
Assemblage and foraging behavior of demersal fishes and large invertebrates across eelgrass and sandflat habitat at False Bay, San Juan Island

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Abstract

Understanding the species assemblage and foraging behavior of demersal fishes and large invertebrates occurring at False Bay was the primary objective of this study. This knowledge can provide valuable insight on future restoration and preservation efforts used for reintroducing critically endangered species, such as salmon. This study provides more information and data on what species are present, the behavior that they exhibit, duration of presence, and whether more predations occur in the eelgrass beds or the open sandflat. We hypotheses that more assemblage and predation will occur in the eelgrass than the sandflat because eelgrass beds provide more protection, habitat, and biodiversity of fauna that can be food resources for large predators. Species assemblage and predation was documented through the use of BRUVs, a baited remote underwater video system, that was placed out via snorkeling at eelgrass beds and sandflat towards the mouth of False Bay. Analyses was separated into two sections: one looking through the video footage and identifying categories of interests such as species and behavior. The second section was creating plots to compare the categories and finding statistical significance in R to determine which variables drove predation and assemblages. 40 occurrences of species assemblage from 7 species were evaluated. After all the statistical analyses, the data and result does not support my hypotheses. The behavior was the most significant variable to determine predation and assemblage. Dungeness crabs was the most abundant species with 19 occurrences with an average size of 12-27 cm in the sandflat and 15-20 cm in the eelgrass. Moreover, Dungeness crab has the most occurrences and largest total duration in both habitats.

Keywords: Species Assemblage, predation, BRUVs, snorkeling, eelgrass, sandflat, behavior

Introduction

In the greater region of the Salish Sea that includes the Puget Sound, Strait of Juan De Fuca, Strait of Georgia, and all waters in between Washington and British Columbia, there arehave been documented to be about 39 species of sculpins found in its waters (Pietsch & Orr, 2015). In just the San Juan Islands, there are about 35 species of sculpins (Pietsch & Orr, 2015). These range from the family Cottidae, Rhamphocottidae, Psychrolutidae, and Hemitriteridae with the majority of the genus falling in Cottidae. Sculpins are small, spiny fish that can be found in both fresh and salt water of the benthic region of the water column (Finnegan & Reu-Beacon, 2017). They can occupy a variety of habitats, ranging from intertidal to deep water marine environments as well as to freshwater streams, rivers, and lakes (Finnegan & Reu-Beacon, 2017). Depending on where the sculpins thrive, they can have a variety of food that consisting of amphipods, polychaetes, shrimps and fishes (Yoshiyama, 1980). This can also be consistent of whether the sculpins are resident to a habitat or a transient where they are just swimming by. Sculpins that thrive in tidepools or shallow waters have adapted to be resilient to extreme temperatures and conditions as they must acclimate to higher salinity and temperatures during low tide. Smaller adult and larger juvenile fish of the tidepool sculpins (*Oligocottus* maculosus) occupied warmer, small-volume pools, whereas larger adults occupied larger, cooler pools (Wuitchik et al., 2018). In a survey based in Alaska measuring essential fish habitat (EFH) of eelgrass and kelp, found that northern sculpin was captured at 92% of the eelgrass sites and 96% of the kelp sites (Johnson, 2003). This suggests that sculpins are found more in large, vegetated areas that can adequately provide protection for them. Pacific herring (*Clupea pallasii*) has a large role in the stability of the food web across predators of various trophic levels such as marine mammals to seabirds, mainly from their egg masses (Siple & Francis, 2016). Pacific herring also support valuable commercial fisheries worth

$17 million in 2013 (Siple & Francis, 2016). This makes Pacific Herring to hold ecological and economical importance and maintaining the reliability of the herring resource is a high priority (Siple & Francis, 2016). This could make the studying of Pacific Herring in False Bay is critical to the ability to create and maintain the natural habitat that resides in False Bay. Fish assemblage data are often used to help understand human activities influencing marine ecosystems (Logan et al., 2017).

Eelgrass (*Zostera*) beds are a submerged vegetation that provided food resources, cover, and nursery habitat for many marine species (Johnson, 2003). Eelgrass beds and kelp forest are remarkably productive and diverse habitat as they provide critical structures and are primary producers (Gross et al., 2018). In the rocky intertidal environment, organisms tend to respond to environmental heterogeneity by zonation or relocation (Wuitchik et al., 2018). The primary sediment of False Bay is sandy soft-sediment but there is little knowledge on the structure and community assembly.

Some of the most observed species found in False Bay are Dungeness crab (*Metacarinus magister*) and rock crab (*Cancer productus*) but little knowledge is known about their assemblage and abundance. Crabs are important predators in marine benthic communities are used to test foraging models (Smith et al., 1999). Dungeness crabs are a soft bottom species distributed from California to Alaska (Iribarne et al., 1994). Local population abundance of juvenile crabs in the intertidal zones is controlled by availability of refuges such as bivalve shell assemblages or eelgrass (Iribarne et al., 1994). Dungeness crabs are found at higher densities in intertidal or subtidal areas that offer some type of shelter (Fernandez et al., 1993). Red rock crabs are a major predator on buried soft-shell clams (*Mya arenaria*) and have been shown to prefer the species that occur the same habitat (Smith et al., 1999). Red rock crab primary habitat includes rock, shells, hard-packed sand, or cobble and primarily feed on barnacles, mussels, snails, clams, and oysters (Yamada & Groth, 2016). Adult crabs are highly mobile and are known to move into intertidal zones at high tide to forage (Yamada & Groth, 2016). Larger crabs leave structured nursery and move to more open ground and larger hiding places in deeper waters (Yamada & Groth, 2016). This can mean that crabs may use the eelgrass beds in False as their main habitat and areas to forage for food. Other species that is known to exist in False Bay are kelp crab (*Pugettia producta*). The kelp crab and the graceful kelp crab (*Pugettia gracilis*) are both common in kelp beds in the Pacific Northwest but their feeding behavior on dominant species of canopy-forming kelp (*Nereocystis luekeana*) (Dobkowski, 2017).

In this study, our objective for this research is 1) to document the species assemblage and 2) the foraging behavior that occurs in the open water column compared to the protected waters of eelgrass beds and open sandflat in False Bay. We hypothesized that assemblage will be highest in the eelgrass habitat than the open water sandflat because of less tidal currents and more areas for protection for the predators. Additionally, we also hypothesized that, across sites, the bait on the substrate will result in greater amount of foraging coming from benthic organisms such as crabs, demersal fishes, and other fauna than the species suspended in the open water column.

Materials and Methods

Field Survey

Most underwater observations were made by skin diving and during stormy weather of winter months, confined observations were made to relatively sheltered sites (Green, 1970).

Species assemblage was measured during October and November of 2021 within two habitats at False Bay on San Juan Island: eelgrass beds and open sandflat. Eelgrass and sandflat were chosen because they represent the main habitats found in False Bay. Sampling was conducted between the 29th of October to the 19th of November taken at the southwest end of the mouth of False Bay. (Figure 1). We accessed this location from a house with beach access that belongs to a supportive landowner of the Friday Harbor Labs. Every sample took place during low tide if applicable and at subtidal depth from 1.8 m to 3 m where the tide is at an ebb and shifts to high tide. The eelgrass bed chosen was a small patch (~183.39 m^2) relative to the larger beds also found and was approximately 30 m from shore. The sandflat sampling area was about 15 m apart and was about 50 m away from that eelgrass bed. Four sample sites were chosen, two in the eelgrass and two in sandflat to quantify the species richness and abundance. The sites were chosen on location on the first day that can adequately represent the distribution of both habitats and is also feasible to reach with six replicates. All sampling was conducted via snorkeling in ~10 C water temperature and ranged from 57 minutes to 97 minutes. We carried a floatation device that can hold a 5 gallon bucket to hold the baits and cameras. All tides and currents were measured via the Kanaka Bay station.

Data Collection

We conducted underwater observations at each site through the deployment of camera and baits called BRUVs, a baited remote underwater video system. BRUVs are a cost effective and robust sampling tool for scientists (Schramm et al., 2020) and are a method of detecting assemblage and predation. BRUVS allowed the sampling of predation with the attractant properties of a bait and to target predatory species of fishes and crabs that would actively avoid a diver or a predator presence (Schramm et al., 2020). One BRUVs was a pair of one camera and one bait that was placed at each site, serving as one deployment. We placed the BRUVS at the same four sites with six days of replicates for a total of 24 deployments. We chose to sample the same sites to have replicates to signify species assemblage at each habitat. We modified the BRUVs to fit our experiment needs consisted of a contraption made of two bricks held down with thin metal wires placed inside a single-open ended cage (21.6 cm x 21.6 cm x 6.35 cm). The cameras we used were Gopros (Hero 4 (2x), Hero 5 Gray, 7 black, and 8 black) that are mounted down to a black piece of plastic via adhesive, which are then zip tied to the top of the cage. Different Gopros were used because these were the ones that we could get a hold of for sampling. A float made up of cut pieces of pool noodles were tied to a long line of about 2.44 m to the cage and were used for marking the location of the BRUVs to be easily visible for retrieval. The floats are tied behind the camera to not interfere with the video while filming.

Two different baits, squid and shrimps, were used to quantity forging behavior of the species found and had different methods of deployment. These baits were chosen to resemble possible prey found in this estuary and are potent to attract more catch. The first method were Squidpops, which was a bamboo garden stake (60.1 cm) with two small pieces of dried squids (1 cm x 1 cm squares or 1.3 cm diameter circles) attached to a barrel swivel. One squid bait is taped with electrical tape at 25.4 cm and the second bait is taped at 40.64 cm measured from the bottom of the stakes. The stakes were jammed into the soft, sandy sediment about 22.86 cm so the bait at 25.4 cm lies at the substrate for bottom-feeders and the other bait was for open water feeder. The end of the stake suspended in the water was marked with surveyor tape to be easily identified in the water column for retrieval. The second method was two large shrimps shoved into crab mesh bait bags frequently used in crab traps (30.5 cm x 30.5 cm). Bait bags were weighed down by large rocks found on the beach that are also shoved into the bait bag with enough weight to hold them sturdy on the bottom substrate. The squid was bought from Amazon named as Dried Squid Mantle and the shrimps are from a local grocery store named as Large Jumbo Shrimps.

Many different measurements were taken to understand the behavior and assemblage of species in False Bay. During sampling, we documented the time we entered the water and when we started to deploy each camera and bait, GPS location of each site, habitat type, where each camera resides in each site, tide behavior, and the time we left the water. BRUVs were left recording the bait to get about an hour of footage but some deployments are >1 hour due to weather conditions. All BRUVs were retrieved about an hour after deployment via snorkeling and brought back to the lab to be analyzed. For the cameras, Gopro batteries were replaced, all the video footage were downloaded onto a hard drive, and the SD cards were wiped to be prepared for the next deployment. For the bait, we attempted to replace the old bait with new squid and shrimps to have true replicates. With exception of some consecutive deployments, shrimp bait was kept the same due to not being predated on and to be cost effective.

Analysis

Data analyses resides on reviewing the video footages from the Gopros shot at 1080p and 60 fps except for Gopro 7 Black which was shot at 1440p and 60fps. Data was collected by reviewing through all of the footage and identifying species observed. Abundance was calculated by the number of organisms present within each frame and occurrence was determined when each individual entered the frame and exited fully. There were incidents when the same individuals crossed the frame multiple time, but each time the individual entered the frame again was counted as a separate occurrence. We took note of the duration (seconds) the individual stayed in the frame and the behavior that each individual exhibits. Behavior was characterized in two categories:

whether the individual was predating and/or attempting to feed on the bait (foraging) or whether the individual was just passing by (transient) and showed no interest in the bait. Other behaviors were noted but were not used in statistical analysis. Size of the species are quantified by measuring them against a known measurement of the bait bag (30.5 cm x 30.5 cm) and squidpop (61 cm). These analyses of species, abundance, occurrence, duration, behavior, and size are used to quantify foraging behavior to understand the species across the different habitats.

All the data analyzed were marked in Excel and converted to a cvs file to be processed in R. All statistical analyses were conducted in R version 4.1.0 (R Core Team, 2021) and the figures were made using the packages dplyr (Wickman et al., 2021), tidyverse (Wickham et al., 2019), and ggplot2 (Wickham, 2016). The raw data were synthesized and reduced down into a new table to neglect all of rows that contained no sightings of any species. We created bar charts to compare the overall behavior to other categories of interested (Figure 2 and 4). The reduced data set were also grouped by categories to display specific comparisons of behavior and species to create a new dataset that compared the mean duration value and standard deviation. We made a histogram of total duration (sec) to determine the spread of variability and used the logarithmic value of total duration because it was exponentially decreasing. An Anova was ran to get statistical significance of variance for a response variable of duration from categories of site, behavior, and species (Table 2). This process of creating a new dataset and running an Anova was repeated for size vs time (response variable = total duration), size vs. behavior (r.v. = size), size vs. site (r.v.=size), and duration vs. site (same as first Anova test).

Results

A total of 24 BRUVs deployments over six replicates were collected. 12 of the BRUVs were placed within and on the edge of the eelgrass beds whereas the other 12 BRUVs were placed in the sandflat. Of the 24 deployments, observed species only occurred in 17 deployments where we recorded a total of 7 species from 40 separate interactions (Table 1). The other seven deployments had no observations of any kind within the hour they were deployed. These seven deployments were left out of any statistical analyses. Species observed from six different families: Hexagrammidae, Cottidae, Cancridae, Epialtidae, Clupeidae, and Coenobitidae. The species identified starting from the most abundant occurrence were Dungeness crabs (*Metacarinus magister*, N =19), Red Rock crabs (*Cancer productus*, N = 12), Pacific Herring (*Clupea pallasii*, N = 3), Kelp crab (*Pugettia producta*, N = 3), Hermit crab (*Paguroidea*, N = 1), White spotted Greenling (*Hexagrammos stelleri*, N = 1), and Pacific Staghorn Sculpin (*Leptocottus armatus*, N = 1) (Table 2). Although *M. magister* had the most abundant occurrence, the maximum species abundance in a given frame of the BRUVs were *C. pallasii* (N > 20) whereas for every other species, the abundances was majority N = 1 (Table 1). Only on two other occurrence was when N = 2 and they were *M. magister* for both incidences. Species that were seen foraging on the baits were four species out of the seven with majority occurrence being *M. magister* (N = 13) (Table 2). Species that were transient are five of the seven species observed with majority occurrence being *M. magister* (N = 6) (Table 2). Overall, *M. magister* was the most observed species within the camera deployment and would have the largest impact on studying foraging behavior.

The foraging characteristics of the species observed was significant to the duration they spent by the bait (F value = 10.3670, p = 0.003) (Table 3). *M. magister* has the greatest total duration (seconds) foraging in both habitats: ~1000 seconds (16.6 minutes) in eelgrass and ~2000 seconds (33.33 minutes) in sandflat (Figure 1). *Paguroidea* has the largest mean duration foraging in both habitat with 479 seconds (7.98 min.) as compared to *M. magister* with 359 seconds and *C. productus* with 342 seconds (5.7 min.) (Figure 2). *P. producta* has the largest total duration (sec) transient in both habitat: 1095 seconds (18.25 min.) in eelgrass and 109 (1.82 min.) (Figure 3) in sandflat and the largest mean duration with 438 seconds (7.3 min.) (Figure 2). Behavior also indicated significance to size of the species (F= 10.7795, p = 0.002) (Table 3). *L. armatus* has the largest mean size at 17.8 cm followed closely by *M.* magister with 15.8 cm for foraging species whereas the largest mean size of transient species was *C. productus* with 10.8 cm followed closely by *H. stelleri* with 10.2 cm (Figure 4). Size also showed significance to the duration (F value = 4.4961, p = 0.042) (Table 3) where the largest *M. magister* measured 26.5 cm with mean size of 13.5 cm and duration of 1035 sec. (17.25 min.) (Figure 5). Not-significant factors of foraging behavior were site, species, and species abundance (p > 0.05) (Table 2). Site on the total duration (sec) was p = 0.401 (Figure 6) and site against species was p = 0.347. Site against the mean size has a p = 0.793 (Figure 7). Species abundance against the size (cm) was p = 0.38573, against site was p = 0.793, and against species was p= 0.053 (Table 2 and 3).

Through the study, *M. magister* was the most abundant species to be found in either habitat that has the largest role in the foraging. In Figure 8, there are a more of a size distribution between 12 to 27 cm found within the sandflat then the eelgrass beds with a distribution of size ranging from 15 to 20 cm. However, Figure 8 does include size 0 of the *M. magister* which represents individual crabs that were present in the BRUVs but could not be accurately measured as they were too far from the bait bag and camera. This measurement was still included in the size distribution because they still represented assemblage that is important to each habitat.

Additionally, the total duration (sec) of *M. magister* in the sandflat (~2000 seconds = 33.33 min) has nearly doubled that of the eelgrass (~1000 seconds = 16.6 minutes) (Figure 2). However, the mean duration of *M. magister* in Figure 2 depicts that the trends of *M. magister* are very closely related in both substrates. In the sandflat, foraging behavior of *M. magister* has a mean duration around 325 seconds and in the eelgrass around 300 seconds. But for the transient behavior, the mean duration is higher in the eelgrass with an average of 100 seconds and in the sandflat 50 seconds.

Discussion

We used a modified, large-scale experiment of BRUVs to investigate the species assemblage and foraging behavior of the species identified. After 24 deployments, species assemblage and foraging varied across the species and were most abundant in the open sandflat. We observed that majority of the species occurrence were only a single individual for the larger fish demersal and crustaceans. The only species to be abundant in numbers at a given time during analysis was the pacific herring which characteristics to their species (Siple & Francis, 2016). Furthermore, we found that 29% of the deployment resulted in no observation of any species. This finding may suggest that the species presence in either habitat were not present or avoiding the diver that was in the immediate area (Schramm et al. 2020). As Dungeness crab had the most occurrence and the greatest duration in both habitats suggest that Dungeness crabs are incredibility important to the foraging that occurs throughout the bay. The movement that each species demonstrated may also be subject to their preferred habitat. This movement allows these species to congregate in and near preferred habitat that can be suitable to their age and size as well as to avoid predators (Lewis et al., 2021).

Species assemblage and behavior of foraging in False Bay would favor the eelgrass beds because of the protection and biodiversity that the eelgrass promotes from its physical processes as compared to the eelgrass beds in Alaska (Johnson et al. 2003). This can be quantified by at least 50 species of marine fishes thriving in eelgrass and kelp habitat found in southeastern Alaska (Johnson et al. 2003). With the structure of False Bay and the immense tidal fluctuation, it is coherent that the species are highly mobile such as the three species of fishes and four species of crustacean identified. This can be represented by the kelp crab that was seen only to be transient in the open sandflat as it was not their ideal habitat. Additionally, another kelp crab was transient within the eelgrass substrate and moved to their ideal habitat of the eelgrass where it then proceeded to climb onto the blade and stayed for the duration of the camera deployment. Kelp crabs are also herbivorous crustaceans; therefore, they were likely not attracted by the bait. The movement can also be stated with the staghorn sculpin where the only sighting was in the sandflat, where the coloration and pattern of the sculpin can help it camouflage and blend into the sandy substrate. This correlates to the White spotted greenling that was foraging in and around the bait placed within the eelgrass beds where its movement was to actively hide from a red rock crab nearby in a piece of kelp. The pacific herring was also transient in the shallow subtidal zone of the sandflat where they breezed by the baits as they followed the current and stayed in constant motion. The Dungeness crab and hermit crab were mainly seen to be foraging on the bait as it is their ideal habitats and bait preference with several occurrence of the red rock crab but were seen to be more transient. Dungeness crab and the other crab species covered a large area to travel towards the bait as was seen in the video data.

However, total abundances or count of individuals comes from the Pacific Herring as they congregate in large schools that are greater than 20 at a given time. The low abundances of all species in False Bay may be due to the camera deployment after a major storm that have caused turbidity and strong currents, disrupting the natural tidal fluctuation at False Bay. Additionally, camera deployment was limited by the harsh weather conditions and tides that were unsafe to go out, especially for snorkeling. Moreover, the low abundance of crabs may be a factor of the amount of food available to them and space competition (Iribarne et al., 1994).

The documentation of this movement to actively portray those behaviors have been the success of the BRUVs system. The BRUVs system has also allowed for visual analysis of how the habitats vary and are impacted by the water column and large tidal exchange. The BRUVs depicted the current state of weather and tides forcefully impacting the seafloor habitat through wave motions of the eelgrass blades and extent of the organic matter moving in the water column. The BRUVs was able to observantly capture that the majority of the species assemblage, duration of assemblage, and top-down predation has occurred in the sandflat substrate. Additionally, it has shown that behavior has a large role in the duration of the species that can resemble whether a species is predating or transient (Table 3).

Behavior also shows signs of significance towards the size of the species that can also identify whether the species will assemble in that given habitat. There was a trend where smaller sized species will be seen more in the eelgrass habitat compared to the sandflat. This may be a case of species maturity that wasn't a factor in this study but can possibly be monitored in future studies. Site, species, and species abundance does not have a role in the duration and size of the species found but further replication can show signs of significance depending on the species. Overall, the results of this study have not supported my hypotheses.

Future studies that use this study as a template can increase monitoring of the species assemblage found in False Bay as this study only monitors a small fraction of time. Additionally, deploying camera traps across the entire bay can quantify predation on a larger scale and can monitor the predation and species assemblage spatially. Deployment of BRUVs to the larger eelgrass beds and extending to the kelp forest at the mouth of the bay may greatly improve the understanding of the species that move in and around the water column. Moreover, deploying BRUVs to the terrestrial side of the bay at False Bay Creek and the upper watershed can also quantify the species assemblage of birds and other species that can understand the impact of runoff and nutrients cycling that comes into False Bay. More monitoring of impacts of biological function of the species assemblage such as breeding behavior, time of last meal, and amount of predation occurring can also quantify the sheer size of species assemblage and predation that can be useful to setting up restoration and introduction of salmon back into the upper streams. Additionally, more monitoring of environmental factors can help identify how much the climate and currents are impacting the distribution and abundance of the species found through the bay. This study can be replicated in different season and nutrient cycling of the ocean that can help understand the amount of nutrient flow that promote biodiversity.

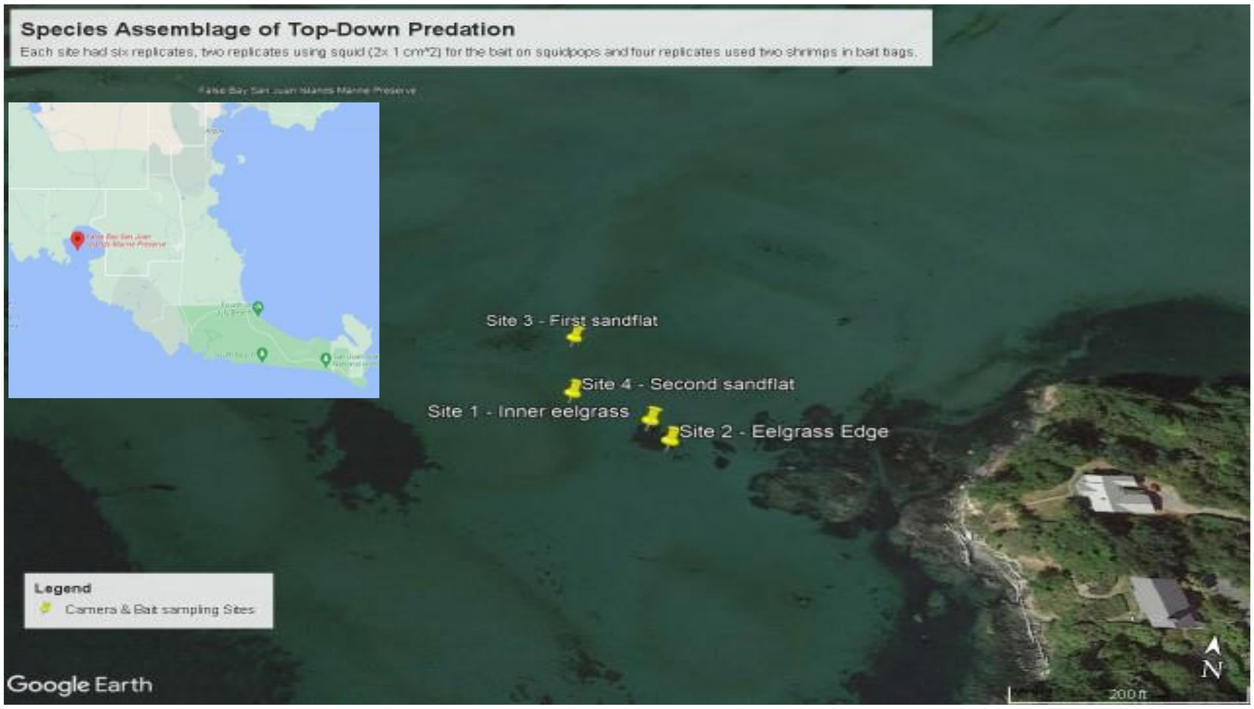

Figure 1: A map of the study site within the open sandflat and eelgrass beds at False Bay, San Juan Islands.

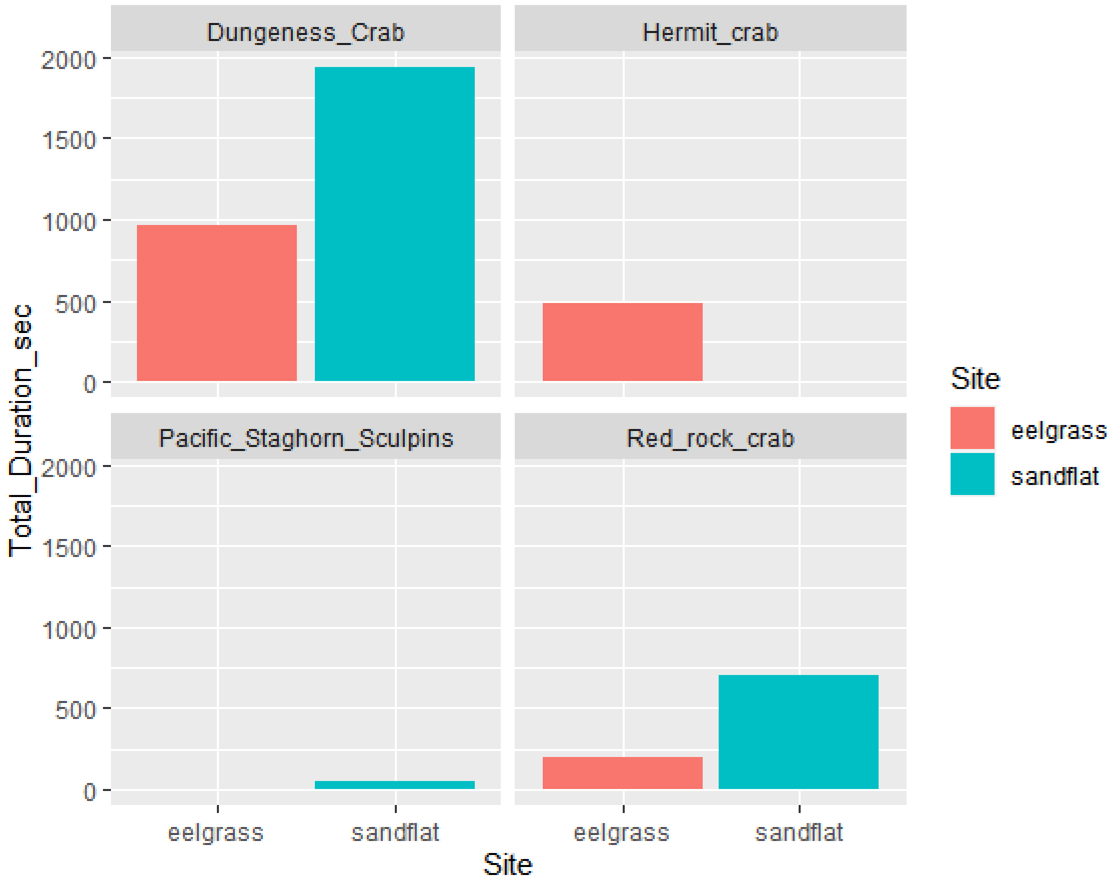

Figure 2: Total Duration (sec) of species found foraging in each habitat of eelgrass and sandflat. Dungeness crab (*M. magister*) has the highest duration in both habitats ranging from ~1000 seconds in eelgrass and ~2000 seconds in the sandflat.

Figure 3: Behavior against the mean duration of all the species identified. The behavior has a significant impact (p-value = 0.003) on the duration of the species present within each habitat type. The error bar represents the mean duration +/- the standard deviation for each species with the unique behavior characteristics. The foraging mean duration (sec) value for each species are: Dungeness crab with 359 (sdtime = 545), hermit crab with 479 sec (sdtime = NA), Pacific staghorn sculpin with 51 (sdtime = NA), and red rock crab with 342 (sdtime = 240). The transient mean duration (Sec) value for each species are Dungeness crab with 54.7 (sdtime = 56.2), kelp crab with 438 (sdtime = 572), Pacific Herring with 35.7 (sdtime = 16.7), red rock crab with 118 (sdtime = 116), and white spotted greenling with 70 (sdtime = NA).

Figure 4: Total duration (sec) species spend transient in each habitat. The kelp crab (*P. producta*) has the highest duration in both habitat with values of 1095 seconds in eelgrass and 108 seconds in the sandflat.

Figure 5: A bar chart depicting the behavior as a significant value (p-value = 0.002) to the size of the species present. The Pacific Staghorn Sculpin has the largest mean size of 17.8 cm for foraging whereas the red rock crab has the largest mean size of 10.8 cm for transient species. The error bar represent mean size with standard deviation of time. The foraging mean size for each species was: Dungeness crab with 15.8 (sdtime = 5.60), hermit crab with 2.54 (sdtime = NA), pacific staghorn sculpin with 17.8 (sdtime = NA), and red rock crab with 12.1 (sdtime = 1.27). The transient mean size for each species were: Dungeness crab with 8.47 (sdtime = 9.46), kelp crab with 2.96 (sdtime = 0.733), pacific herring with 5.08 (sdtime =NA), red rock crab with 10.8 (sdtime = 5.03), and white spotted greenling with 10.2 (sdtime = NA).

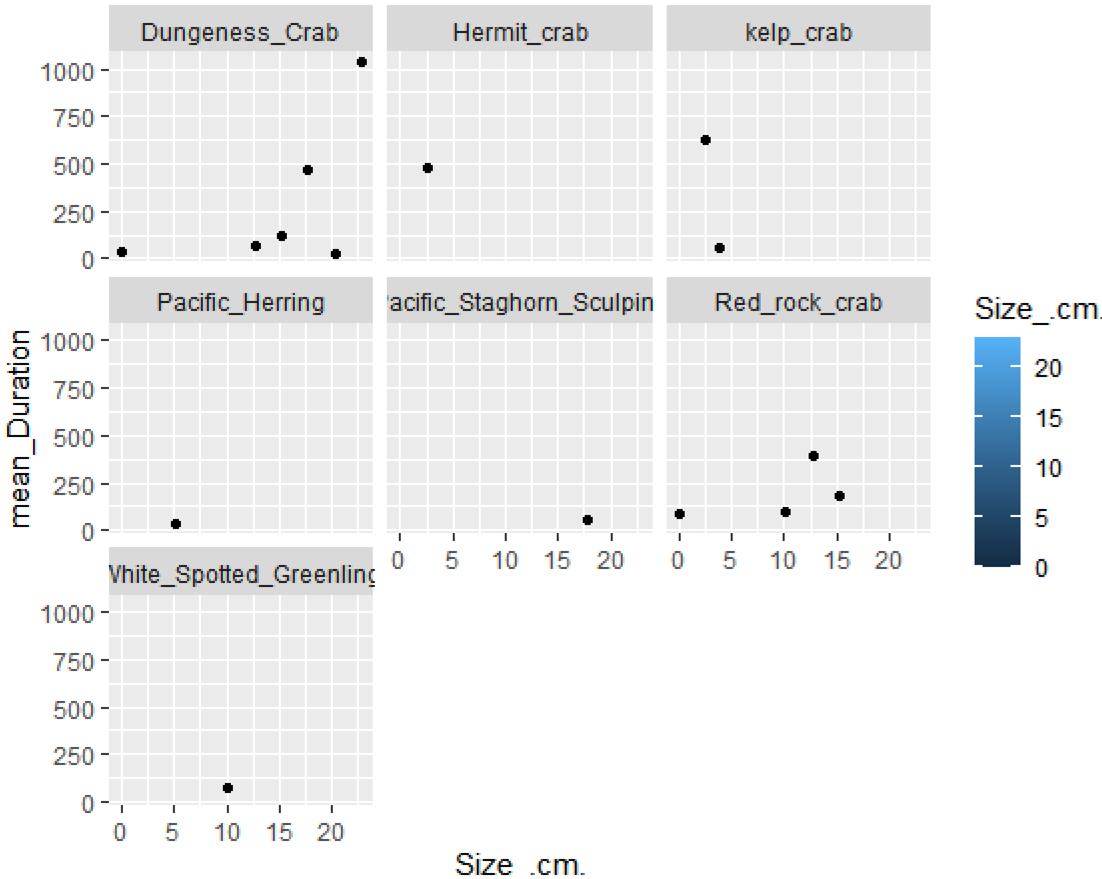

Figure 6: The variability of size (cm) for each species identified compared to the mean duration (sec). Size has a significant value of p = 0.04182 to the mean duration of the species present. Dungeness crab has the largest size measured at 26.5 cm with a mean size of 13.5 cm and duration of 1035 seconds.

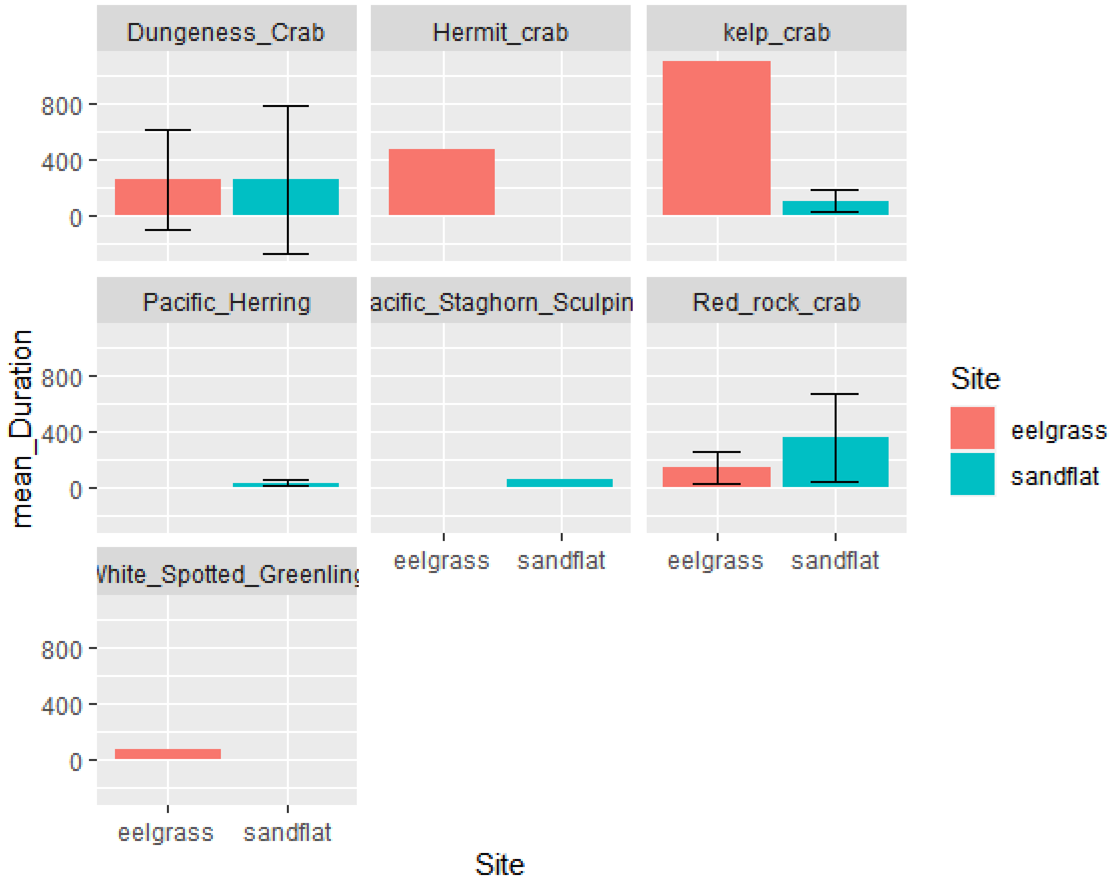

Figure 6: The interaction between site and duration. Site does not impact the duration of which the species spend in each site (p-value = 0.401). It is interesting to see that the kelp crab and hermit crab would have a larger mean duration than the Dungeness crab in the eelgrass and the red rock crab over Dungeness for the sandflat. The error bar represents mean duration with standard deviation of time. The mean duration with sdtime for the species found in eelgrass were Dungeness crab with 259 (sdtime = 357), hermit crab with 479 (sdtime = NA), kelp crab with 1095 (sdtime = NA), red rock crab with 139 (sdtime = 113), and white spotted greenling with 70 (sdtime = NA). The mean duration with sdtime for the species found in the sandflat were Dungeness crab with 265 (sdtime = 526), kelp crab with 109 (sdtime = 72.1), pacific herring with 35.7 (sdtime = 16.7), pacific staghorn sculpin with 51 (sdtime = NA), and red rock crab with 353 (sdtime = 313).

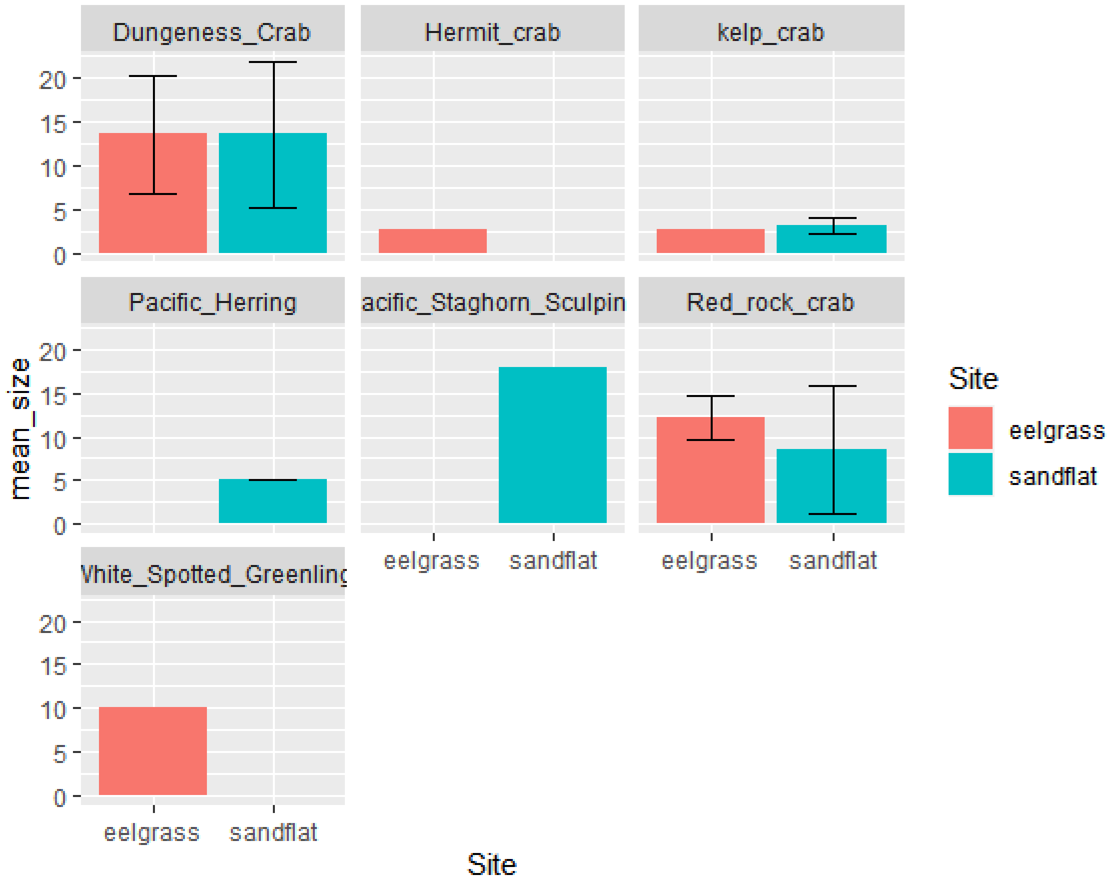

Figure 7: Site against size where site at which each species are present is not significant to the size of the species found (p-value = 0.793). The error bar represent mean size with standard deviation of time. For each species, the mean size and sdtime in eelgrass were Dungeness crab with 13.5 (sdtime = 6.75), hermit crab with 2.54 (sdtime = NA), kelp crab with 2.54 (sdtime = NA), red rock crab with 12.1 (sdtime = NA), and white spotted greenling with 10.2 (sdtime = NA). The mean size and sdtime in sandflat for each species were Dungeness crab with 13.5 (sdtime = 8.26), kelp crab with 3.18 (sdtime = 0.898), pacific herring with 5.08 (sdtime = 0), pacific staghorn sculpin with 17.8 (sdtime = NA), and red rock crab with 8.47 (sdtime = 7.33).

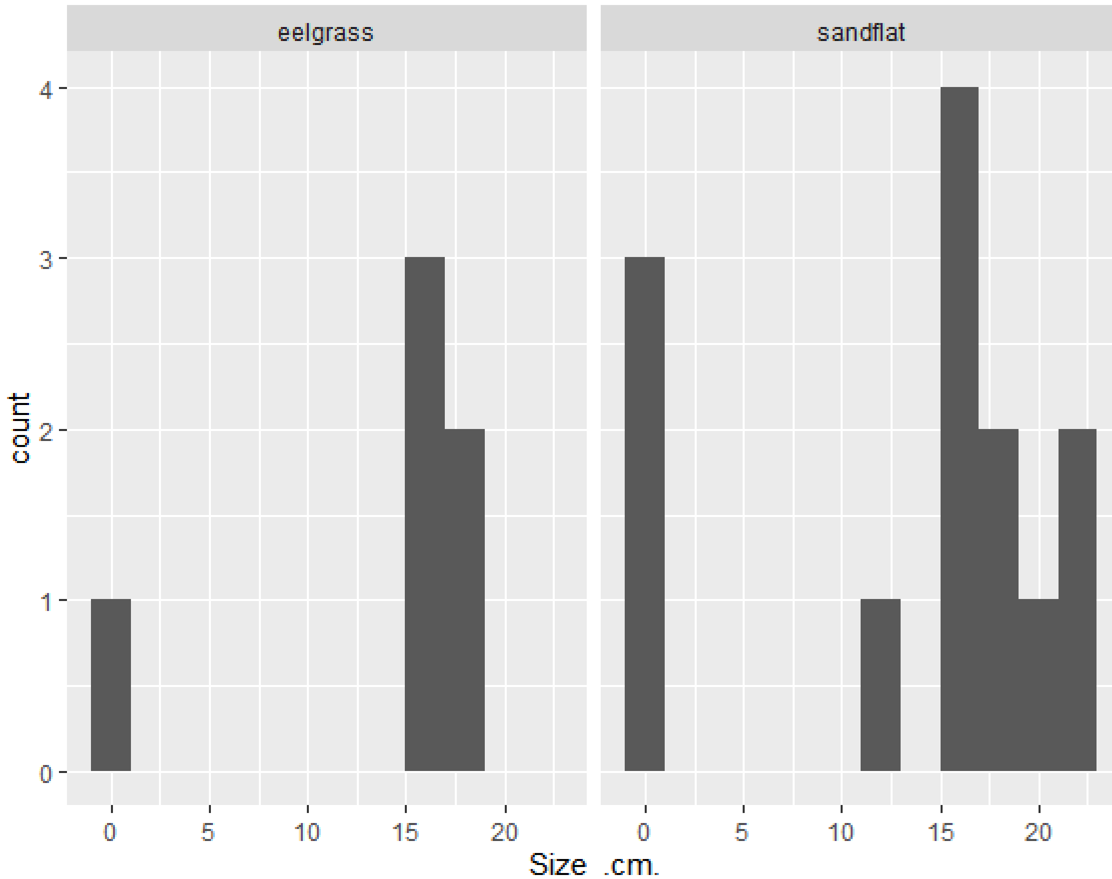

Figure 8: A histogram that compares the size of the Dungeness crabs found in each habitat. This histogram does include zeros from the deployment that has sightings of Dungeness crab but couldn't be measured as they were out of range to make an accurate estimate.

Table 1: Represents the condensed raw data collected from the BRUVs that was used as the main dataset for data analysis in R. This dataset does not include seven camera deployments as there were no sightings of any species during the time of deployment.

Species	Scientific_Name	Size_(cm)	Species_Abundance	Behavior	Bait	Site	Date	Camera_Replicate	Total_Duration_sec
Pacific_Herring	Clupea_pallasii	5.08	20	Transient	Squid	sandflat	11/2/2021	1st_Replicate	55
Pacific_Herring	Clupea_pallasii	5.08	20	Transient	Squid	sandflat	11/2/2021	1st_Replicate	26
Dungeness_Crab	Metacarcinus_magister	15.25	1	Foraging	Squid	sandflat	11/2/2021	1st_Replicate	122
Pacific_Herring	Clupea_pallasii	5.08	20	Transient	Squid	sandflat	11/2/2021	1st_Replicate	26
Red_rock_crab	Cancer_productus	15.24	1	Transient	Squid	eelgrass	11/2/2021	1st_Replicate	182
Red_rock_crab	Cancer_productus	15.24	1	Transient	Squid	eelgrass	11/2/2021	1st_Replicate	6
Pacific_Staghorn_Sculpins	Leptocottus_armatus	10.16	1	Transient	Squid	eelgrass	11/2/2021	1st_Replicate	70
Red_rock_crab	Cancer_productus	15.24	1	Transient	Squid	eelgrass	11/2/2021	1st_Replicate	357
kelp_crab	Pugettia_producta	2.54	1	Transient	Squid	sandflat	11/10/2021	2nd_Replicate	160
Red_rock_crab	Cancer_productus	12.7	1	Foraging	Squid	sandflat	11/10/2021	2nd_Replicate	276
Red_rock_crab	Cancer_productus	10.16	1	Foraging	Squid	eelgrass	11/10/2021	2nd_Replicate	196
Red_rock_crab	Cancer_productus	10.16	1	Transient	Squid	eelgrass	11/10/2021	2nd_Replicate	161
Red_rock_crab	Cancer_productus	10.16	1	Transient	Squid	eelgrass	11/10/2021	2nd_Replicate	32
Red_rock_crab	Cancer_productus	10.16	1	Transient	Squid	eelgrass	11/10/2021	2nd_Replicate	18
Red_rock_crab	Cancer_productus	10.16	1	Transient	Squid	eelgrass	11/10/2021	2nd_Replicate	102
Dungeness_Crab	Metacarcinus_magister	15.24	1	Transient	Shrimp	sandflat	11/13/2021	3rd_Replicate	41
Dungeness_Crab	Metacarcinus_magister	17.78	2	Foraging	Shrimp	sandflat	11/13/2021	3rd_Replicate	625

kelp_crab	Pugettia_producta	3.81	1	Transient	Shrimp	sandflat	11/13/2021	3rd_Replicate	58
Red_rock_crab	Cancer_productus	0	1	Transient	Shrimp	sandflat	11/13/2021	3rd_Replicate	85
Red_rock_crab	Cancer_productus	12.7	1	Foraging	Shrimp	sandflat	11/13/2021	3rd_Replicate	697
Dungeness_Crab	Metacarcinus_magister	20.32	1	Transient	Shrimp	sandflat	11/13/2021	3rd_Replicate	30
Pacific_Staghorn_Sculpins	Leptocottus armatus	17.78	1	Foraging	Shrimp	sandflat	11/13/2021	3rd_Replicate	51
Dungeness_Crab	Metacarcinus_magister	15.24	1	Transient	Shrimp	eelgrass	11/13/2021	3rd_Replicate	163
Red_rock_crab	Cancer_productus	12.7	1	Foraging	Shrimp	eelgrass	11/13/2021	3rd_Replicate	197
Dungeness_Crab	Metacarcinus_magister	15.24	1	Foraging	Shrimp	eelgrass	11/13/2021	3rd_Replicate	286
Dungeness_Crab	Metacarcinus_magister	0	1	Transient	Shrimp	sandflat	11/17/2021	4th_Replicate	59
Dungeness_Crab	Metacarcinus_magister	12.7	1	Foraging	Shrimp	sandflat	11/17/2021	4th_Replicate	70
Hermit_crab	Paguroidea	2.54	1	Foraging	Shrimp	eelgrass	11/17/2021	4th_Replicate	479
Dungeness_Crab	Metacarcinus_magister	15.24	1	Foraging	Shrimp	eelgrass	11/17/2021	4th_Replicate	54
Dungeness_Crab	Metacarcinus_magister	0	1	Transient	Shrimp	sandflat	11/17/2021	4th_Replicate	2
Dungeness_Crab	Metacarcinus_magister	15.24	1	Foraging	Shrimp	sandflat	11/17/2021	4th_Replicate	114
Dungeness_Crab	Metacarcinus_magister	15.24	1	Foraging	Shrimp	sandflat	11/18/2021	5th_Replicate	54
kelp_crab	Pugettia_producta	2.54	1	Transient	Shrimp	eelgrass	11/19/2021	6th_Replicate	1095
Dungeness_Crab	Metacarcinus_magister	17.78	1	Foraging	Shrimp	eelgrass	11/19/2021	6th_Replicate	56
Dungeness_Crab	Metacarcinus_magister	17.78	1	Foraging	Shrimp	eelgrass	11/19/2021	6th_Replicate	962
Dungeness_Crab	Metacarcinus_magister	0	1	Transient	Shrimp	eelgrass	11/19/2021	6th_Replicate	33

Dungeness_Crab	Metacarcinus_magister	17.78	1	Foraging	shrimp	sandflat	11/19/2021	6th_Replicate	213
Dungeness_Crab	Metacarcinus_magister	0	1	Foraging	Shrimp	sandflat	11/19/2021	6th_Replicate	41
Dungeness_Crab	Metacarcinus_magister	22.86	2	Foraging	Shrimp	sandflat	11/19/2021	6th_Replicate	1932
Dungeness_Crab	Metacarcinus_magister	22.86	1	Foraging	Shrimp	sandflat	11/19/2021	6th_Replicate	138

Table 2: A summary of the ANOVA test that compares four variables to the response variable of Total Duration (sec) that are statistically significant in determining species assemblage and foraging within False Bay. Every ANOVA test conducted, species and species abundance were not included together (Species Abundance was only compared to size (cm)) because I wanted to compare the relative size to the abundance to determine species assemblage. Behavior, site, and species could not be response variable was because they were characters or had non-numerical values. Duration wasn't a regular variable because duration came from the response of the species to these other factors.

Response:	Log (Total Duration sec)				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Site	1	1.089	1.089	0.725	0.401
Behavior	1	15.569	15.569	10.367	0.003
Species	6	10.552	1.759	1.171	0.347
Size (cm)	1	7.208	7.2083	4.496	0.042

Table 3: A summary of the ANOVA test that compares four variables to the response variable of Size (cm) that are statistically significant in determining species assemblage and foraging within False Bay. Every ANOVA test conducted, species and species abundance were not included together (Species Abundance was only compared to size (cm)) because I wanted to compare the relative size to the abundance to determine species assemblage. Behavior, site, and species could not be response variable was because they were characters or had non-numerical values. Duration wasn't a regular variable because duration came from the response of the species to these other factors.

Response:	Size				
	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Site	1	2.67	2.668	0.070	0.793
Behavior	1	392.66	292.66	10.780	0.002
Species Abundance	1	28.93	28.93	0.7943	0.379
Species	6	542.55	90.425	2.364	0.053

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