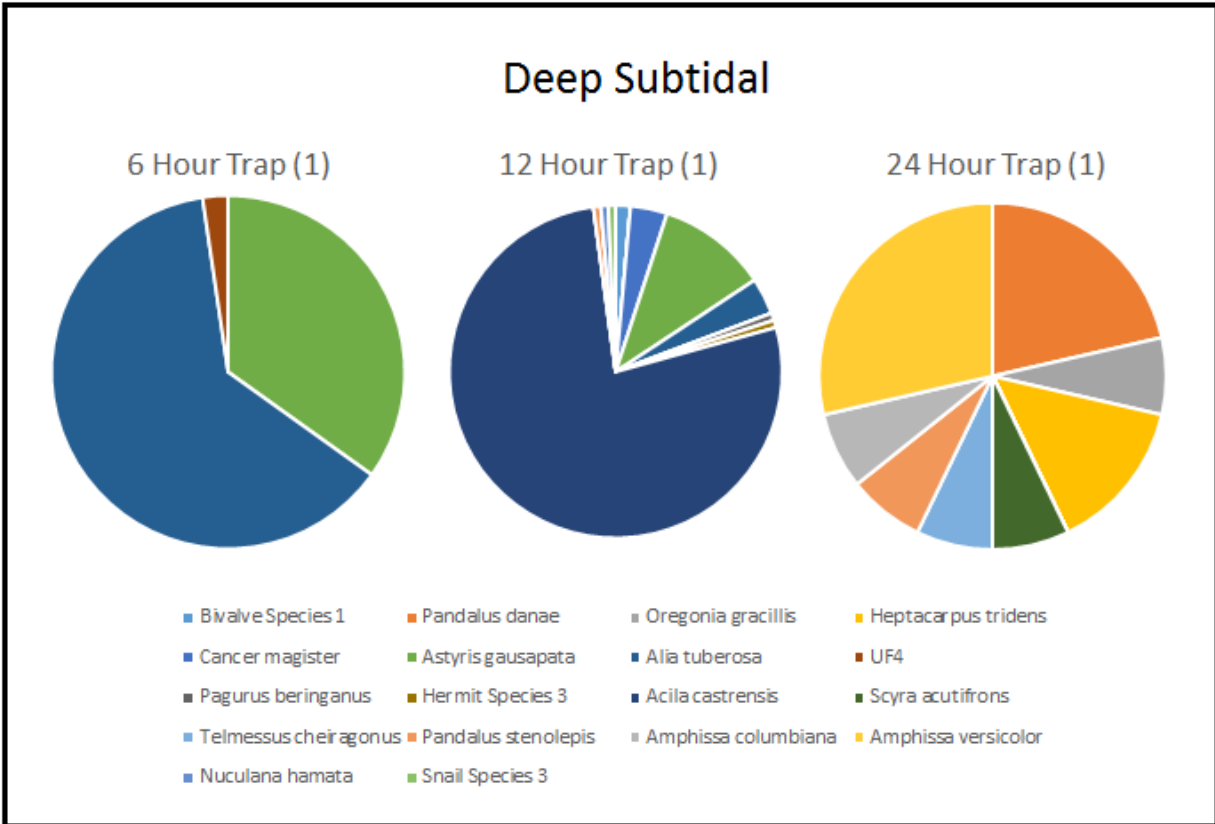


Figure 4. The scavenger compositions in the deep subtidal habitat deployed off the Friday Harbor Labs dock (14 m) for the 6, 12, and 24 hour traps. The 2 in parenthesis explains that there were two replications of each trap, and the data from both trials is included in the pie chart.

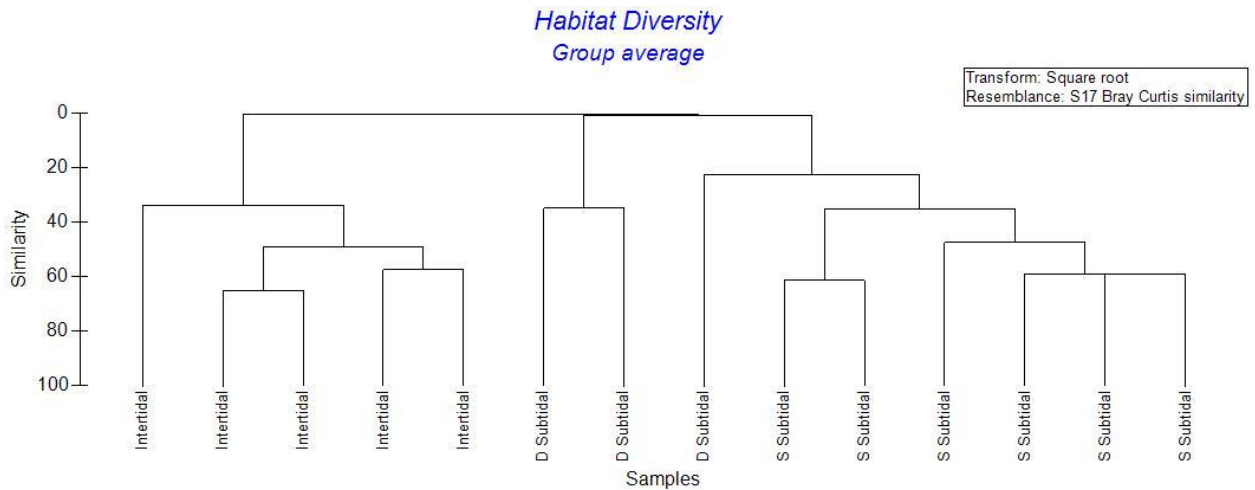


Figure 5. Bray-Curtis Dendrogram displaying the groupings of each habitat: Intertidal, D Subtidal (Deep Subtidal) and S Subtidal (Shallow Subtidal).

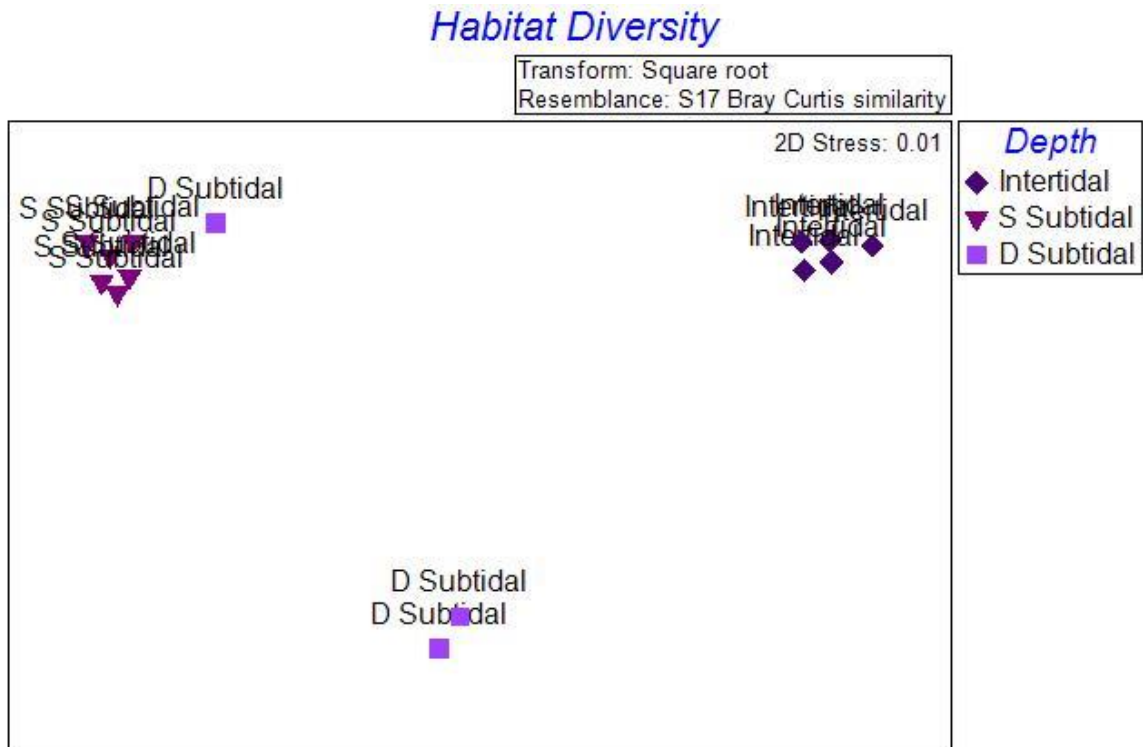


Figure 6. A Multidimensional scaling (MDS) plot helping to visualize how different the Intertidal, Deep Subtidal, and Shallow Subtidal scavenger data sets are.

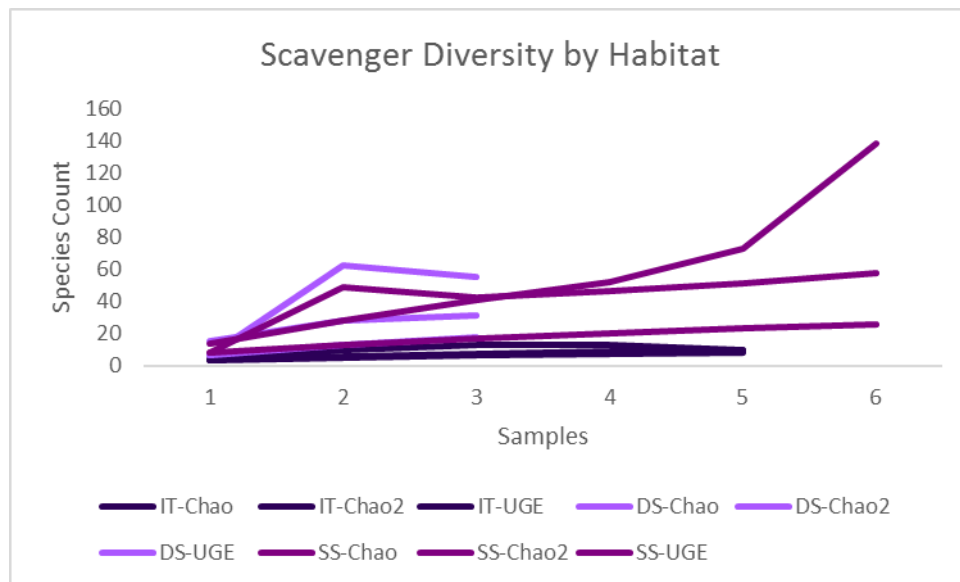


Figure 7. A Diversity Graph created in Primer that uses Chao 1 Chao 2, which are biodiversity estimates, and UGE, which randomizes the data, to determine scavenger diversity. IT represents Intertidal, DS represents Deep Subtidal, and SS represents Shallow Subtidal.

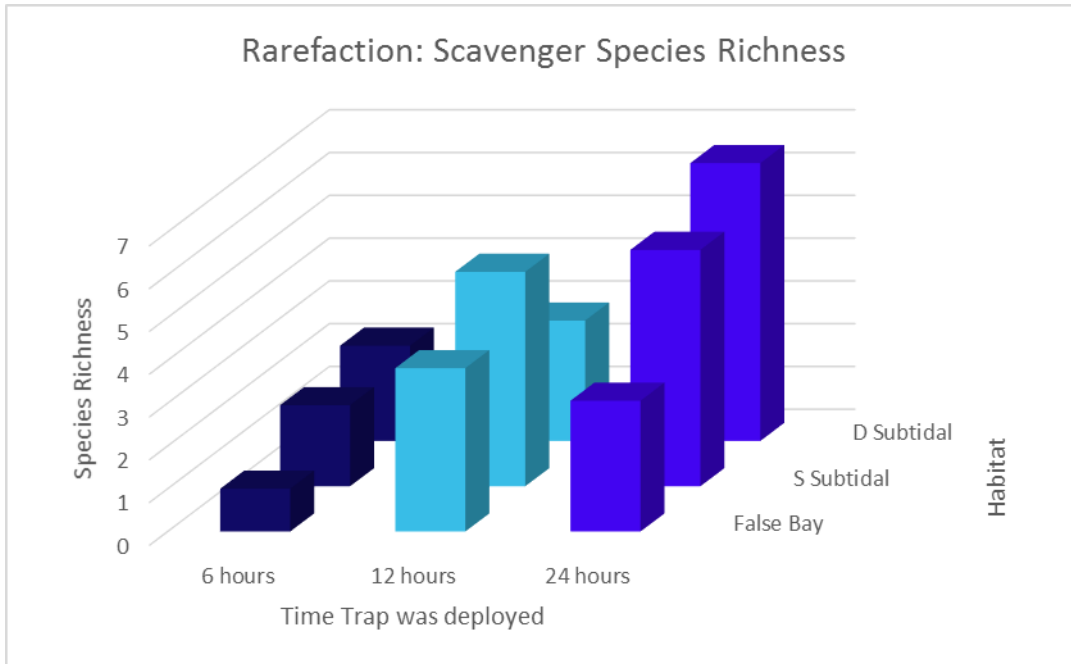


Figure 8. Rarefaction, a technique used to determine species richness by Primer, displayed in a graph that shows the richness for each depth for each time. For trials that were replicated, they were averaged.

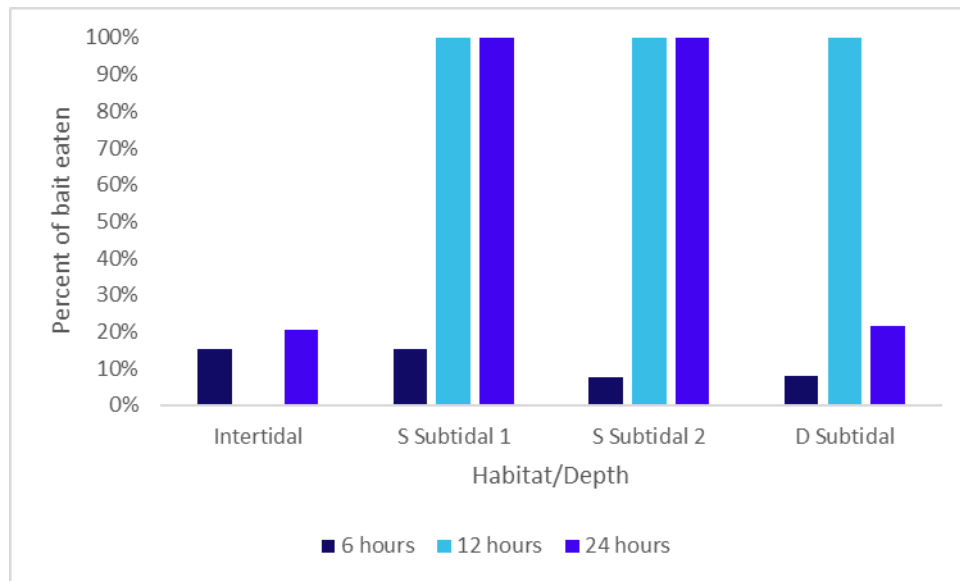


Figure 9. Using the bait weights from before a deployment and after for each trap, the percent of bait eaten was calculated. This shows how much of the two herring placed in each trap was missing when the trap was retrieved.