How Edge Effects in Eelgrass Habitats Impact Organism Abundance and Diversity in the Puget Sound

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Abstract

Habitat transitions occur all over the globe. They can be seen in both terrestrial and marine environments and produce influential edge effects. In the Puget Sound, eelgrass habitats are commonly seen with abrupt habitat changes at the edge of the eelgrass bed. These habitat changes in eelgrass beds provides opportunities for changes in the community of organisms that reside there. The purpose of this study was to determine how an edge of a bed differs from the interior of the bed in terms of total organisms counted and different species observed. It was observed that the edge communities of eelgrass beds contained more species and an increased amount of organisms when compared to the interior. There was a total of 25 species observed along the edge of the eelgrass bed across all sites and only 19 in the interior. This indicates that these habitat edge effects have a very significant impact on the community composition that, in turn, greatly affect the local ecosystem.

Introduction

Habitat transitions are ubiquitous features of marine and terrestrial ecosystems. There can be one main habitat in an area and there can be an abrupt change in habitat in the same area. These changes in habitats can have very prominent effects on the ecosystem and organisms that reside in them (Ewers and Didham 2006). It is important to observe and study the edges of habitats because these interactions are important for understanding the possible migration patterns of the organisms or how predation and competition is changed due to these habitat and structural changes (Dorenbosch et al. 2005). Unfortunately, many of these habitat changes are not the focus of studies, so little is known of the organisms response to these transitions.

Puget Sound in Washington State is home to many different marine habitats and the organisms that inhabit these areas vary greatly. Some of these habitats include mudflats, kelp beds, sand bottoms, and seagrass beds (Daily et al. 1997). One of the main habitats that is found in the Puget Sound are mud or sand flats. This habitat can hold and array of organisms that are responsible for a large part of the food web, for example mudflats are home to organisms such as crabs and other filter feeders that can have a significant impact on water chemistry and sedimentation along with having a great effect on predation (Quammen 1984, Levington 1989, Iribarne 1997). On the exposed sea floor organisms such as sea cucumbers, seas stars, and benthic fish also are part of the diversity and complexity of the food web (Lie 1964). The benthic organisms that are found in these habitats have consistent population sizes but there are occasional shifts in which different species will be the most dominant strictly according to numbers (Lie and Evans 1973). These habitats throughout Puget Sound and other marine environments like it contain habitats that are seen in mosaic patterns throughout (Barrell and

Grant 2015). While the majority of Puget Sound is this habitat, the shallows contain vast amounts of eelgrass beds. These habitats have an important impact on the other habitats and the ecosystem as a whole.

Eelgrass (*Zostera marina*) habitats can be seen throughout Washington's waters and along the western coast of North America up to Alaska and are able to provide home and shelter to many organisms (McRoy 1970, Bulthuis 1994, Ugarelli et al. 2017). In Puget Sound, there is a total of ~22,000 hectares of eelgrass beds along Puget Sound's shore lines (Christiaen et al. 2017). Salmon and herring have been known to use these habitats as a natural nursery and red rock crab can be found within the grass beds sharing the seafloor with other benthic fish species that all play a role in the eelgrass community (Short and Wyllie-Echerverria 1996, Mumford and Thomas 2007). These eelgrass beds also have significant impact on the composition of the water, carbon dioxide (CO_2) levels, and oxygen (O_2) in the water (McRoy 1970). This decrease in CO_2 levels raises the pH of the water so calcifying organisms in these areas are healthier than these same organisms in the water column with a lower pH (Orr et al. 2005).

The eelgrass also has a large impact on the water column and sediment by influencing the currents and wave action which in turn has an effect on the benthic organisms that reside at the base of the eelgrass, and organisms that are on the eelgrass blades (Ginsburg and Lowenstam 1958, Wood et al. 1969, Scoffin 1970, Orth et al. 1984, Paquier et al. 2018). There is also an impact on predation where predation from large organisms decreases within the beds but has an increase outside of the eelgrass bed (Summerson and Peterson 1984, Mahoney et al. 2018).

Since these eelgrass beds are widespread throughout the euphotic zone of Puget Sound waters, it is important to understand the impact this habitat has on the ecosystem. Eelgrass exists in a mosaic pattern throughout it’s distribution in Washington state, leaving many edges that may affect the distribution and behavior of associated species (Barrell and Grant 2015). These edges can have an impact on populations due to mortality and protection when compared to the interior of the bed (Hovel and Lipcius 2001). These edges may also be important in terms of community dynamics within the ecosystem. Previous studies have suggested that survivability for organisms can change whether or not they reside within the interior of the bed or along the edge (Mahoney et al. 2018).

Research questions and hypotheses

The main question I posed is what happens to the ecology of the eelgrass and organisms that reside in it when there is an abrupt change of habitat and how do these organisms respond? In the past, coastal management has had a tendency to ignore these edge effects and treat these habitats separately rather than joined together in one ecosystem (Boström et al. 2006). In this work, I examined the differences in marine community abundance and diversity of marine organisms on the edge of an eelgrass bed where there is an abrupt habitat change and within the interior of the same eelgrass bed. I hypothesized that (1) there is a greater abundance of organisms that reside within the interior of the eelgrass bed due to the protection that the eelgrass provides from predation but (2) there is a wider array of species in the edge of the bed. Looking at these organisms in these different parts of the eelgrass beds can help give us an idea of how edge effects impacts the behavior of organisms in these habitats.

Methods

Field surveys of species abundance and composition were conducted at the edge and interior of eelgrass beds. Scuba diving was used to collect eelgrass samples and record the organisms seen in the field. To quantify organisms quadrats a quarter meter (0.635 m) per side with a total area of 0.403 m^2 were placed at the edges of eelgrass beds and within the interior of the same bed. At each location a total of 3 quadrat plots were placed along the edge and interior of the bed at different locations. If the entire quadrat contained eelgrass shoots with at least 2 m of continuous eelgrass on three sides of the quadrat and a different habitat on the fourth this was considered the edge. The interior of the bed was defined as where there was at least 2 m of continuous eelgrass around all four sides of the quadrat (Fig 3A & 3B). These observations at an ideal site with good conditions (high enough visibility, tolerable temperature, and working equipment) can be done in one dive.

At each of the plots, the creatures observed were counted and recorded on a data sheet with common organisms found in Puget Sound listed, along with pictures that were taken. Mobile organisms and eggs were recorded while other organisms such as kelp and algae were ignored. Larger organisms were identified and counted in the field (ex. crabs, benthic fish, etc.). If there was a mobile organism seen within the quadrat that later moved away from the observed area, it was still counted as being within the quadrat. Organisms that swim into the quadrat after it had been placed will be ignored. Small organisms that reside on the eelgrass (ex. snails, limpets, etc.) were saved and counted out of the water.

Within each quadrat, a sample of eelgrass was collected and placed into a gallon ziplock bag labeled “edge” or “interior”. Minimal disturbance of the eelgrass and removal at these sites was important in order to have as minimal of an impact on the overall ecosystem as possible.

This minimal disturbance also aids in the research due to the low visibility of the Puget Sound and avoiding kicking up sediment from the seafloor. Each shoot had about six or seven blades of eelgrass attached.

Once out of the water, the contents of either the “edge” or “interior” bag was emptied into a bin and then placed in another bin after counting in order to keep track of what has been counted and observed so far. Each piece of eelgrass was observed for small organisms and the organisms found are recorded on a separate part of the sheet used in the field. This process was repeated for the rest of the individual strands of eelgrass and once all of the data has been recorded the eelgrass was taken and placed back into the water along with the organisms on it. Data recorded was sorted between total organisms counted at the edge compared to the interior, along with total number of species observed at the edge compared to interior.

For analysis of the data, a t-test: paired two samples for means was used to show whether or not a significant difference was found between the means of the most abundant groups of organisms. The edge and interior data was compared to determine if there were differences. The most common organisms across all of the sites visited were analyzed using this method. Each organism was analyzed on its own so a total of three organisms were analyzed.

Results

Overall, the total number of species found at all sites were 25 on the edge and 19 in the interior. The total number of organisms counted were 585 on the edge and 279 within the interior (Table 1; Fig. 1; Fig. 2A & 2B). These results counter the initial hypothesis that there would be more organisms in the interior of the eelgrass bed. Many more organisms were found along the edge of the eelgrass bed. However, the second hypothesis was supported, there are higher species diversity along the edge of the bed compared to the interior.

The first site where data were collected from was Lab 11 Beach (A in Fig. 1) located on the Friday Harbor Lab's (FHL) campus on 6/27/18, 7/2/18, and 7/4/18. At the edge, 13 different species of organisms were observed with a total of 156 organisms counted. Within the interior of the bed, 9 species of organisms were observed with a total of 79 organisms and eggs counted (Table 1; Fig. 1).

The second site where data were collected was Indian Cove (B in Fig. 1) located on the southern side of Shaw Island on 7/3/18. The total number of quadrats (6) were collected here during one dive. Eight different species were found at this site and the total organisms including eggs found here was 93 along the edge quadrats. The interior quadrats held 9 different species and a total of 69 organisms (Table 1; Fig. 1).

The third site where collection occurred was False Bay (C in Fig. 1), located on the southwestern side of San Juan Island on 7/6/18. All quadrats were counted normally in exception to one of the interior plots where the eelgrass was exceptionally thick and visibility was poor enough that field observations could not be made so only lab data were collected. The edge quadrats contained 8 species and a total of 207 organisms counted. The interior quadrats had 4 species and 21 organisms total (Table 1; Fig. 1).

The fourth site where data were collected was at Alki Junkyard (D in Fig. 1) in Seattle, Washington on 2/18/19 and 3/3/19. Due to the extensiveness of the eelgrass bed at this location, two data collections were performed at different parts of the bed. The first dive was performed closer to the south tip of the peninsula and the second dive was performed farther north. The edge contained 7 species and a total of 83 organisms counted. The interior contained 9 species and 78 organisms counted (Table 1; Fig. 1). *Polychaete spp.* (POLY) were found at this site and this species was not observed at other collection sites.

The final data collection occurred in April of 2019 at Redondo Beach (E in Fig. 1) in Des Moines, Washington on 4/13/19. This dive was done on the northern part of the beach. The quadrats contained 8 species and 46 total organisms counted at the edge. The interior had 6 species and 32 total organisms observed. *Caprella mutica* (CAMU) were only found at this collection site and this was the most prominent species found.

After analysis was conducted for the three organisms, *Lacuna spp. eggs* (LACU EGGS), *Lacuna spp.* (LACU), and *Copepod spp.* (COPE), at the five sites, it was discovered that the differences of abundance in the edge versus interior were not statistically significant. For LACU EGGS a p-value 0.136 was found, this is above the 0.05 (5%) value needed to show significance. Similar high percentage values were calculated for LACU (p=0.142) and COPE (p=0.348).

Discussion

Overall, the data collected show that there were more species and total organisms located along the edge of the eelgrass beds. This goes against the original hypothesis (1) that there would be a greater abundance of organisms within the interior of the eelgrass bed. However, this provides evidence of the hypothesis (2) that stated there would be more species at the edge of the bed compared to the interior. The structural complexity of these habitat boundaries allows prey to escape their predators (Hovel et al. 2015). The edge of the eelgrass could provide opportunities for organisms to hunt in the more open habitat outside of the eelgrass and retreat within the eelgrass for protection. The density of eelgrass has an effect on the behavior of both prey and predator, specifically kelpfish and shrimp, where shrimp would hide in the eelgrass rather than flee and kelpfish would only pursue shrimp that left the eelgrass bed (Hovel et al. 2015). This could explain why there are more species located at the edge in order to take advantage of both hunting and protection opportunities, such as *Pholis late* (PHLA) that use the eelgrass as shelter from predators and easy access to food outside of the bed. This finding supports the theory gathered from previous studies that mobile predators have a large impact in more open environments but very little impact within the eelgrass bed itself (Summerson and Peterson 1984). It has also been theorized that prey may have a harder time detecting predators when habitats are dense so it is beneficial to be in an area of the eelgrass bed where the eelgrass is not as thick (Catano et al. 2015). The total density of the habitat may also have an impact on a predator being able to detect its prey as well (Michel and Adams 2009). However, this theory that organisms use the eelgrass for protection would be stronger if observed at night. It is known that some organisms will use natural cover for protection during the day then come out to areas of higher predation at night due to the lack of visibility (Odgen et al. 1973). Observing these areas at night would be beneficial to understanding how the eelgrass impacts predation. Organisms can also use the edge to be able to know when a predator is coming.

At the majority of the sites, the same species were observed across all sites. There were some exceptions such as *Haminoea vesicula* (HAVE) were only found at False Bay, and the many copepods (COPE) observed were found at False Bay in the summer and farther south in at Alki Junkyard and Redondo Beach during the winter. There were not as many fish seen near the edge at these sites compared to other sites which could explain why there was a large abundance of these copepods (Polis et al. 1989).

It would be ideal to gather more data from other eelgrass sites throughout Puget Sound in order to see if this trend continues. Factors such as tide, time of day, and season were not taken into account. More research continuously throughout the year with different environmental conditions would help us understand edge effects better. However, data are important in understanding what edge effects have on the organisms that reside there. This study shows that the edge contains more organisms and leads to a higher diversity of species, thus adding to a more complex food web and ecosystem (Paine 1966). Studying and understanding the possible effects may lead to answer some of the more complex questions about ecology in both marine and terrestrial environments. Having a good understanding of how these edge effects impact ecosystems can lead to improved methods of managing the environment and future development.

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Table 1: Total organisms observed across all sites. SP_CODE is the short hand code for organisms used for data collection.

SP_CODE	Name	Edge	Interior
PAGU	*Pagarus spp.*	2	1
SCMA	*Scorpaenichthys marmoratus*	1	0
MOSP	*Mopalia spp.*	9	0
PERE	*Pendtidotea rescata*	3	0
PAPL	*Pandalus platyceros*	6	3
CAAN	*Callistoma annulatum*	6	0
TECH	*Telmessus cheriagonus*	3	1
MEMA	*Metacarcinus magister*	3	5
EGG (LACU)	*Lacuna*	168	94
LAVI	*Lacuna vincta*	1	5
PHLA	*Pholis laeta*	2	11
LEAR	*Leptocottus armatus*	0	1
PERE	*Pentidotea rescata*	3	0
LACU	*Lacuna spp.*	104	52
HAVE	*Haminoea vesicula*	15	10
EGG (HAVE)	*Haminoea vesicula*	2	3
POLY	*Polychaete spp.*	1	0
IOPE	*Iottia pelta*	4	0
ARLA	*Artedius herringtoni*	0	2
PESO	*Petrale sole*	0	2
DIAL	*Dirona albolineata*	1	0
AMPH	*Amphipod spp.*	3	16
COPE	*Copepod spp.*	190	32
MELI	*Melibe spp.*	1	0
PUPR	*Pugettia richii*	1	0
POLY	*Poluchaete spp.*	9	18
DIAS	*Diodora aspera*	0	3
BANU	*Balanus nubilis*	4	0
NULA	*Nucella lapillus*	1	1
HEPT	*Heptacarpus spp.*	0	2
UNTU	*Unidentified tube worm*	1	0
MAAM	*Caprella mutica*	25	13
UNPL	*Platyhelminthes spp.*	1	1
CAPR	*Cancer productus*	0	2

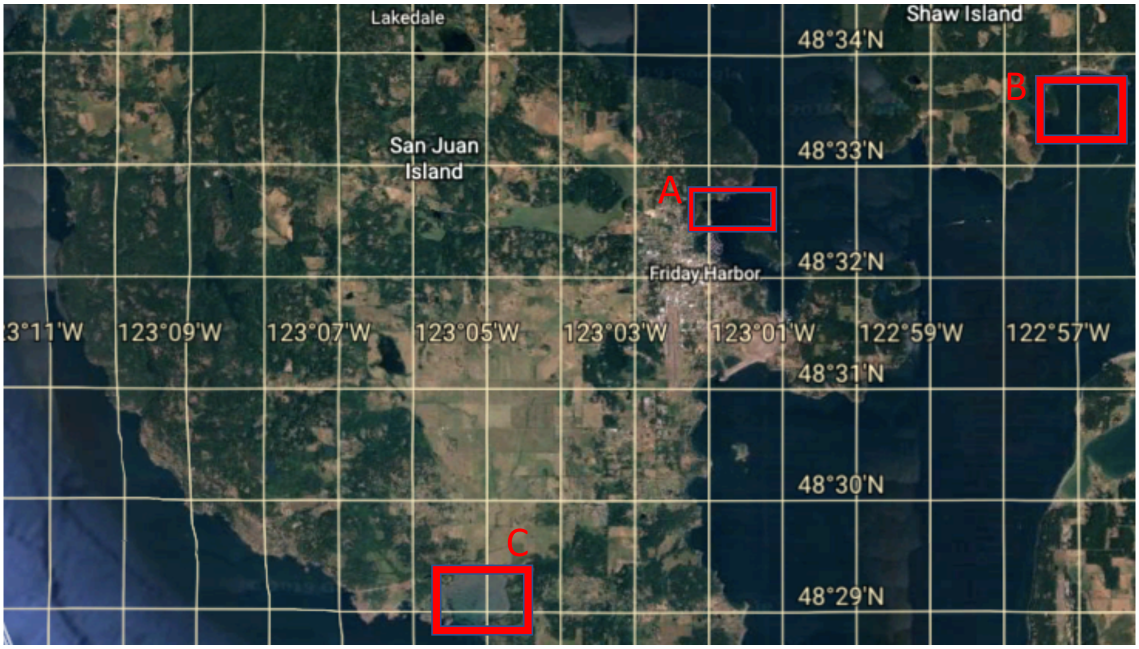
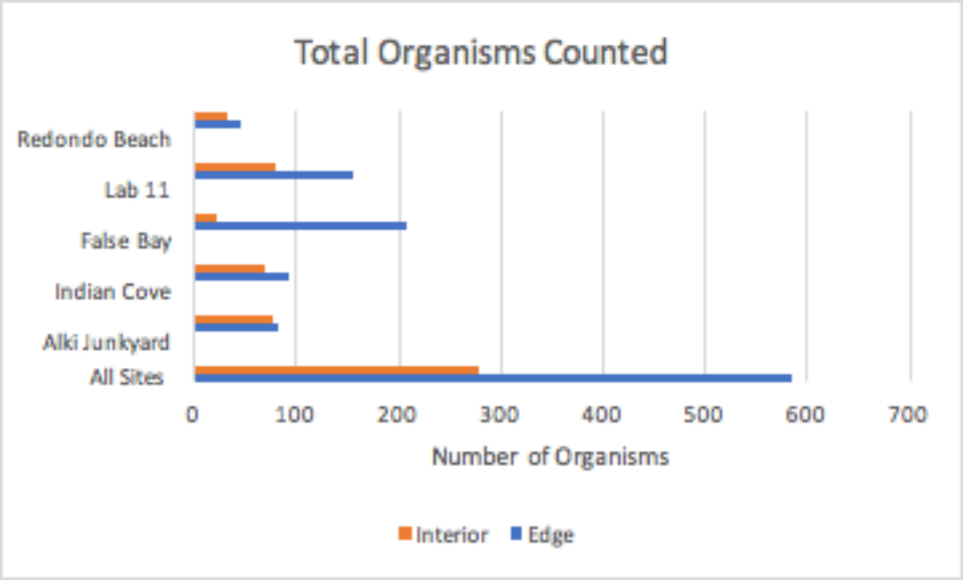


Figure 1: Data collection sites throughout Puget Sound. A) Lab 11 Beach. B) Indian Cove. C) False Bay. D) Alki Junkyard. E) Redondo Beach.

A



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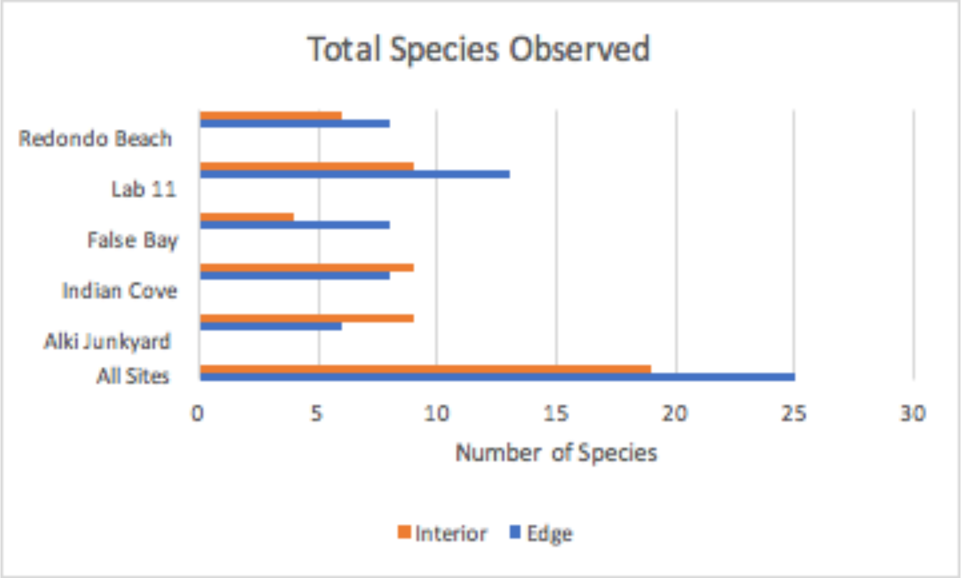

Figure 2: A) Total organisms counted separated by collection site and total. B) Total species observed separated by collection site and total.

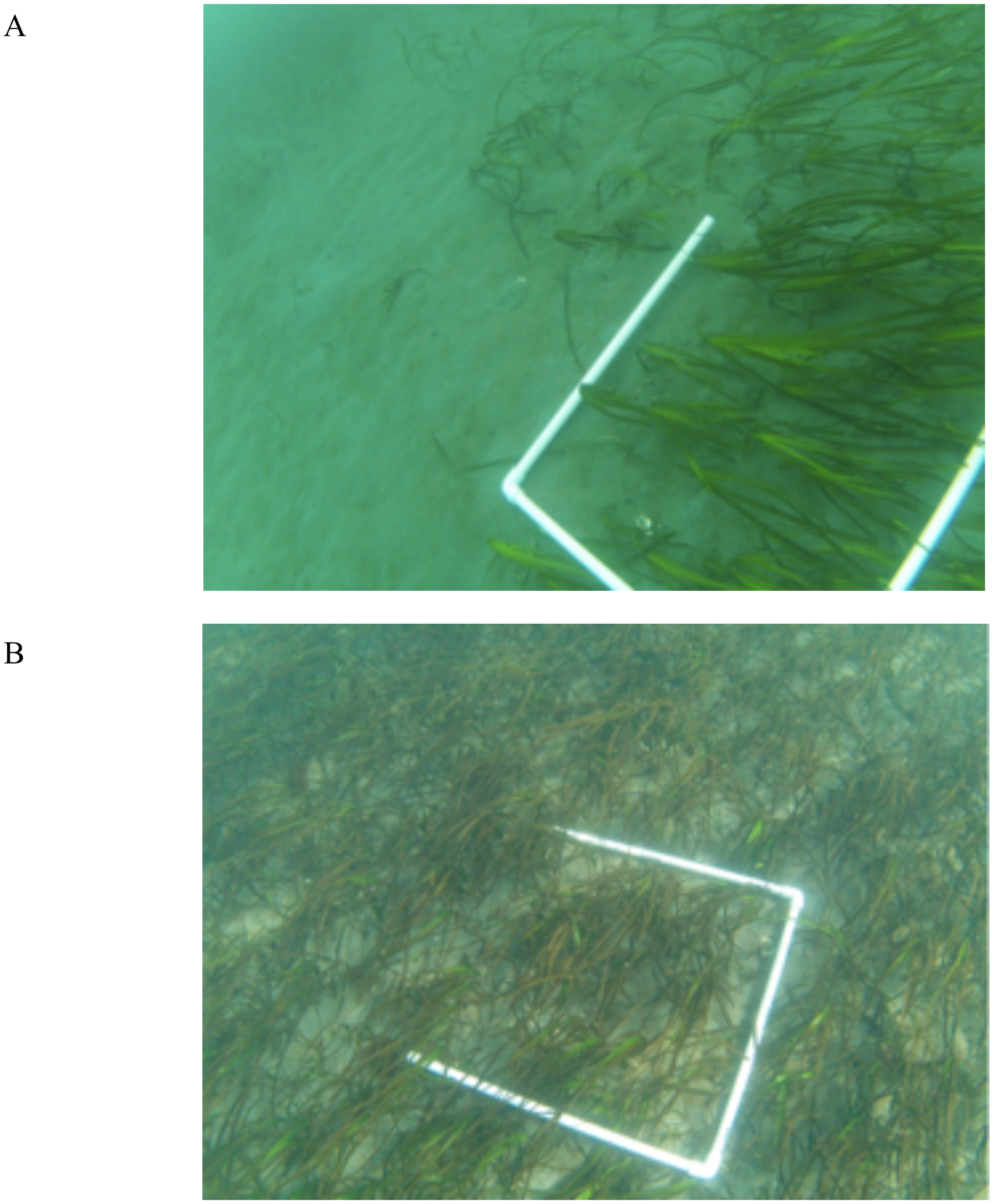

Figure 3: A) What the edge of the eelgrass bed looks like in order to better understand what is considered the edge. Notice that 3 of the 4 sides of the quadrat are surrounded by eelgrass. B) What is considered the interior of the eelgrass bed. All 4 sides of the quadrat are surrounded by eelgrass.

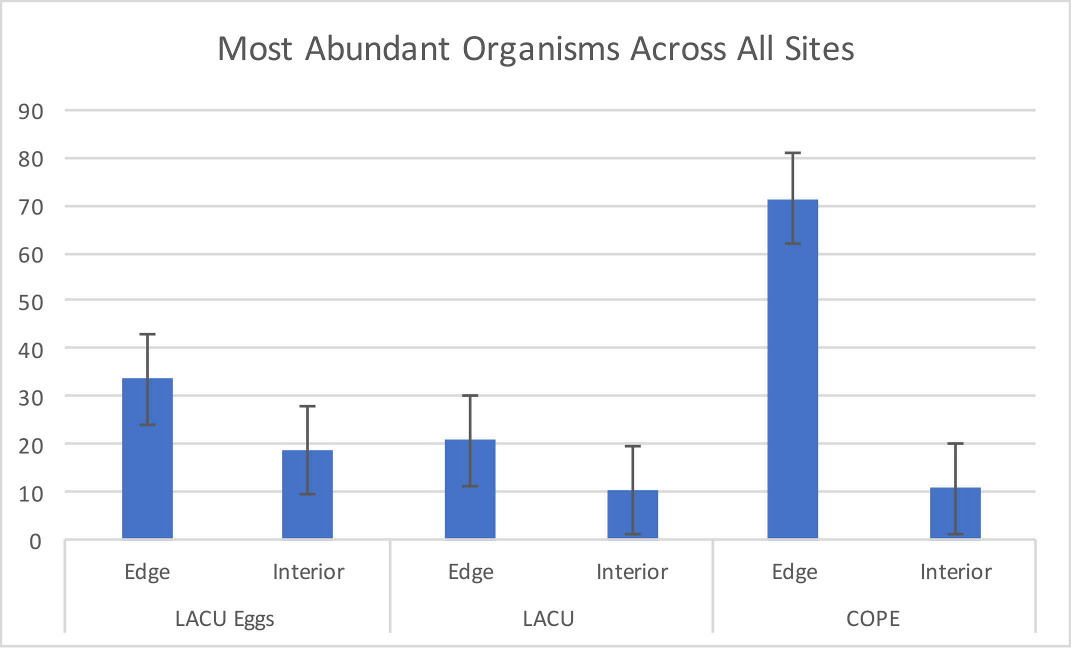

Figure 4: The averages of the 3 most abundant organisms across all sites. Columns are the average number of the specific organism for both interior and edge. Error bars are the standard derivation for each individual set of data.