Baiting the Lens: Analysis of Environment, Species, and Interactions in Seagrass Beds Using Baited Remote Underwater Video (BRUV)

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ABSTRACT

Seagrass ecosystems are one of the most biodiverse habitats on the planet, supporting a wide variety of species across many trophic levels. This ecosystem is under threat due to its proximity to coasts where seagrasses are negatively impacted by anthropogenic activities, such as eutrophication and rapidly warming waters. Over the last few decades, baited remote underwater video (BRUV) surveys have been implemented for studying underwater ecosystems, representing a non-extractive and non-destructive sampling method that can observe species diversity within different habitats. In this study, we aimed to determine the feasibility of utilizing BRUVs in an estuarine seagrass ecosystem to analyze the seasonal environmental parameters, species diversity, and species interactions. We performed a yearlong study, deploying a total of 200 BRUV units at varying distances from seagrass across three depth profiles in Tampa Bay. This study reveals that although environmental parameters varied across seasons, the number of species documented throughout the year did not significantly differ between the wet and dry seasons. When seagrass was detected (n = 37), we observed a greater number of species and broader representation of functional groups than when seagrass was absent (n = 110). A variety of species interactions were successfully observed between both conspecific and heterospecific assemblages, that were positively influenced by the presence of seagrass. Our deployment of BRUVs in Tampa Bay identified challenges, such as technological issues, difficulty in replication of deployment location due to seasonal tidal changes, and turbidity altering video clarity reducing the accuracy of species identification. Overall, this study resulted in 147 successful deployments supporting the feasibility of utilizing BRUVs to monitor seagrass ecosystems by measuring species diversity in a fluctuating coastal environment.

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Chapter I

INTRODUCTION

Seagrass ecosystems are a vital coastal environment that serves a wide variety of services, ranging from enhancing water quality and sediment stabilization to providing habitat for a diverse group of species creating intricate trophic webs (Cullen-Unsworth et al., 2018). Seagrasses are a type of marine flowering plant (angiosperm) that completes its entire life cycle underwater. This submerged aquatic vegetation (SAV) exists all over the world (except Antarctica) in shallow marine environments where there is sufficient light availability. Seagrass grows in large meadows or beds which can cover thousands of hectares (Cullen-Unsworth et al., 2018; Unsworth & Cullen-Unsworth et al., 2017). Due to the broad distribution of seagrass species, there is a range in blade morphology that resembles ribbons, paddles, and fern-like phenotypes, each with a root structure consisting of rhizomes. The blades of the seagrasses utilize photosynthesis, like many terrestrial plants, producing oxygen, while the roots perform carbon sequestration. (Reynolds, 2018). These marine plants grow in areas of soft sediment near coastlines, helping to prevent erosion, and providing habitat for an array of species (Duffy, 2006). The high productivity of this ecosystem is not just due to the occurrence of photosynthesis, but the species that reside and utilize this system supporting a diverse food web with high levels of secondary and tertiary production (Unsworth & Cullen-Unsworth, 2014).

All living organisms have a role in their respective ecosystem, called a niche. A niche is characterized as how an individual utilizes the resources, habitat, and interacts with other

organisms in their ecosystem (Vandermeer, 1972). Certain niches are so vital that without them the ecosystem would collapse because each species or individual performs a vital functional role (Levine & HilleRisLambers, 2009). Due to the variety of niches in an ecosystem, each species has morphological characteristics that assist with the overall community health and the organisms' survival, called functional diversity (Petchey & Gaston et al., 2006). The identification of species morphology, dietary habits, and where the species resides within the environment helps scientists determine the functional role of each species (Garcia-Rodriguez et al., 2020). By understanding an organism's functional role in their ecosystem and the interactions of other species that are similarly categorized, researchers can then determine trophic-level distinctions. In the case of seagrass beds, there are a variety of seagrass and macroalgae species that are the primary producers gaining their energy from the sun and conducting photosynthesis. The next level consists of primary consumers, which include a wide range of heterotrophic organisms that feed on primary producers, such as sea urchins, crabs, manatees, dugongs, and sea turtles (Orth et al., 2006). Secondary consumers are the next trophic level that incorporates organisms that feed upon primary consumers (Duffy, 2006). Within seagrass beds, there is a combination of specialists and generalists coexisting within the ecosystem that can consume either a narrow or broad range of resources, respectively. For example, West Indian Manatees (*Trichechus manatus*) and Green Sea Turtles (*Chelonia mydas*) rely primarily on only seagrass as a food source, making them specialists (TBEP, 2006), whereas Hardhead Catfish (*Ariopsis felis*) are generalist, which are opportunistic feeders that can adapt their diet to what is readily available (Olsen & McCulloch, 2024; Pensinger et al., 2021;Thomas & Betancur, 2020). This highly productive ecosystem can be made up of a single or combination of seagrass species, in a range of densities, which can in turn influence the representation of function diversity. For

example, seahorses prefer denser seagrass beds (Curtis & Vincent, 2005), which can impact where organisms prefer to settle. Identifying trophic level distinctions can be important for understanding how to protect a fragile ecosystem, such as a seagrass bed, (Duffy, 2006) whose health can largely depend on the presence of feeding aggregations, the types of species interactions, and the conditions of the habitat (Livingston, 1982).

The representation of functional diversity within seagrass ecosystems has been shown to be in decline and under threat from sea level rise, increasing ocean temperatures, and nutrient pollution from anthropogenic activities (McHenry et al., 2021). Seagrass beds support 43% to 64% more species compared to areas that are unvegetated (McHenry et al., 2021). However, anthropogenically induced degradation of seagrass will likely result in a decrease in the number of species that these areas can support. This decline can have devastating economic impacts given that there are many commercially important fish species that utilize seagrass beds as nursery habitats and protection from predators (Heck Jr. et al., 1997; Unsworth & Cullen-Unsworth, 2017). For example, Atlantic Cod (*Gadus morhua*), which has the third highest catch rate of commercial fish species, relies on seagrass beds where vulnerable juveniles spend their life prior to adulthood (Lilley & Unsworth, 2014). Protection of seagrass ecosystems has been successful and continued monitoring of these environments can provide valuable information to create conservation plans (Neckles et al., 2012). To create a conservation plan, data is collected using a variety of techniques depending on the priorities of the researchers. Some of these techniques include collection of core samples to examine macrofauna in the sediment (Lewis III & Stoner, 1981), bottom-trawling to gather organismal abundance (Cappo et al., 2004), quadrat and transects to understand percent cover (Neckles et al., 2012), aerial surveys (Duffy et al., 2018; Meehan et al., 2005), and seine netting to sample the species the reside and utilize seagrass

beds (Jänes, 2021). Each of these sampling techniques are associated with different benefits and disadvantages (as outlined below), that may lead researchers to select one versus another when planning a research program.

Typically, bottom trawling has been used to quantify the distribution and abundance of organisms; however, this method can be destructive to benthic habitats and the organisms collected (Cappo et al., 2004). Bottom trawling can cause long term damage, in which the benthos recovers slowly or is destroyed (Olsgard et al., 2008). This sampling method also causes an increase in turbidity, making it difficult for photosynthesis to occur (Palanques et al., 2001). In seagrass beds, bottom-trawling can be an effective method for obtaining species counts, but organisms that are captured are highly susceptible to mortality (Meyer et al., 1999). For example, pink shrimp (*Penaeus duorarum)* are targeted by commercial fisherman using trawls, however this method also leads to large amounts of bycatch, as well as the uprooting of grass bed root systems (Zaima, 2014). These negative impacts of trawling have been recognized by many states in the United States and by countries around the world, which has resulted in this method being banned (Stiles et al., 2010). Nonetheless, bottom trawling can be a beneficial method in certain environments where turbidity is high, such as the Northern Gulf of Mexico off the coast of Louisiana, Texas, and Mississippi (Scruton et al., 1953), where underwater visual census (UVC) or underwater cameras cannot be utilized due to low visibility when the observer cannot quantify all the organisms reliably (Philpott et al., 2025).

The use of seine nets is a common way to sample seagrass ecosystems around the world to analyze species diversity, abundance, and biomass (Hayes et al., 2020; Philpott et al., 2025). The disadvantages of using seine nets are that they easily snag on obstructions, researchers are restricted to shallow waters, and nektonic species are more difficult to capture (Philpott et al.,

2025). Additionally, seine nets become tangled with a variety of benthic organisms, such as oyster reefs, and this method may not fully capture all species present during sampling due to organisms escaping or active avoidance. Seining results that only report presence or absence of species can be misinformative compared to calculating the abundance of different species in seagrass areas.

Aerial surveys are a common way to assess large marine mammal populations sizes (Ferguson et al., 2018, Kunz et al., 2025, Ljungblad et al., 1982) and are also used to monitor seagrass coverage (Price et al., 2022). These surveys have been performed in a few ways using fixed-wing aircraft, helicopters, satellites, drones, and unoccupied aerial vehicles (UAV) to monitor ecosystems without being destructive or extractive (Carpenter et al., 2022; Duffy et al., 2018; Jones III et al., 2007; Price et al., 2022). One benefit of aerial surveys is identification of changes in seagrass cover seasonally and disturbances in cover, such as observations of burrowing areas of macrofauna (Chand & Bollard, 2021). Although aerial surveys can be useful for broad assessments of seagrass coverage, this methodology has several limitations, such as water clarity declining in high turbid waters, reflectivity off the surface during certain times of the day, and varying depth profiles of seagrass beds all leading to inaccuracies in the data. These challenges require many calibrations and corrections to be made to survey equipment, such as cameras and satellites, to ensure the accuracy of the data (Komatsu et al., 2020). While aerial surveys are greatly utilized for surveying seagrass coverage and large species, such as manatees (Langtimm et al., 2011), this method does not encompass the full scope of the less charismatic or cryptic species.

With increased emphasis on researchers' desire to understand organismal diversity within the coastal marine environment, the rapid advancement in technology has made underwater

videography possible, leading to the development of baited remote underwater video (BRUV) techniques. BRUVs are a submersible device that consists of a camera, a bait source, and a structure to hold the components (Whitmarsh et al., 2017). BRUV technology has advanced in the last 15 years with sampling being conducted in a wide range of habitats and is commonly used as a method to assess fish assemblages (Whitmarsh et al., 2017). BRUV studies began in the nineties as camera technology became more affordable and accessible (Ellis & DeMartini, 1995).

The process by which BRUVs are deployed can vary depending on the location of study and what researchers are attempting to observe, resulting in variation in how the BRUVs units are set up to record video footage optimally. BRUVs are being used as a minimally invasive, non-destructive, and non-extractive sampling method for examining marine biodiversity (Cappo et al., 2004; Harvey et al., 2007). Once the deployment of BRUV units is completed, researchers then analyze the video footage to assess species abundance and diversity. One of the most common metrics that is used in BRUV studies is MaxN (Cappo, 2010; Louiseau et al., 2016), which is the maximum number of individuals that appear in the frame at one time (Harvey et al., 2007). MaxN ensures that individuals are not counted multiple times because it would lead to an overestimation of species abundances and instead this metric provides a relative abundance of a species (Watson et al., 2010; Andradi-Brown et al., 2016). MaxN is used in BRUV technology because many designs do not observe the entire surrounding environment but rather one frame of view, such as cameras limited to a 180-degree angle (Whitmarsh et al., 2017). Researchers performing BRUV studies have attempted to standardize BRUV deployments and video analysis (Cappo et al., 2007). However, due to the different goals of research projects, approaches may

vary to maximize the capabilities of BRUVs making it difficult to compare results across studies (Whitmarsh et al., 2017).

In many studies, species identification is the central question for BRUV studies, such as understanding the biodiversity of fish assemblages in a particular habitat or baiting a BRUV unit for a target species. To conduct a species specific BRUV study, the researchers can utilize bait that will attract the desired focal species, such as blacktip reef sharks (Sentosa et al., 2020), elasmobranchs (Sherman et al., 2018), and semi-aquatic mammals (Rolim et al., 2022). Often baits are made up of chum, which include pilchards, sardines, abalone and tuna (Wraith et al., 2013). BRUV studies have been shown to report more fish communities than underwater visual census (UVC) surveys (Cheal et al., 2021) and can be useful for species diversity surveys across various ecological settings. For example, La Manna et al. (2021) performed a comparison of survey methodologies in marine protected areas (MPA) versus a non-MPA and found BRUV units documented more species diversity than underwater visual surveys conducted via snorkeling.

Given the ability for researchers to modify BRUV unit designs, researchers can customize BRUV units to fit the needs of their specific study requirements, such as challenges with depth, current, and camera limitations. The reason that BRUV unit designs vary in their construction is often due to cost-effectiveness (Tomasi et al., 2022; Langlois et al., 2010; Whitmarsh et al., 2017) and the ecological conditions for the habitat where they are deployed. Studies have used BRUV technology on all continents and in various habitats, including coral reefs, rocky intertidal zones, pelagic zones, and benthic environments (Whitmarsh et al., 2017). BRUV studies that have prioritized monitored coral reefs due to the ecosystem hosting a wide variety of commercially important fish species (Whitmarsh et al., 2017; Veron et al., 2009).

Coral and rocky reef habitats are commonly studied using BRUV units due to the clarity of the water, otherwise known as turbidity. Anthropogenic activities have had substantial impacts on coastal marine ecosystems due to increased population density on coastlines causing runoff in waterways leading to eutrophication (Halpern et al., 2015). BRUV deployments are restricted by turbidity due to the video analysis that is required to collect data from the camera footage (Jones et al., 2019). With coral bleaching on the rise, scientists are finding new ways to observe biodiversity as the anthropogenic threats for this vital ecosystem increase. Increasing our understanding of all the ocean's ecosystems is crucial, therefore BRUV studies are on the rise in estuaries, pelagic zones, seagrass beds (Kiggins et al., 2018), and even in deep zones of the oceans that humans cannot assess via SCUBA or submersibles (McLean et al., 2015).

In this study, we aimed to determine the feasibility of deploying BRUVs successfully in an estuarine environment with varying habitats, seasonal changes in water quality, and tidal fluctuations across an entire year. By utilizing BRUVs, we aim to successfully measure species diversity and species interactions across varying depth profiles and distance from seagrass. To achieve our objectives, we selected a seagrass bed in a partially enclosed estuary in Tampa Bay, Florida. Given that Tampa Bay is experiencing increasing levels of urbanization, anthropogenic activity, and decreases in seagrass cover (Raulerson et al., 2020), this research can provide baseline data for a potential long-term monitoring program.

Chapter II

METHODS

Study Site

Tampa Bay is the largest open water estuarine system in the state of Florida and is economically and ecologically important to the region. Tampa has a large watershed (5,700 km^2) with millions of people who reside in the area. There are large amounts of freshwater runoff entering the bay due to urban land use (Lewis & Estevez, 1988; Russel et al., 2015). The water quality of Tampa Bay fluctuates due to seasonality, extreme weather events, such as drought and hurricanes, and anthropogenic effects resulting from urbanization, such as the introduction of fertilizer from runoff (Greening et al., 2018). The Florida coastline has a large distribution of seagrass meadows supporting around 1.2 million acres (1.1 million hectares; Dawes et al., 2004). As of 2016, Tampa had seagrass beds covering 41,655 acres (TBEP, 2017). The increase in urbanization of Tampa Bay is leading to shoreline alteration and water quality degradation across the region, resulting in Tampa Bay officials implementing restoration projects, however seagrass ecosystems are still declining (Cicchetti & Greening, 2011).

The study site for BRUV unit deployments was located in Old Tampa Bay (27°52'31"N 82°32'10"W) where our selected seagrass bed was located near anthropogenic activities, including a boat channel, coastal construction, dredging, and runoff from urbanization (Figure 1). This area of the bay has experienced seagrass loss, degradation, and even regrowth over the last

few decades. For instance, in 1982 Tampa Bay had 21,653 acres and exhibited slow regrowth to 40,295 acres in 2014 (Sherwood & Kaufman, 2016).

Figure 1

Map of the BRUV deployments in Old Tampa Bay in proximity to a seagrass bed

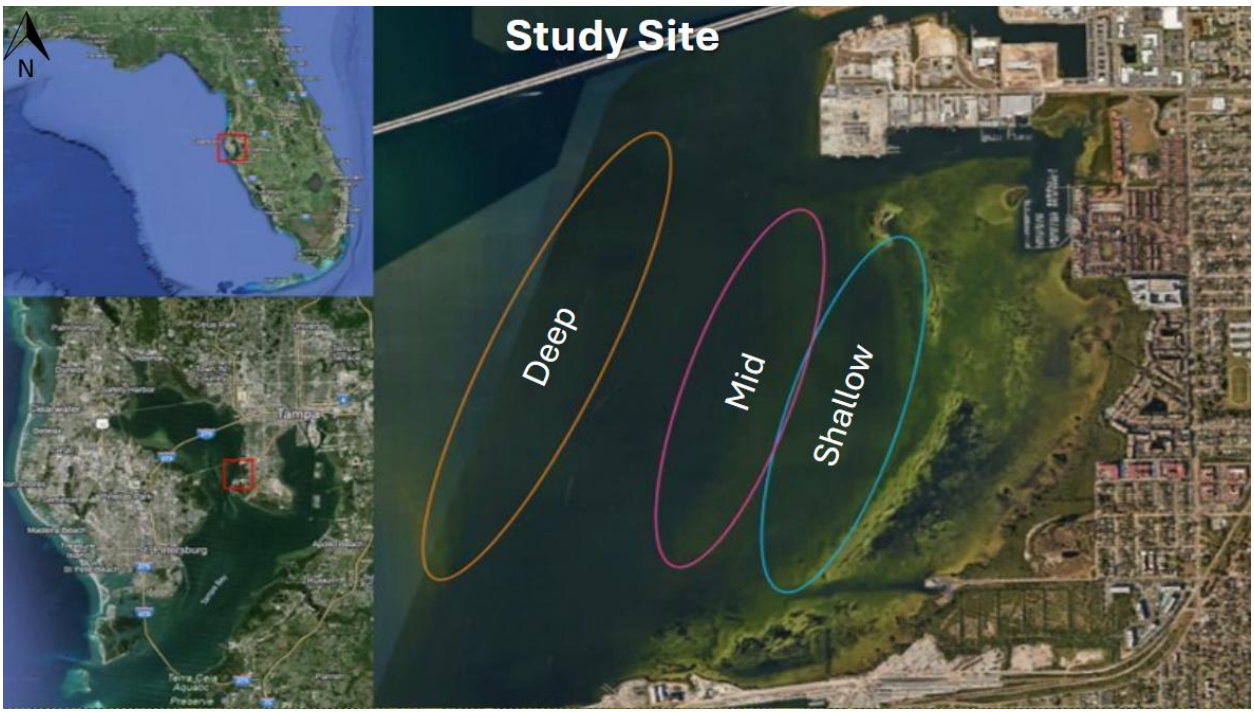


Figure 1. Blue is the area of shallow depth deployments (1.8 m to 6 m), pink is the mid depth (3 to 4.8 m), and orange is the deep depth (4.8 to 6.7 m). The seagrass bed is located to the right of the shallow treatment (blue) and the boating channel is between the deep (orange) and mid (pink).

Baited Remote Underwater Video (BRUV)

For this study, a custom BRUV unit was designed (Figure 2) and deployed within and along varying depth profiles at the site (Figure 1). The BRUV unit consisted of a GoPro camera (1080p to 4K resolution) (GoPro Hero 4 or GoPro 9 Black) in a GoPro waterproof housing that was fixed to a (Polyvinyl Chloride) PVC pipe (1 in) that was constructed into a cube (50 cm^3), a modified design of O'Brien et al., 2021(Appendix A). The PVC was filled with cement to weigh down the BRUV unit and prevent it from floating away from the deployment location. Attached to the unit was a LED dive flashlight, 3 to 9 meters of nylon rope, and a floating buoy was

attracted at the end of the roto to assist in locating and retrieving the unit (For assembly instructions, see Appendix A). A bait bag made of Black Plastic Hardware Netting attached to the BRUV unit was filled with pre-made chum mix consisting of 1 block of Tournament Green Label Chum with five 1-pound bags of thread herring (herring was cut up) prior to deployment.

Figure 2

Photo and Schematic of Baited Remote Underwater Video (BRUV)

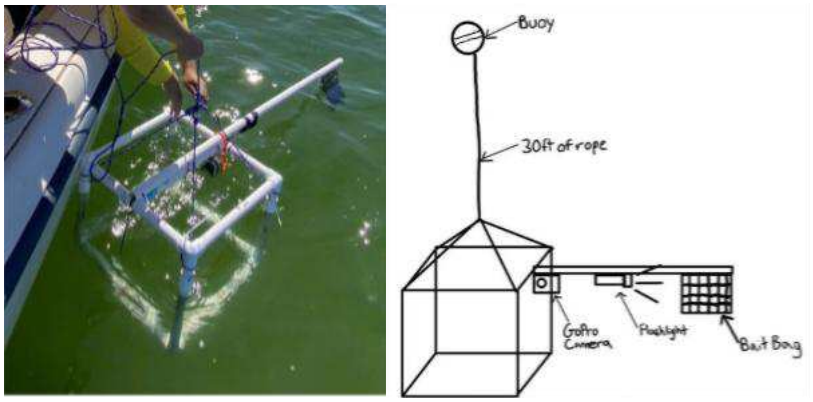


Figure 2. Pictured above (left) is a photo of the completed BRUV unit design being deployed. To the right, is a schematic of the BRUV design.

Collection of Environmental Data

Seawater was collected during each BRUV unit deployment via a Van Dorn bottle that was positioned 1 m above benthos at the deployment site to minimize the introduction of sediment in the sample. Water temperature (°C) and depth (m) were measured immediately at each site, and a GPS coordinate was recorded for each unit's deployment location. We collected a variety of environmental parameters prior to each individual deployment, which included turbidity (Oakton Turbidimeter), nitrite (Hanna Instruments), phosphate (Hanna Instruments), water temperature (glass thermometer), pH (YSI meter), salinity (refractometer), depth (depth meter) and tide status (rising, falling, slack) (NOAA Tides and Currents). Water samples were placed into a collection tube, stored in a holding container, and measured back at the lab.

Field Deployment

All BRUV unit deployments were performed along the western edge of the seagrass bed (Figure 1). Sampling occurred over the course of a year between February 2022-January 2023 once a month (excluding March 2022 and June 2022 due to inclement weather conditions). This yearlong sampling period coincided with the wet season from May to October and the dry season from November to April. Deployments were conducted in three depth profiles representing the treatment areas: shallow (1.8 to 6 m), mid (3 to 4.8 m), and deep (4.8 to 6 m). These depth treatments were chosen to border the seagrass beds near shore and along the channel varying in distance from seagrass. The depth (m) and distance from seagrass (m) were measured for each deployment to determine how well each sampling replication fit within the three treatments.

To obtain each deployments' distance from the seagrass bed, we utilized ArcMap 10.8.1 to map the deployments, measure distance from seagrass, and map Tampa Bay seagrass status from 2022 (FWC GIS Librarian, 2019). Next, the GPS points were converted from degrees, minutes, and seconds into decimal degrees to be used in ArcMap. To measure distance from seagrass we obtained a seagrass map layer from 2022 Florida Fish and Wildlife Conservation Commission (FWC and WRI, 2019) and the "Measure Tool" was used to measure the distance from seagrass in meters (the GPS point to the nearest seagrass).

During each monthly sampling event, 5 BRUV units were placed approximately 200 m apart in a line parallel to the seagrass bed for each of the three depth treatments: shallow, mid, and deep. Within depth treatments, replications were positioned 200 m apart to avoid overlap of bait plumes. A total of 15 BRUV units were deployed for each sampling period (5 in each treatment). During February of 2022 and October of 2022, 45 BRUV units were deployed with 15 replicates for each of the three depth profiles. Each BRUV was deployed for 45 to 90 minutes

and remained stationary on the benthos and then retrieved after that allotted time. All BRUV deployments took place between 08:00 - 18:00 hours to maximize sunlight availability.

Video Analysis

Once the deployments were completed, approximately 200 hours of video was collected over the course of a year (February 2022 to January 2023). Each camera collected an average of 3658.59 ± 96.73 seconds or 60.5 minutes of footage. Next, the success of the deployment was recorded. The success score of the deployment is a number given to each of the replicates based on if the video footage was able to provide complete data and if water quality was correctly collected. Scores included 0 = no success due to lack of video or poor visibility due to water quality, 1= Video success, water quality collection, and BRUV unit was set in the upright position, 2 = Water quality ONLY but no video success and 3 = Water quality and video obtained but not useable because BRUV unit was set improperly because unit fell on side, upside down, facing the surface, being drug around (moving from the original place it was deployed).

To conduct the video analysis, a standard starting point requirement was established, which was defined as when the sediment settled, and the bait bag became visible (1 to 2 minutes after BRUV reached the benthos). Video review ended when the BRUV was retrieved or the camera battery died, depending upon which event occurred first. The time between the starting and ending point was deemed the "Survey Time". At the start of the survey, a screenshot of the habitat type was taken and categorized into seagrass presence or absence. If seagrass was visible in the frame of view, the deployment was scored as "1" and if no seagrass was observed, the deployment was given a score of "0".

Species were analyzed by 'bouts' of activity, which is defined as the duration of time in which there are organisms present in the frame. A bout starts when organism(s) enter the frame

of view and ends when all organisms have left the frame of view. MaxN, the maximum number of fish documented in frame during the bout, and total abundance, a running count of any individual who entered the frame throughout the entire bout, were calculated for each video. Given that individuals were not tagged, the same organisms could reenter the frame after leaving, resulting in the total abundance number potentially being an overestimation of the number of organisms.

To measure species richness, all specimens were identified using various methods, which include the Florida Fish and Wildlife Conservation Commission Profiles, A Field Guide to Coastal Fishes: From Maine to Texas (Kells & Carpenter, 2011), and prior knowledge down to the species level if possible. If a species could not fully be identified, then they were identified down to the family level. Identified species were placed into functional groups, including omnivore, carnivore, herbivore, planktivory, and detritivore based on their primary diet (in the case of the omnivore it is equal amounts of herbivory and carnivory). These distinctions were made with peer-reviewed citations (Appendix B).

After each camera's footage was analyzed, each replication was summarized for the MaxestN of each camera (the largest MaxN across all the bouts per video), total number of bouts, total survey time (sec), total time of interspecies interactions, total time of intraspecies interactions, functional richness (total number of functional groups represented), and species richness. During survey time, interaction analyses were conducted, including interspecies (IE), intra-species (IA), or both inter- and intra-species (IB) presence. Within these three categories, the interaction type was then further categorized into shoaling, schooling, predator/prey, competition, territorial, foraging, and aggression (Table 1). When an interaction was identified, total time, species involved, species composition including conspecific (same species interacting)

and heterospecific (different species interacting), and MaxN during the interaction were recorded.

Table 1

Ethogram of organism interactions

Interaction/Term	Defined/Explained	Point or State Event	IE/IA/B
Interspecies Presence (IE)	Occurs when two or more species are interacting with one other. This includes touching, chasing, acknowledging the other species is there, predator/prey, competition, shoaling and schooling	Not applicable	Not applicable
Intraspecies Presence (IA)	Occurs when the same species of two or more individuals are interacting with one another. This includes touching, chasing, acknowledging the other individual(s) present, shoaling and schooling.	Not applicable	Not applicable
Both Intra- and Inter-species Presence (B)	Occurs when 2 or more of one species plus the presence of 1 or more other species are presence in the frame together. The number of species can vary.	Not applicable	Not applicable
Schooling	Identified when members of a species (typically 1 species of multiple individuals, 3 individuals or more) are all moving/swimming in the same direction.	Point	IA only
Shoaling	Recorded when individuals are swimming in the frame of view in a non-orderly fashion (all individuals are swimming in different directions)	State	IA and B
Predator/Prey	Occurs when a predator is biting, chasing, consuming or attempting to consumer the prey	Point	IE
Competition	Occurs when an interaction between individuals of the same species or different species are both show interest in the same food source (bait bag)	State	IE, IA, B
Territorial	Occurs when an individual(s) are protecting the bait bag from others and	State	IE and IA

	chasing off individuals that approach the area or bait bag.		
Aggression	Occurs when individuals are fighting and chasing off other individuals **not** protecting the bait bag	Point	IE, IA, B
Foraging	Occurs when two or more individuals are swimming near the bait bag near the benthos looking, smelling or digging in the sand, seagrass and other substrates looking for bait that has fallen from the bait bag.	State	IA and B

Table 1. Ethogram of organism interactions that were identified in BRUV footage. Interactions are defined, identified as point or state events, and the interaction type of each event.

Data Analysis

Before the main statistical analysis could be determined, all numeric variables were tested for variance and normality in RStudio (Appendix C). The Shapiro-Wilks test was used to assess the distribution of the data, then histograms were constructed for visualization. To test for variance between groups, a Levene's test was conducted using the "car" package. All numeric variables (Appendix C) were run against three factors, Tide Status, Season, and Seagrass Presence. To obtain the means and standard error of each numeric variable, R package "plotrix" was utilized (Appendix D). Only the means of successful deployments were analyzed.

Environmental Analysis

To visualize any statistical differences between the 3 factors (Tide Status, Season, and Seagrass Presence) and environmental variables, boxplots were created using the R package "ggplot2" (Appendix E). To understand, variation between groups and within those groups for environmental data we ran a PERMANOVA which tested for differences between seagrass presence, season, and tide status against environmental variables overall (salinity, pH, nitrite, phosphate, temperature, depth, turbidity, and distance from seagrass). We used the package

"vegan". The "Euclidean" distance matrix was utilized because it is used for environmental data (Grimmel et al., 2020). Seasonal differences in environmental parameters were run individually and not all together with Kruskal-Wallis tests (non-parametric).

To visualize the variation in environmental parameters in seagrass presence a PCA (Principal Component Analysis) biplot was performed using packages "tidyverse" and "factoextra". The environmental parameters examined were distance from seagrass, pH, salinity, phosphate, nitrite, turbidity, depth, and temperature and these were standardized due to the varying scales using the prcomp function in R. Next, a PCA biplot was produced using PC1 and PC2 to visualize potential separation between replicates with seagrass presence or absence. Then t-tests were run on PCs 1-8 to understand the difference qualitatively.

Species Analysis

To analyze the effects of season, seagrass presence, and tide status on MaxestN and Total Species Observed (species richness) the package "ARTool" was utilized for the ART ANOVA. To visualize the interactions, interaction plots were generated with the untransformed, raw data using the package "ggplot2". To analyze how species composition varied between the presence of seagrass and across environmental variables, an ANOSIM analysis with BIOENV was performed in R using the "vegan" package. The ANOSIM (function "anosim") was run on the species matrix created (presence and absence of species) and environmental data grouped by seagrass presence with 9999 permutations. Next, the BIOENV analysis (function "bioenv") was run using the community species matrix with the environmental data. BIOENV used "Euclidean distance", which calculates the dissimilarity between the environmental parameters.

Functional group richness was analyzed by seagrass presence and depth treatments, and heat maps were used to visualize mean richness of each functional group using R packages

"dplyr", "tidyr", and "ggplot2". Visualization of the deployments relatedness to one another based on the seagrass presence and functional group composition was conducted using a non-metric multidimensional scaling (nMDS) plot with vectors was created. A matrix made up of presence and absence of functional groups. Then, using the package "dplyr" the data was sorted to obtain functional groups richness. The Bray-Curtis dissimilarity index was utilized to create the nMDS plot the R package "vegan" was used. To visualize the functional groups driving the deployments vectors were overlayed on the plot.

The top 10 most observed species were compared within and outside of seagrass using the number of BRUV deployments on which they appeared by creating a stacked bar graph in R, using packages "dplyr", "ggplot2" and "tidyr".

Interaction Analysis

Observations of the interactions across season, seagrass presence, and depth treatment were totaled across all BRUV unit deployments to be examined qualitatively. To visualize the average time of competition and shoaling interaction across species composition and seagrass presence interactions were created using the package "ggplot2".

Chapter III

RESULTS

A total of 200 BRUV deployments were completed over the yearlong study resulting in 147 successful deployments and 149 hours of footage surveyed for habitat, species diversity, and species interactions. The distribution of the successful deployments (Table 2) indicates that over ninety percent of the replicates reported species with all deployments occurring within the shallow depth treatment, including all seagrass replicates, has species observed.

Table 2

Distribution of Successful BRUV Deployments

	Season		Seagrass		Depth Treatment		
	Wet (May-Oct)	Dry (Nov-Apr)	Presence	Absent	Shallow	Mid	Deep
BRUV (n =147)	70	77	37	110	60	54	33
No Species (n =14)	5	9	0	14	0	5	9
With Species (n =133)	65	68	37	96	60	49	24

Table 2. Distribution of Successful BRUV Deployments across season, seagrass presence, and depth treatments. Shows the number of deployments that had species or no species observed across the 3 categories.

1. Environmental Parameters

Across the 147 successful deployments, water samples were collected to measure eight parameters including pH (n = 129), salinity (n = 147), phosphate (n = 141), nitrite (n = 147), turbidity (n = 146), depth (n = 147), and temperature (n = 146), and GPS coordinates were used for calculating distance from seagrass (n =144). Not all of the deployments with successful video

footage had successful water quality samples due to instrumentation not working properly. The results of the PERMANOVA indicated that the environmental parameters differed significantly due to seagrass presence ($p = 0.001$) and season ($p = 0.02$), whereas tide status was not significant ($p = 0.206$) (Table 3). Furthermore, the r^2 (0.29772) explained 30% of the variation in environmental conditions when seagrass is present compared to absent. In addition, season ($r^2 = 0.03783$) explained only 4% of the variation in the data (Table 3).

Table 3

PERMANOVA of Environmental Parameters

Factor	df	Sum of Squares	R^2	Pseudo-F	p-value
Seagrass P/A	1	4360166	0.29772	61.471	**0.001*** **
Season	1	554004	0.03783	5.7008	**0.02***
Tide Status	2	306269	0.02091	1.5379	0.206

Table 3. PERMANOVA of Environmental Parameters (8 parameters) that were observed in seagrass presence/absence, season (wet/dry), and tide status (rising/falling/slack). The results are based on Euclidean Distance. $P < 0.05$ in **bold.**

The results of the Kruskal-Wallis test suggested that there were significant differences between the season for turbidity ($p = 8.327e-05$), water temperature ($p < 2.2e-16$), pH ($p = 0.001995$), and salinity ($p = 0.0003249$). Potential explanations for those parameters differing by season are listed below (Table 4). Season did not have an impact on phosphate ($p = 0.1348$) and nitrite ($p = 0.4619$) levels in the water samples. Depth ($p = 0.1074$) did not differ by season, which indicated our sampling methodology was executed successfully across the three depth treatments.

Table 4

Kruskal-Wallis Test showing environmental parameters by season

Kruskal-Wallis Test (Non-parametric)	**df**	**p-value**	**Why?**
Turbidity (ntu) (n = 146)	1	**8.327e-05***	**Wet season having more nutrients**
Water Temperature (°C) (n = 146)	1	**< 2.2e-16***	**Colder in dry season**
pH (n = 129)	1	**0.001995***	**Runoff in wet season diluting pH**
Salinity (ppt) (n = 147)	1	**0.0003249***	**Runoff in wet season diluting salinity**
Phosphate (ppm) (n = 141)	1	0.1348	No difference
Nitrite (ppm) (n = 147)	1	0.4619	No difference
Depth (m) (n = 147)	1	0.1074	No difference

Table 4. Kruskal-Wallis Test showing environmental parameters by season and the potential explanations for those differences

To further understand the environmental parameters, a Principal Component Analysis (PCA) were conducted to identify the key drivers in the environmental differences, excluding "Distance from SG" due to the measurement being a confounding variable of seagrass presence. In the case of BRUV unit deployments with seagrass present, the PCA showed weak correlation due to PC1 explaining 24.2% of the variation and PC2 explaining 18.6% of the variation, indicating that the data's total variance is not captured by the first two dimensions. To achieve at least 80% of the variation, we would need to extend to PC5. There was an overlap between seagrass present (green ellipses) and absent (gray ellipses) deployments indicating that the environmental parameters for the two groups are highly similar. When examining the vectors on the biplot, the largest drivers for PC1 are salinity: -0.645, average turbidity: - 0.472, and pH: -0.443. The largest drivers of PC2 are temperature: 0.546, nitrite: -0.451, and pH: -0.444. All vectors pointed away from the mean of the seagrass present data (large green triangle) suggesting that the largest drivers only resulted in small differences between the two groups (Figure 3).

Figure 3

Principal Components Analysis (PCA) of environment parameters

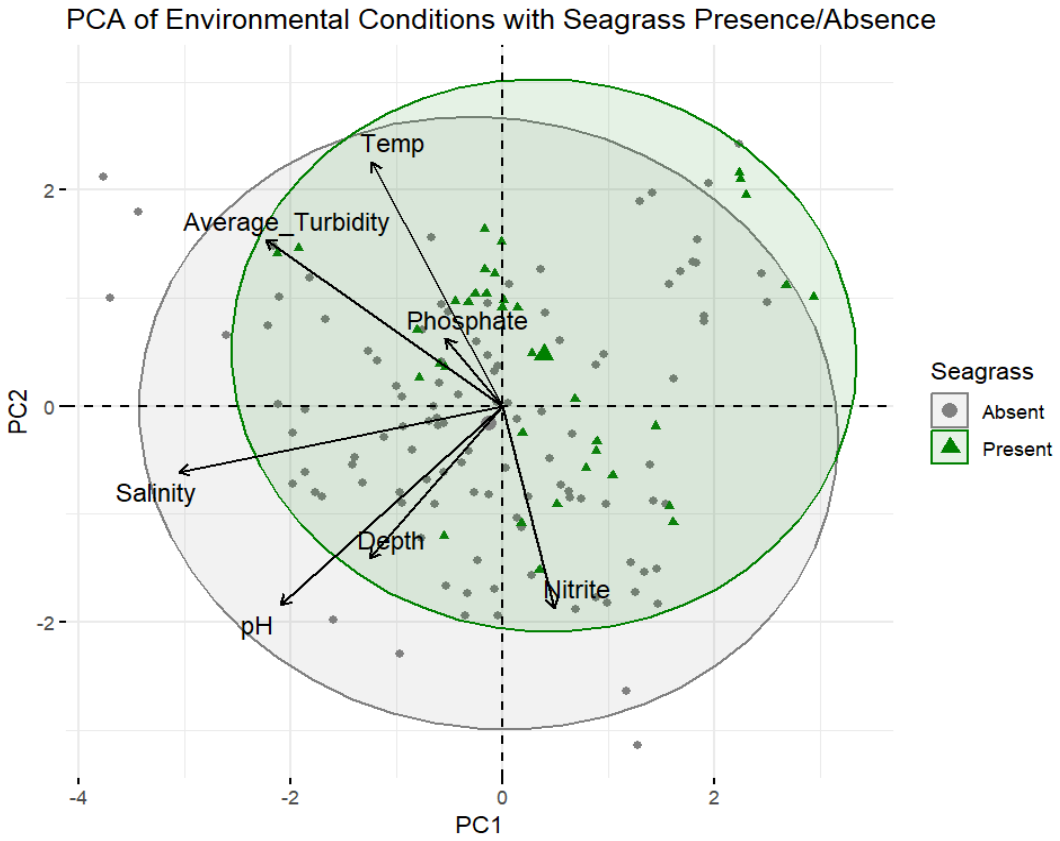


Figure 3. Principal Components Analysis (PCA) of environment parameters (depth, pH, salinity, temperature, turbidity, phosphate, and nitrite) with the data standardized, Euclidean distance and the habitat status. The BRUV deployments are represented by the points (Seagrass Present: n = 37 and Seagrass Absent: n =110) and the environmental parameters represented by the vectors.

2. Species Results

Of the 147 successful deployments, 133 replicates observed species during the footage and 14 exhibited no species (Table 2). In the successful deployments, a total of 51 species were observed representing the functional groups: Carnivores – 22, Herbivore – 4, Omnivore – 10, Planktivore – 8, and Detritivore – 7 (Table 5). Screenshots from the video footage of select species with their identification and respective function group distinctions can be found in Appendix F.

Table 5

Functional Groups and Common Names

Carnivore - 22	Herbivore - 4	Omnivores - 10	Planktivore - 8	Detritivore- 7
Atlantic Stingray	Sea Hare sp.	Hardhead Catfish	Comb Jelly sp.	Dwarf Hermit Crab
Southern Stingray	Green Sea Turtle	Southern Pufferfish	Pipefish sp.	Large Hermit Crab
Cownose Ray	Arrow shrimp	Horseshoe Crab	Atlantic Thread Herring	Spider Crab
Florida Crown Conch	West Indian Manatee	Pinfish	Minnow sp.	Tube Building Amphipod
Lighting Whelk		Scrawled Cowfish	Scaled Sardine	Blenny sp.
Lined Sea Star		Orange Filefish	Clupeidae (Herring sp.)	Snail Small
Gulf Flounder		Unknown Filefish sp.	Clupeidae sp. 1	Unknown Small Snail
Unknown Flounder		Haemulidae sp.	Clupeidae sp. 2	
Spiny Searobin		Bonnethead Shark		
Sand Perch		Sheepshead		
Bluntnose Jack				
Gafftop Sail Catfish				
Striped Burrfish				
Bull Shark				
Double-Crested Cormorant				
Gerreidae sp.				
Sparidae sp.				
Silver Jenny				
Ladyfish				
Lettered Olive Snail				
Nudibranch sp.				
Sharksucker				

Table 5. Species Identified in Successful BRUV footage sorted into their respective functional group by common names

The ANOSIM with BIOENV that examined species composition (occurrence 0 or 1) in relation to seagrass presence and the environmental variables showed no relation, indicating that environmental parameters all together did not explain the variation in the species occurrence ($R = -0.0137$, $p = 0.617$). BIOENV reported that the best correlation of environmental parameters was phosphate, average turbidity, depth, and temperature (correlation = 0.1892), suggesting there is a weak relationship between the environmental parameters and species occurrence (Table 6).

Table 6

BIOENV Results of Environmental Parameters

Environmental Parameters	Size	Correlation
Depth	1	NA
Depth, Temp	2	NA
Average_Turbidity, Depth, Temp	3	NA
Phosphate, Average_Turbidity, Depth, Temp	4	0.1892
Salinity, Phosphate, Average_Turbidity, Depth, Temp	5	0.1673
Distance_SG, Salinity, Phosphate, Average_Turbidity, Depth, Temp	6	0.1484
Distance_SG, pH, Salinity, Phosphate, Average_Turbidity, Depth, Temp	7	0.1308
Distance_SG, pH, Salinity, Phosphate, Nitrite, Average_Turbidity, Depth, Temp	8	0.1076

Table 6. BIOENV Results of Environmental Parameters (Correlation Values)

To understand the influence of seagrass on functional group presence, a heat map was generated and indicated that when seagrass is present, the functional richness was greater than when seagrass was absent. Not only were more species observed in seagrass, but omnivores were the most abundant, whereas seagrass was absent, no omnivores were observed (Figure 4). Further visualization through an nMDS plot shows which deployments were the most related to each other by presence and absence of seagrass and functional group. The points lacked clustering in any particular area. The vectors indicated that certain deployments had more members of functional groups than others. The three most clustered functional groups included replications where herbivores, planktivores, and carnivores were all present. In the case of omnivores, the deployments in the vicinity of the omnivore vector have a high presence of omnivores but not a high presence of detritivores since that arrow is in the opposite direction showing little overlap for these two groups with each other or the clustering of the three groups previously mentioned. The model can be trusted due to the stress value being 0.127 being less than 0.2, meaning the original numeric data is represented in the ordination of the plot. (Figure 5).

Figure 4

Heat Map of Functional Group Richness by Seagrass P/A

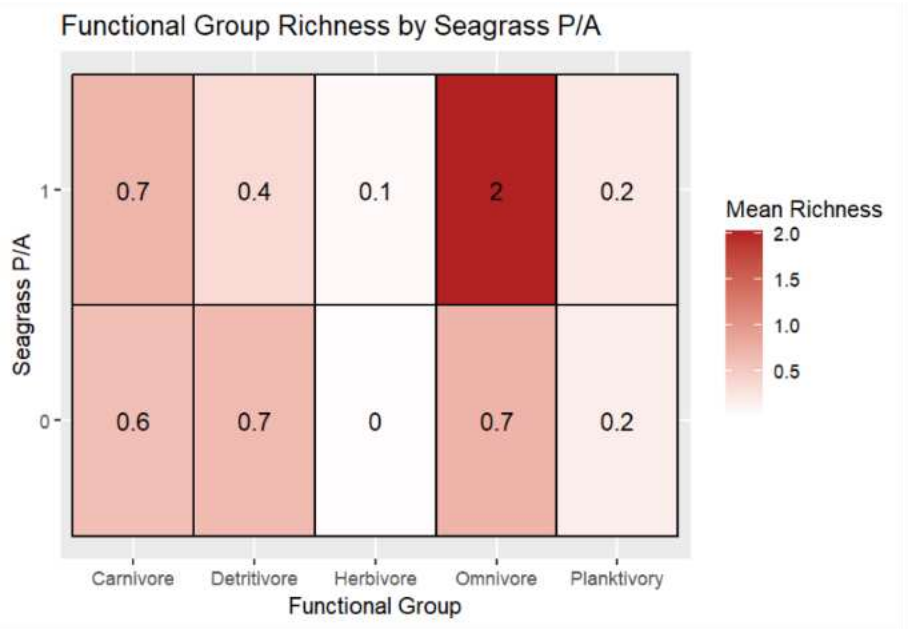


Figure 4. Heat Map of Functional Group richness when seagrass is present vs. absent. (1 = Seagrass Present, 0 = Seagrass Absent). The darker the box the more each functional group was observed. Lighter means the functional group was seen less or if at all.

Figure 5

nMDS Analysis of Functional Group Occurrences by Seagrass P/A

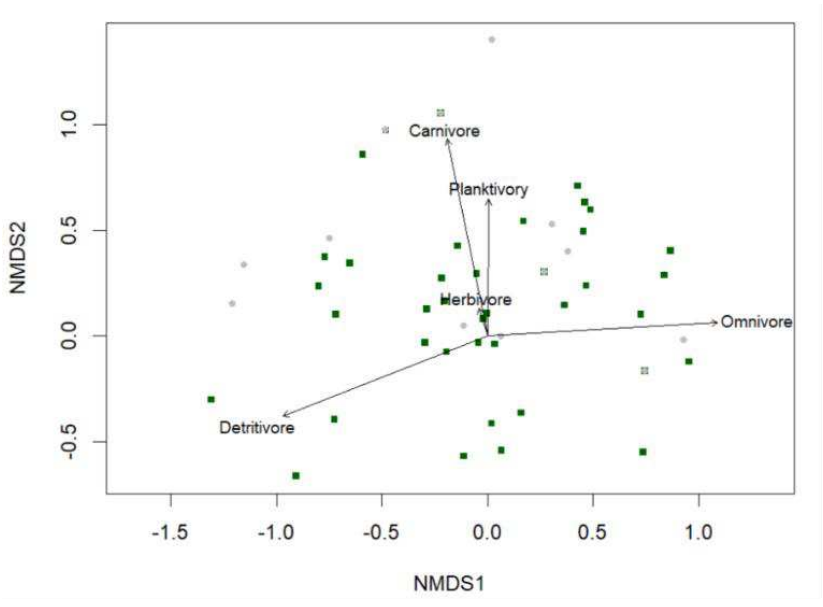


Figure 5. nMDS plot of Functional Group occurrences by seagrass presence showing the relatedness of successful BRUV deployments (points = deployments, green squares = seagrass presence, gray circles = seagrass absence). The vectors represent the functional groups, and they pointed in the direction of the deployments they were mostly likely found on.

Functional group richness varied by treatment. The shallow treatment exhibited the highest richness of the three depth profiles, and omnivores were the best represented functional group in the shallows (1.72). The mid treatment resulted in representation of all functional groups with the highest richness average being detritivores (0.74). The deep treatment observed all functional groups except herbivores. The deep treatment exhibits greater functional richness of detritivores (0.61) (Figure 6).

Figure 6

Heat Map of Functional Group Richness by Treatment

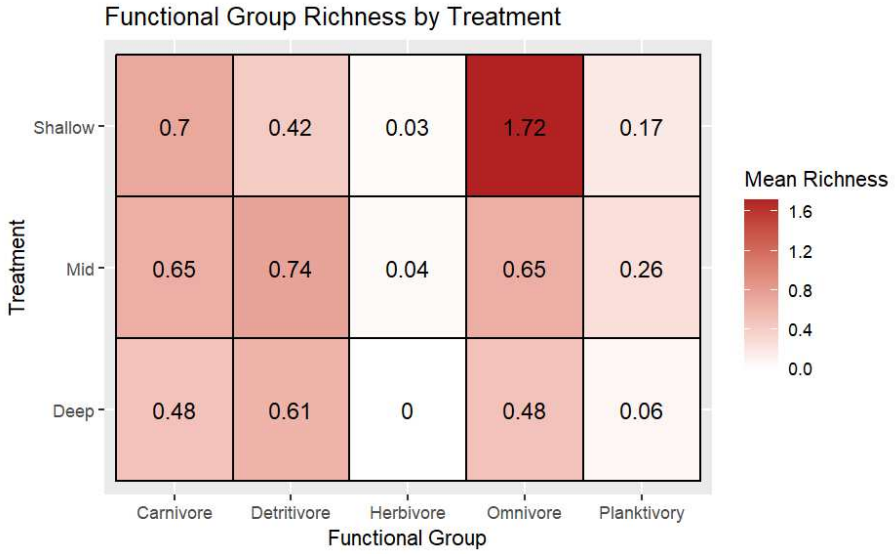


Figure 6. Heat map of functional group richness by depth treatment group (Shallow, Mid, and Deep). The darker the box the more often the functional group was observed. Lighter means the functional group was seen less or not at all.

There were differences observed in MaxN due to seagrass presence and the interactions between seagrass presence:season, and seagrass presence:season:tide status (Table 7). The post hoc analysis of the main effect of seagrass presence indicated that there was a difference between

the MaxestN (ART ANOVA, p = <.0001). The post hoc analysis of the interaction between seagrass presence and season showed significant differences with 3/6 combinations (Table 8). The interaction plot created with the non-transformed data of MaxestN and the interaction between seagrass presence and season indicated that MaxestN was greatest with seagrass present. The interaction plot exhibited a decrease in the MaxestN when seagrass present in the wet season and an increase in MaxestN when seagrass was absent in the wet season (Figure 7). MaxestN relative to tide status indicated that overall the MaxestN was greatest when seagrass was present (Figure 8). The post hoc analysis revealed that when deployments were observed in seagrass absence, dry season, and rising tide significantly differed between 3 combinations of interactions listed below (Table 9). Overall, the average MaxestN was 8.04 individuals (± 1.395018).

Table 7

Art ANOVA Table: Season, Seagrass P/A, and Tide Status with MaxestN

	df	df res.	F-value	P-value
Seagrass P/A	1	135	25.22524	**1.585e-06*** **
Seagrass P/A:Season	1	135	10.87049	**0.0012489** **
Seagrass P/A:Season:Tide Status	2	135	3.78996	**0.0250375***

Table 7. Non-significant values were excluded from the table. This indicates the differences in MaxestN in Seagrass P/A, Seagrass P/A:Season and Seagrass PA:Season:Tide Status.

Table 8

Post Hoc Analysis: Seagrass P/A:Season

Interaction	**SE**	**df**	**t.ratio**	**p-value**
Seagrass Absent,Dry - Seagrass Absent,Wet	9.25	135	-3.192	**0.0094**
Seagrass Absent,Dry - Seagrass Present,Dry	16.30	135	-4.022	**0.0005**
Seagrass Absent,Dry - Seagrass Present,Wet	13.50	135	-4.334	**0.0002**
Seagrass Absent,Wet - Seagrass Present,Dry	16.70	135	-2.173	0.1359
Seagrass Absent,Wet - Seagrass Present,Wet	13.90	135	-2.091	0.1613
Seagrass Present,Dry - Seagrass Present,Wet	19.40	135	0.369	0.9827

Table 8. Post Hoc Analysis of the ART ANOVA for MaxestN for the interaction between seagrass presence and season. Significant interactions are indicated with **bold**.

Figure 7

Interaction Plot of MaxestN for Season and Seagrass P/A

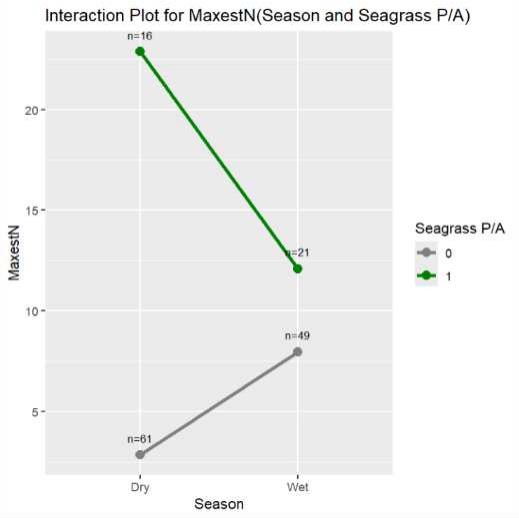


Figure 7. This plot displays the interaction between season and seagrass presence for MaxestN. The green or "1" indicates when seagrass is present and grey or "0" when seagrass is absent. Season is on the x-axis and MaxestN on the y-axis. Data plotted are the mean MaxestN.

Figure 8

Interaction Plot of MaxestN (Seagrass P/A, Season, and Tide Status)

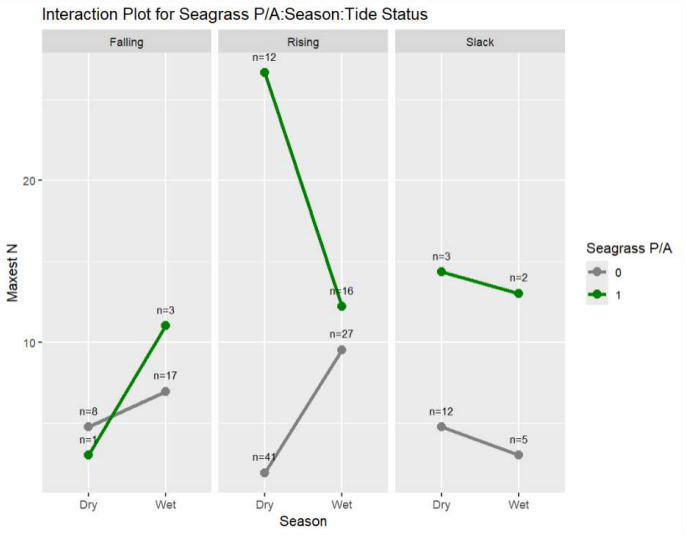


Figure 8. Interaction Plot of MaxestN interaction between Seagrass Presence, Season, and Tide Status for the untransformed data.

Table 9

Post Hoc Analysis of Seagrass P/A: Season: Tide Status

Interaction	SE	df	t.ratio	p-value
Absent,Dry,Rising - Present,Dry,Rising	12.20	135	-4.984	**0.0001**
Absent,Dry,Rising - Present,Dry,Slack	22.20	135	-3.550	**0.0255**
Absent,Dry,Rising - Present,Wet,Rising	11.00	135	-4.664	**0.0004**

Table 9. Post Hoc Analysis of the ART ANOVA for MaxestN of the significant interaction combinations between seagrass presence, season and tide status. Non-significant values were excluded from the table.

The ART ANOVA revealed that the total species observed (species richness) was significantly different between deployment locations with seagrass presence and absence ($p = 0.001$) (Table 10) with more species observed when seagrass was present (Figure 9). Total species did not significantly differ across season (Figure 10) or tide status.

Table 10

ART ANOVA for Total Species Observed with Seagrass P/A, Season, and Tide Status

ART ANOVA	df	Df res.	F-value	Pr (> F)
Seagrass P/A	1	135	10.4817000	**0.0015172**
Season	1	135	0.9832878	0.3231624
Tide Status	2	135	0.4339439	0.6488492
Seagrass P/A:Season	1	135	0.0030413	0.9561022
Seagrass P/A:Tide Status	2	135	0.1316190	0.8767873
Season:Tide Status	2	135	0.1057027	0.8997665
Seagrass P/A:Season:Tide Status	2	135	0.1779970	0.8371410

Figure 9

Average Total Species Observed by Seagrass P/A

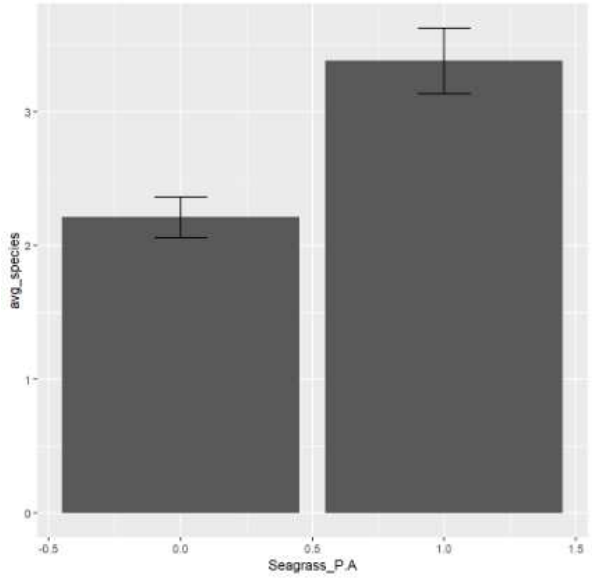


Figure 9. Average Total Species Observed by Seagrass Presence visualization using a bar graph showing the difference between the mean (+/- 1 standard error) species observed when seagrass is present (1) and when seagrass is absent (0). n = 147 (n = 37, seagrass present (1), n = 110, seagrass absent(0)).

Figure 10

Average Total Species Observed by Season

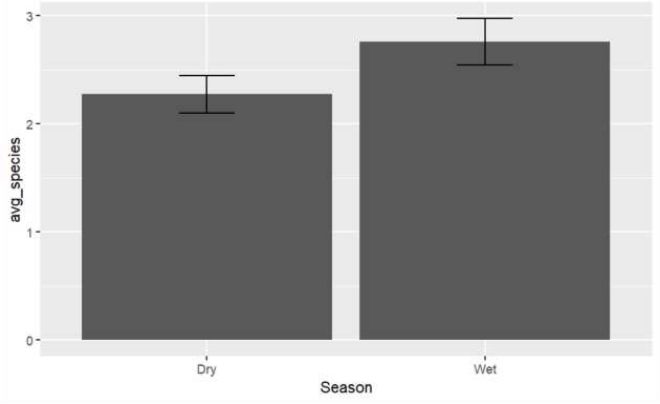


Figure 10. Average Total Species Observed by Season visualization using a bar graph with standard error bars. Average species on the y-axis and season on the x-axis. The wet season showed higher mean species.

The results indicated that Hardhead Catfish (*Apriosis felis*) was observed on the greatest number of BRUV deployments, appearing on 71 of the 133 deployments with organism sightings. *A. felis* were also observed on 35 of the total 37 deployments with seagrass present. Orange Filefish (*Aluterus schoepfii*) was the only species in the top ten that was not observed in seagrass (Figure 11).

Figure 11

Top 10 Species by the Number of Deployments and Seagrass P/A

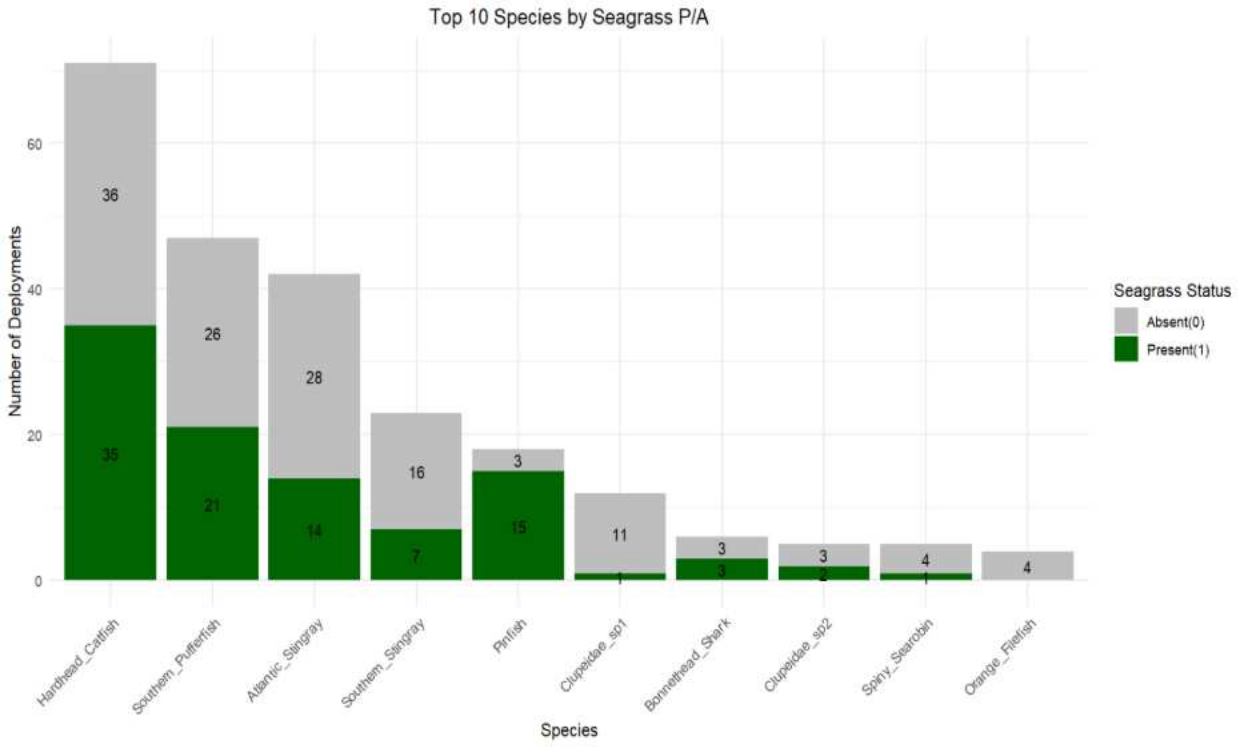


Figure 11. Stacked bar graph showing the top 10 most observed species by number of deployments and split by how many of the deployments reported sightings of each species when seagrass was Present (1) (green) vs. Absent (0) (gray).

3. Interactions

Overall, there were 579 observations of the 7 interaction types across 68 successful BRUV deployments (Table 11). There were 29 species that were observed taking part in the

interactions. The distribution of interactions across season, seagrass presence, and depth treatment can be observed in Table 12. In Table 12, we combined Predator Prey and Foraging because they both involve obtaining energy from resources. Aggression and Territorial behaviors were combined because both involve defensive strategies. Predator Prey & Foraging, Schooling, Aggression & Territorial were similarly distributed across season and seagrass presence. However, across depth treatments we observed a trend where the greatest number of interactions occurred in the shallows (Table 12). We observed a different trend in the two most observed interactions (Shoaling n = 407 and Competition n = 75) across season, seagrass presence, and depth treatments. Competition occurred more often in the wet season, when seagrass was absence, and in the shallow treatment, while shoaling exhibited the same trends with season and depth treatment yet differed by seagrass status with more occurrences in the presence of seagrass. (Table 12).

Table 11

Interaction Observations by Number of BRUVs and Interaction Totals

Interactions	**Number of BRUVs**	**Total Occurrences**
Aggression	17	22
Competition	17	75
Foraging	10	27
Predator Prey	7	7
Schooling	15	21
Shoaling	47	407
Territorial	7	20

Table 12

Number of Interaction Occurrences by Season, Seagrass, and Treatment

	Season		Seagrass		Depth Treatment		
	Wet	Dry	Presence	Absent	Shallow	Mid	Deep
Predator Prey & Foraging (n = 34)	13	21	20	14	30	1	3
Schooling (n = 21)	13	8	10	11	12	9	0
Aggression & Territorial (n = 42)	22	20	22	20	31	4	7
Competition (n = 75)	58	17	25	50	33	28	14
Shoaling (n = 407)	258	149	254	153	378	21	8
Total Interactions (n = 579)	**364**	**215**	**331**	**248**	**484**	**63**	**32**

The qualitative analysis of shoaling and competition time by seagrass presence icides with and species composition revealed interesting trends. Regardless of the interaction type (shoaling and competition), we observed that heterospecific interactions took place for a longer duration of time (seconds) than conspecific interactions, yet the number of occurrences are less frequent for shoaling in heterospecific groupings but not different between the two species composition groups for competition (Figure 12 a, b). Regardless of seagrass status, greater shoaling occurred (number of occurrences) when seagrass was absent for conspecifics than heterospecific groupings (Figure 12a). Regardless of species composition, competition shows

trends where there were more occurrences of when seagrass was absent (n = 50) and less when seagrass was present (n = 25) (Table 12 and Figure 12).

Figure 12

Interaction plots of Shoaling and Competition by Seagrass P/A

a) b)

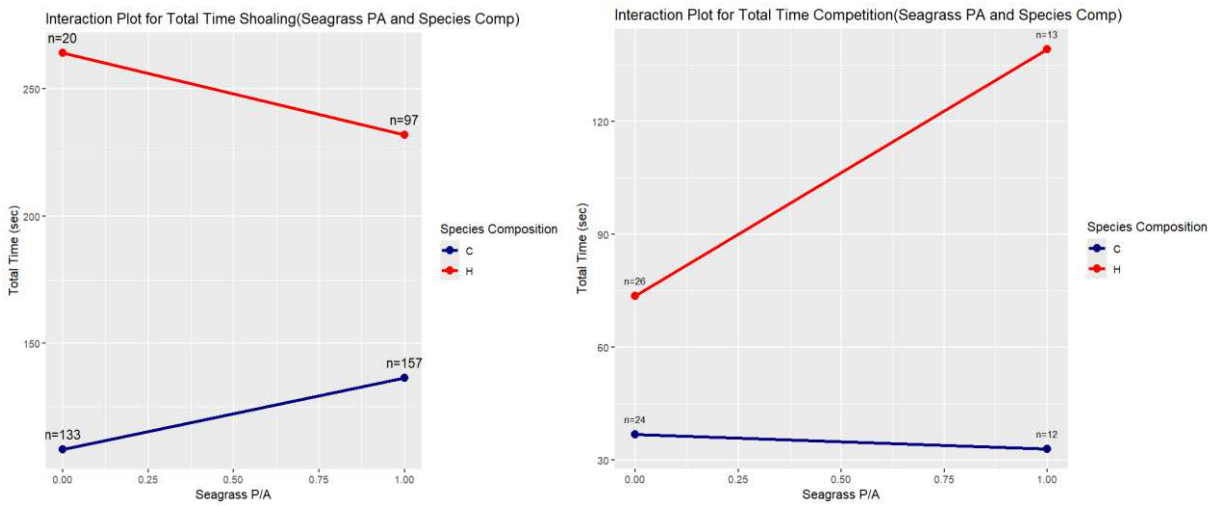


Figure 12. Interaction plots of (a) average shoaling time (y-axis scale: 0 to 300 seconds) and (b) average competition time (y-axis scale: 0 to 150 seconds) by seagrass presence and species composition. Seagrass Presence (0 = Seagrass Absent, 1 = Seagrass present) and Species Composition (C = Conspecific (navy blue line), H = Heterospecific (red line)).

Chapter IV
DISCUSSION

Within the last few decades, there has been an increase in the number of BRUV studies to understand species diversity, calculate organismal abundance, and observe species behaviors underwater in ecosystems across many geographic areas worldwide (Whitmarsh et al., 2017). Although BRUV studies have been broadly used, only 4% have been conducted in estuarine environments (Whitmarsh et al., 2017) and even fewer studies (2%) in seagrass beds (Whitmarsh et al. 2014). Recently, researchers have conducted studies in shallow water environments and seagrass beds (Grimmel et al., 2020; Kiggins et al., 2018) which were successful, but not without limitations. However, as advances in methodology and new technology develop, some of the challenges have become less problematic for successfully obtaining footage in seagrass ecosystems. In this study, we aimed to determine the feasibility of successfully deploying BRUV units using our modified design in an estuarine environment in Tampa Bay with varying seasonal environmental conditions to obtain species diversity data and observe species interactions at varying depth profiles and distances from seagrass. Although we had difficulties with replication of deployment locations and technical difficulties, the collection of environmental parameters, reporting of species diversity, and observations of interactions were each successfully completed throughout the yearlong study.

Experimental Design

In this study, there were a total of 200 BRUV units deployed with 147 (73.5%) of those resulting in usable footage for data analysis along with successful collection of environmental parameters. Throughout the sampling period (February 2022 to January 2023) we had close to equal sampling efforts across the seasons (Wet: 70 and Dry: 77). Across the 3 depth treatments there were 60 in shallow, 54 in mid, and 33 in deep water that were successfully deployments (Table 2). The variation in sample size, particularly for the deep treatment, was likely due to the attached rope not being long enough for the deepest areas of the survey location and stronger currents in the channel on either side of the mid and deep locations. Deployment locations in the 3 depth treatment profiles were not equally replicated due to currents and tide status affecting the precision of deployment location during certain times of the month and time of day. If the tide was high, we had the ability to deploy our BRUV units closer to the selected seagrass bed for shallow treatment replications, which then altered where mid and deep deployment locations as well. The opposite happened when the tide was low, where the treatment site shifted further from the seagrass bed. Grimmel et al., 2020 indicated that during their study low tide limited access to their sites that were too shallow to sample, which could have restricted their deployment location replication, which is similar with our findings. The benthic habitat of Tampa Bay is constantly changing due to channel dredging, sea-level rise, tides, and runoff sediment flowing from rivers, which all alter the benthos, ultimately impacting depth profiles and seagrass status in our selected site (TBEP, 2020).

Environment

Overall, we observed that the environmental parameters measured in the study differ by the presence of seagrass and across season, but not by tide status (Table 3). Further examination

of environmental parameters by season showed that turbidity, water temperature, pH, and salinity differed significantly between the wet and dry months of the study. The seasonal differences likely occurred due to increases in runoff in the wet season causing eutrophication that leads to an increase in turbidity, but rainfall is diluting salinity and pH (Halpern et al. 2015) (Table 4). Given that the seagrass surveys represent 62% of the successful shallow water replicates, the environmental parameters for seagrass presence was comparing the seagrass replicates located only in the shallows while the seagrass absent data includes water quality from replicates across all three depth profiles. Therefore, we cannot confidently state that the measured environmental parameters in this study were the only parameters predicting seagrass presence in this ecosystem. When examining the parameters "distance from seagrass" and "depth", the deeper replicates were less likely to have seagrass due to less availability of sunlight, particularly where turbidity is high and the sunlight being absorbed by particles in the water column (Greve & Binzer 2004).

Water parameters in previous BRUV studies have been shown to influence the number of species observed and organism abundances. Our study revealed that the highest MaxestN was observed at locations where seagrass was present during the wet season. The average turbidity in this study was highest in the wet season (Appendix E). When turbidity is high, it reduces the quality of the footage, making it difficult to accurately obtain counts for species abundance (Jones et al., 2021; Whitmarsh et al., 2017; O'Byrne et al., 2018). The MaxestN was likely influenced by turbidity, which can lead to inaccuracies when visibility is low, but seagrass obstructing the view could also have contributed to a possible underestimation in counts. During the peak of the wet season, seagrass is also at its peak development with the longest blades throughout the year (Vettori & Marjoribanks, 2021), thus obstructing the view from the BRUV

and magnifying the effect that species or individuals may not all be accounted for in a complex habitat. Seagrass often hindered our ability to observe the nektonic species but limited the view of cryptic species residing within the seagrass (Grimmel et al., 2020). BRUVs can be modified specifically to observe cryptic species in seagrass, such as with a mini-BRUV (Kiggins et al., 2018) placed directly in the seagrass bed at the base of the blades. Our BRUVs were designed to observe species in the water column and above seagrasses, not the benthos directly, which hindered our ability to observe all possible species (Cappo et al., 2011).

Species

Out of the 147 successful deployments, only 133 exhibited species. All deployments in the shallows (n = 60), including those with seagrass present (n = 37), had species observed (Table 2). For the successful shallow deployments, 62% (n = 37) were conducted in seagrass and the other 38% (n = 23) had seagrass absent. The depth treatments had varying degrees of organismal observations, with 0 % of shallow, 9 % of mid, and 27 % of the deep replicates that exhibited no species on the footage. Deployments that are in close proximity to seagrass may have observed more species due to the influence of edge effects. Studies that examine edge effects in seagrass beds have been shown to have higher abundances of species along the edge of seagrass habitats compared to the center of the grass beds (Smith et al., 2008); however, this could also be influenced by the types of species seen along the edges. For example, Smith et al. (2011) found that predatory fish species were observed near the edges of seagrass beds; whereas the prey fishes were seen toward the center of the bed. Additionally, the presence of bait on the BRUV unit, representing a novel food source in the grass beds, which could have likely influenced the location, abundances, and type of species that were observed, regardless of edge effects (Whitmarsh et al., 2014).

The presence of seagrass had a strong influence on the number of species and their abundances given that we observed a greater number of species when seagrass was present (Figure 9). Grimmel et al. 2020 observed that when seagrass coverage was 0% they documented the lowest species diversity and when seagrass cover was 65% or higher, they reported the highest species observed during the study. The ANOSIM-BIOENV comparison of environmental parameters relative to seagrass presence and species occurrence showed no significant results ($R = -0.0137$, p-value = 0.617). This result suggested that all environmental parameters together were not the sole influence for the presence of species and suggested that there are other factors resulting in the recruitment of species to the BRUV units, such as habitat differences. Habitat has been shown to influence species richness, as well as organismal abundances (Dorman et al., 2012). Although environmental parameters did not predict the presence of species in seagrass, there are other factors that could be impacting these results, such as the status of seagrass. The seagrass growth in Tampa Bay fluctuates seasonally between the wet and dry seasons (TBEP, 2006), likely influencing species observations. Given that the highest productivity occurs in the wet season, there is a greater abundance of species and individuals, creating a larger, more diverse food web, as evident in the present study as more species were observed in the wet season and in seagrass (Figure 9 and 10). For example, syngnathid fishes residing in Tampa Bay seagrass beds have been shown to be most abundant during the wet season (Masonjones et al., 2010).

Habitat plays a role in the range of functional diversity present in each ecosystem because each species can only fill the specific niches available in that particular environment. We found the presence of seagrass in the shallows revealed greater functional group richness than the mid or deep locations (Figure 4). The only functional group that was observed more when seagrass is

absent were detritivores. Detritivores have been found in benthic environments mainly characterized by sediment or sand both in this study and previous BRUV studies (Vetter, 1998). The most observed functional group was omnivores (10 species), given that many of these species are able to utilize seagrass beds as a feeding ground, but also capable of forging and obtaining other means of gaining energy, such as the bait from the BRUV unit or alternative habitats. The functional group richness of omnivores was heavily influenced by one species, Hardhead Catfish (*Ariopsis felis). A. felis* were the most observed species by BRUV unit deployment and were seen during 35 of the 37 (94%) deployments with seagrass present (Figure 11). When examining the functional group richness by treatment (Figure 6), more of a gradient was observed, and shallow replicated exhibited the highest richness. The shallow treatment was characterized by seagrass presence, close proximity to seagrass, and increased light availability which promoted photosynthesis and seagrass growth, all of which likely led to a greater number of functional groups, especially omnivores and carnivores. The mid and deep treatment are characterized by seagrass absence, further distance from seagrass, and less light availability, where detritivores were more abundant and no herbivores were found. Similarly, Scott et al. (2022) found that shallow habitats are characterized by different species and a wider range of functional groups when compared with deeper habitats that have fewer functional groups but were dominated by piscivores and invertivores. Habitat type and depth strongly influenced the functional group abundances in coral reef, estuarine, and seagrass (Grimmel et al., 2020; Reis-Filho et al., 2019; Rolim et al., 2022).

Life history traits of organisms play a large role in where they are observed relative to distance from shore, depth profiles, and seasonally. *A. felis* were the most observed species seen equally across sites regardless of seagrass presence (Figure 11). This is likely due to the fact that

this species is reported to be behave as a generalists, omnivores, opportunistic feeders, and mouth brooders (Thomas & Betancur 2020; Pensinger et al., 2021; Olsen & McCulloch 2024; Jones et al., 1978). *A. felis* have been shown to not be limited to one habitat versus another in their geographic range based on their feeding and breeding traits. The stingrays and planktivores that were observed have a different set of life history traits that can limit where they are found. Southern Stingrays (*Hypanus americanus*) were observed on 23 of the 133 (7 in seagrass and 16 with no seagrass) BRUV deployments and found more in non-seagrass replicates than in seagrass (Figure 11); this is likely due to their ability to burry themselves in sand as a form predator avoidance. *H. americanus* are found in sandflats near seagrass beds and utilize this habitat for foraging (carnivorous) and giving birth (ovoviviparous) (Carlson et al., 2020; Flowers et al., 2021). These are just a few of the life history traits of the species observed in this study that may influence where species were observed.

Interactions

Overall, we observed a greater number of interaction occurrences in the wet (n = 364) than the dry season (n = 215, Table 12), which also coincides with when the greatest number of species are observed (Figure 10). The number of interactions observed across the three depth profiles paralleled the number of successful BRUV replications that were conducted within each depth treatment. The interactions were highly biased towards the shallows with 84% occurring near shore while only 12% occurred in the mid depth and 4% within the deepest depth profile. Replications that occurred within seagrass had more interactions (57%) compared with the non-seagrass locations (43%).

Competition and shoaling were the most often observed behavioral interactions in the present study (Table 11), which were highly influenced by presence of seagrass and the

composition of the organisms involved in the interaction, being either conspecifics or more than one species together. One of the reasons we could have observed more heterospecific interactions, regardless of seagrass status, for longer durations could be due to the functional group composition. For example, there could be multiple Hardhead Catfish (*A. felis*, omnivore) and multiple Sliver Jennys (*Eucinostomus gula,* carnivore) shoaling together or even a slower moving Spider Crab (*Libinia emarginata*), detritivore) and Southern Pufferfish (*Sphoeroides nephelus*, omnivore) competing for the same source, the bait bag. Given that *A. felis* were the most observed species (Figure 11) known to occur in large abundances (Flinn et al., 2019), this species could have influenced many of the conspecific occurrences that were observed in greater numbers but for shorter durations. Given the greater number of organisms observed during the wet season, the results that competition was observed more during this season were to be expected given the high level of productivity in the ecosystem and tropic web during those months. Competition also occurred less often in seagrasses during the study, with more competition was observed with species utilizing the bait resource when seagrass was absent (n = 50), likely due to fewer resources available in a barren habitat.

Being able to analyze and attract species to the BRUV units in a natural environment allows researchers to document how animals behave and interact with one another without bringing them into a lab setting. Generating behavioral trials in a laboratory setting can often cause organisms to behave differently than if they were to be out in their natural environments (Calisi & Bentley, 2009). BRUVs are a useful tool to identify fish assemblages, however the presence of bait could have biased the behavior and occurrence of individuals. The bait plumes that disperse in the water column from varying currents, wind, and turbidity can alter observations (Taylor et al., 2013). Certain baiting methods attract more carnivorous fish to the

BRUV units (Coghlan et al., 2017), which is consistent with this study as the most observed functional group was carnivores (n = 22) (Table 5). Other studies have examined habitat-specific behaviors and whether behavioral interactions took place between the same species (intraspecific interactions between conspecifics) or different species (interspecific behaviors with heterospecifics) (Sabando et al. 2020). Nocturnal and low light deployments have been performed to analyze active organisms during the evening (O'Brien et al., 2021); however these types of deployments need a light source and have been shown to alter the behaviors of those particular species (Fitzpatrick et al., 2013). Having a light source on BRUV units can alter species presence this generates a new type of bait because zooplankton are attracted to light which can draw in other types of predators (Becker et al., 2013) and planktivorous fish (O'Brien et al., 2021). Light is not the only aspect of the BRUV unit design that can alter species, but the presence and type of bait used can influence species attracted to the unit and influence the species richness depending on the amount and contents of the bait (Jones et al, 2020; Dorman et al., 2012). A new resource being introduced into the ecosystem can alternate trophic level abundances which alter the interactions observed. Bait can bring in many opportunistic feeders, like *A. felis* observed in this study, causing large aggregations that can deter smaller species or other predators from approaching, resulting in a diluting effect (Lehtonen & Jaatinen, 2016). A previous study compared different baited types across several European locations in the Northern Atlantic Ocean and determined that the baited BRUV units attracted more fish assemblages compared to the non-baited units and that mackerel and squid were superior bait for attracting scavenger species (Jones et al., 2020).

One of the reasons for choosing our survey site was due to its' proximity to anthropogenic activities, allowing us to document how the different disturbances in the

environment could potentially impact organismal observations. This study measured many environmental variables, but one that was not measured was boat noise in the region. The study site is located near a marina, and there is a boat channel that runs directly through the mid and deep depth sites (Figure 2). Boat noise, especially in shallower waters, can alter species' behaviors (Shrivastava et al., 2014). Although acoustics and boat traffic were not recorded in the study, the footage from the BRUV units did record acoustics that could be analyzed in the future. Measuring acoustics to determine the intensity and rates of disturbances could provide a better understanding of the effects of anthropogenic impacts on species interactions and abundances.

Future Directions

To determine the effectiveness of BRUV methodology, a combination of field survey techniques have been compared to identify the benefits and challenges of these when used in similar habitats to measure species diversity (Whitmarsh et al., 2017). Comparative studies have investigated the results from BRUV surveys with remote operated vehicles (ROV) (Schramm et al., 2020; Jessop et al., 2022), baited vs. unbaited units (Harvey et al., 2012), and invasive trawling techniques (Cappo et al., 2004). Many of the comparison studies have found pros and cons to the methods depending on the complexity of the habitat and approach in how they record footage.

This study observed a wide spectrum of species across functional groups with variation in habitat composition. The cameras used in the present study only captured a 180-degree view or less, which limited our ability to track individuals and led to the use of MaxN instead of total abundances. Other studies have configured different BRUV set ups to account for a broader views. Stereo-BRUV units consist of two cameras mounted on a unit that record in parallel at the same time to allow for a wider field of view, ability to measure fish sizes, and distances (Cundy

et al., 2017). Stereo-BRUV units are typically arranged in a way that they converge in frame to make sure the same organism to being observed in both cameras (Langlois et al. 2020) and can assist researchers by measuring the sizes of individuals that are more difficult to observe, especially in turbid waters. Instead of identification of an organism down to the family which often occurred in this study (Table 5), future work utilizing Stereo BRUV units could narrow down organismal measurements require for species identification. On-going studies are being conducted in our study site using our same BRUV design with a T-bar attachment to assist with organismal measurements. Although this T-bar method was cost effective, this has resulted in limited capabilities for obtaining accurate measurements (unpublished data, Mason). Another way in which BRUV units are configured is using a 360-degree camera which can observe all the individuals that are near the BRUV unit so video analysis does not require MaxN to be assessed. 360-degree BRUV units can also be utilized in hydrodynamic environments because if they flip or fall over, they can still record the environment without changing the frame of view, therefore allowing for a better representation of the ecosystem, especially in complex habitats like rocky reefs (Gomes et al., 2024).

Comparison to Fisheries Surveys

The combination of data obtained using BRUV units, along with results from traditional fishery survey methods can provide a more robust interpretation of species distributions and diversity. Flaherty-Walia et al. (2023) compared BRUV surveys to seine netting in Florida marine ecosystems and found that both methods captured similar species richness, diversity, and abundance. Given that seine nets are not easily utilized in deeper waters or across a complex benthic habitats, the introduction of BRUV units provides a unique opportunity to observe species in these habitats. Many agencies in the`Tampa Bay area, such as Florida Fish and

Wildlife Commission (FWC) and the Fisheries Independent Monitoring (FIM) program, perform regular sampling in seagrass beds throughout the bay to identify species diversity within the ecosystem and the health and abundance of the seagrass. In the future, we would compare fisheries survey data to the results of our study to understand species composition, especially the seagrass deployments in Tampa Bay.

Interactions between species and individuals in BRUVs are understudied across a variety of ecosystems (Whitmarsh 2017). Examining the interactions that occurred in this study further, such as the combinations of which species were involved across the different depth and seagrass habitats and which anthropogenic impacts could be influencing them, will allow for a more complete understanding and assessment of this ecosystem. The current analysis identified 7 interactions (Table 11) and their distribution across season, seagrass presence, and depth (Table 12) but interpreting which of these interactions were a result of interspecies (IE), intraspecies (IA), and inter- and intraspecies (IB) as described in Table 1 will provide a more thorough explanation of these behaviors. This study was the first of its kind in Tampa Bay to examine organismal interactions overall in seagrass ecosystems without species specific targeting.

Final Conclusions

Overall, this study successfully deployed BRUV units in an estuarine environment in Tampa Bay across varying depth profiles and distance from seagrass to understand species diversity and organismal interactions. We observed that environmental parameters vary across season (Table 4) but not across seagrass status (Figure 3). Results indicated more species were observed during the wet season and in seagrass beds than non-seagrass habitats (Figure 9). Functional group composition was successfully measured by depth treatments (categorical measurement of distance from seagrass) and seagrass presence (Figure 4 and 6) demonstrating

there is variation in habitat usages for the diverse functional roles of species that were observed. Competition and shoaling were the most observed interactions with season, treatment, seagrass status, and species composition contributing to the variability in duration and occurrence (Figure 12). With long term monitoring, utilizing our method and study site set up, Tampa Bay seagrass ecosystems can have more robust documentation of fluctuations in species diversity, habitat composition, and variation in water quality conditions. Utilization of BRUV units can lead to more cohesive conservation management plans for species that rely on seagrass beds, resulting from BRUV technology that can be effectively used to monitor their status in long-term studies.

REFERENCES

Andradi-Brown, D. A., Gress, E., Wright, G., Exton, D. A., & Rogers, A. D. (2016). Reef fish community biomass and trophic structure changes across shallow to upper-mesophotic reefs in the Mesoamerican Barrier Reef, Caribbean. *PLoS One*, *11*(6), e0156641.

Cappo, M., Speare, P., & De'ath, G. (2004). Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park. *Journal of Experimental Marine Biology and Ecology*, *302*(2), 123–152.

Cappo, M., Stowar, M., Syms, C., Johansson, C., & Cooper, T. (2011). Fish-habitat associations in the region offshore from James Price Point: a rapid assessment using baited remote underwater video stations (BRUVS). *Journal of the Royal Society of Western Australia*, *94*, 303–321.

Carlson, J., Charvet, P., Blanco-Parra, MP, Briones Bell-lloch, A., Cardenosa, D., Derrick, D., Espinoza, E., Morales-Saldaña, J.M., Naranjo-Elizondo, B., Pacoureau, N., Schneider, E.V.C., Simpson, N.J., Pollom, R. & Dulvy, N.K. 2020. Hypanus americanus. The IUCN Red List of Threatened Species 2020: e.T181244884A104123787. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T181244884A104123787.en

Carpenter, S., Byfield, V., Felgate, S. L., Price, D. M., Andrade, V., Cobb, E., Strong, J., Lichtschlag, A., Brittain, H., Barry, C., & Fitch, A. (2022). Using unoccupied

aerial vehicles (UAVs) to map seagrass cover from Sentinel-2 imagery. *Remote Sensing*, *14*(3), 477.

Chand, S., & Bollard, B. (2021). Detecting the spatial variability of seagrass meadows and their consequences on associated macrofauna benthic activity using novel drone technology. *Remote Sensing*, *14*(1), 160.

Connolly, R. M. (1994). Comparison of fish catches from a buoyant pop net and a beach seine net in a shallow seagrass habitat. *Marine Ecology Progress Series*, *109*, 305–309.

Cullen-Unsworth, L. C., Jones, B. L., Lilley, R., & Unsworth, R. K. (2018). Secret gardens under the sea: What are seagrass meadows and why are they important? *Frontiers for Young Minds*, *6*(2).

Dorman, S. R., Harvey, E. S., & Newman, S. J. (2012). Bait effects in sampling coral reef fish assemblages with stereo-BRUVs.

Duffy, J. E. (2006). Biodiversity and the functioning of seagrass ecosystems. *Marine Ecology Progress Series*, *311*, 233–250.

Duffy, J. P., Pratt, L., Anderson, K., Land, P. E., & Shutler, J. D. (2018). Spatial assessment of intertidal seagrass meadows using optical imaging systems and a lightweight drone. *Estuarine, Coastal and Shelf Science*, *200*, 169–180.

Ellis, D. M., & DeMartini, E. E. (1995). Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. *Oceanographic Literature Review*, *9*(42), 786.

Ferguson, M. C., Angliss, R. P., Kennedy, A., Lynch, B., Willoughby, A., Helker, V., Brower, A. A., & Clarke, J. T. (2018). Performance of manned and unmanned aerial surveys to collect visual data and imagery for estimating arctic cetacean density and associated uncertainty. *Journal of Unmanned Vehicle Systems*, *6*(3), 128–154.

Flaherty-Walia, K. E., Gervasi, C. L., Davis, J. P., Trabelsi, S., Fratto, Z., Santos, R. O., & Rehage, J. S. (2023). Seines and baited remote underwater video document consistent spatiotemporal patterns in nekton communities of subtropical coastal habitats. *Marine Ecology Progress Series*, *722*, 37-64.

Flinn, S., Midway, S., & Ostrowski, A. (2019). Age and growth of hardhead catfish and gafftopsail catfish in coastal Louisiana, USA. *Marine and Coastal Fisheries*, *11*(5), 362-371.

Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute. (2019). *Seagrass Habitat in Florida* [Data set]. https://geodata.myfwc.com/datasets/myfwc::seagrass-habitat-in-florida/about

Flowers, K. I., Heithaus, M. R., & Papastamatiou, Y. P. (2021). Buried in the sand: Uncovering the ecological roles and importance of rays. *Fish and Fisheries*, *22*(1), 105-127.

García-Rodríguez, E., Vivas, M., Torres, M. Á., Esteban, A., & Bellido, J. M. (2020). Revealing environmental forcing in the different trophic guilds of fish communities off the Western Mediterranean Sea. *Journal of Sea Research*, *166*, 101958.

Gomes, M. A., Alves, C. M., Faria, F., Neto, R., Fernandes, E., Troncoso, J. S., & Gomes, P. T. (2024). Unleashing the Potential of the 360° Baited Remote Underwater Video System (BRUVS): An Innovative Design for Complex Habitats. *Journal of Marine Science and Engineering*, *12*(8), 1346. https://doi.org/10.3390/jmse12081346

Greening, H., Janicki, A., & Sherwood, E. T. (2018). Seagrass recovery in Tampa Bay, Florida (USA). In *The Wetland Book: II: Distribution, Description, and Conservation* (pp. 495–506). Springer.

Greve, T. M., & Binzer, T. (2004). Which factors regulate seagrass growth and distribution. *European Seagrasses: An Introduction to Monitoring and Management*, *19*.

Grimmel, H. M., Bullock, R. W., Dedman, S. L., Guttridge, T. L., & Bond, M. E. (2020). Assessment of faunal communities and habitat use within a shallow water system using non-invasive BRUVs methodology. *Aquaculture and Fisheries*, *5*(5), 224–233.

Hayes, M. A., McClure, E. C., York, P. H., Jinks, K. I., Rasheed, M. A., Sheaves, M., & Connolly, R. M. (2020). The differential importance of deep and shallow seagrass to nekton assemblages of the great barrier reef. *Diversity*, *12*(8), 292.

Jänes, H., Carnell, P., Young, M., Ierodiaconou, D., Jenkins, G. P., Hamer, P., Zu Ermgassen, P. S., Gair, J. R., & Macreadie, P. I. (2021). Seagrass valuation from fish abundance, biomass and recreational catch. *Ecological Indicators*, *130*, 108097.

Jones, R. E., Griffin, R. A., Herbert, R. J., & Unsworth, R. K. (2021). Consistency is critical for the effective use of baited remote video. *Oceans*, *2*(1), 215–232.

Jones, R. E., Griffin, R. A., Januchowski-Hartley, S. R., & Unsworth, R. K. (2020). The influence of bait on remote underwater video observations in shallow-water coastal environments associated with the North-Eastern Atlantic. *PeerJ*, *8*, e9744.

Jones III, E. L., Heinl, S., & Pahlke, K. (2007). Aerial counts. In *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations* (pp. 399–410).

Jones, P. W., Martin, F. D., & Hardy Jr, J. D. (1978). Development of fishes of the Mid-Atlantic Bight. An atlas of egg, larval and juvenile stages: I. Acipenseridae through Ictaluridae. *Biological Services Program*.

Kells, V. A., & Carpenter, K. E. (2011). *A field guide to coastal fishes: From Maine to Texas*. Johns Hopkins University Press.

Kiggins, R. S., Knott, N. A., & Davis, A. R. (2018). Miniature baited remote underwater video (mini-BRUV) reveals the response of cryptic fishes to seagrass cover. *Environmental Biology of Fishes*, *101*(12), 1717–1722.

Komatsu, T., Hashim, M., Nurdin, N., Noiraksar, T., Prathep, A., Stankovic, M., Phuoc, T., Son, H., Thu, M., Van Luong, C., & Wouthyzen, S. (2020). Practical mapping methods of seagrass beds by satellite remote sensing and ground truthing. *Coastal Marine Science*, *43*(1), 1–25.

Kunz, A., Freedman, R., Morten, J., & Hastings, S. (2025). Aerial monitoring of endangered whales in the Santa Barbara Channel to enhance and inform whale conservation. *Western North American Naturalist*, *85*(2), 185–192.

Langtimm, C. A., Dorazio, R. M., Stith, B. M., & Doyle, T. J. (2011). New aerial survey and hierarchical model to estimate manatee abundance. *The Journal of Wildlife Management*, *75*(2), 399–412.

Lehtonen, J., & Jaatinen, K. (2016). Safety in numbers: the dilution effect and other drivers of group life in the face of danger. *Behavioral Ecology and Sociobiology*, *70*(4), 449-458.

Levine, J. M., & HilleRisLambers, J. (2009). The importance of niches for the maintenance of species diversity. *Nature*, *461*(7261), 254-257.

Lewis III, F. G., & Stoner, A. W. (1981). An examination of methods for sampling macrobenthos in seagrass meadows. *Bulletin of Marine Science*, *31*(1), 116–124.

Lilley, R. J., & Unsworth, R. K. F. (2014). Atlantic Cod (*Gadus morhua*) benefits from the availability of seagrass (*Zostera marina*) nursery habitat. *Global Ecology and Conservation*, *2*, 367–377.

Livingston, R. J. (1982). Trophic organization of fishes in a coastal seagrass system. *Marine Ecology Progress Series*, *7*, 1–12.

Ljungblad, D. K., Moore, S. E., Van Schoik, D. R., & Winchell, C. S. (1982). *Aerial surveys of endangered whales in the Beaufort, Chukchi & Northern Bering Seas* (No. NOSCTD486).

Masonjones, H. D., Rose, E., McRAE, L. B., & Dixson, D. L. (2010). An examination of the population dynamics of syngnathid fishes within Tampa Bay, Florida, USA. *Current Zoology*, *56*(1), 118-133.

McHenry, J., Rassweiler, A., Hernan, G., Uejio, C. K., Pau, S., Dubel, A. K., & Lester, S. E. (2021). Modelling the biodiversity enhancement value of seagrass beds. *Diversity and Distributions*, *27*(11), 2036–2049.

McLean, D. L., Green, M., Harvey, E. S., Williams, A., Daley, R., & Graham, K. J. (2015). Comparison of baited longlines and baited underwater cameras for assessing the composition of continental slope deepwater fish assemblages off southeast Australia. *Deep Sea Research Part I: Oceanographic Research Papers*, *98*, 10-20.

Meehan, A. J., Williams, R. J., & Watford, F. A. (2005). Detecting trends in seagrass abundance using aerial photograph interpretation: problems arising with the evolution of mapping methods. *Estuaries*, *28*(3), 462–472.

Meyer, D. L., Fonseca, M. S., Murphey, P. L., McMichael Jr, R. H., Byerly, M. M., LaCroix, M. W., Whitfield, P. E., & Thayer, G. W. (1999). Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. *Fishery Bulletin*, *97*(1), 193–199.

Neckles, H. A., Kopp, B. S., Peterson, B. J., & Pooler, P. S. (2012). Integrating scales of seagrass monitoring to meet conservation needs. *Estuaries and Coasts*, *35*(1), 23–46.

O'Brien, D. A., Masonjones, H. D., Bethel, E., & O'Shea, O. R. (2021). Nocturnal surveys reveal novel insights into the community dynamics of an anchialine ecosystem from The Bahamas. *Estuarine, Coastal and Shelf Science*, *262*, 107588.

O'Byrne, M., Schoefs, F., Pakrashi, V., & Ghosh, B. (2018). An underwater lighting and turbidity image repository for analysing the performance of image-based non-destructive techniques. *Structure and Infrastructure Engineering*, *14*(1), 104–123.

Olsen, Z., & McCulloch, J. (2024). Trends and distribution of hardhead catfish in Texas estuaries—shifting relative abundance of a highly ubiquitous generalist predator. *Environmental Biology of Fishes*, *107*(9), 1017–1043.

Palanques, A., Guillén, J., & Puig, P. (2001). Impact of bottom trawling on water turbidity and muddy sediment of an unfished continental shelf. *Limnology and Oceanography*, *46*(5), 1100–1110.

Pensinger, L. G., Brown-Peterson, N. J., Green, C. C., & Midway, S. R. (2021). Reproductive biology of hardhead catfish *Ariopsis felis*: evidence for overwintering oocytes. *Journal of Fish Biology*, *99*(2), 308–320.

Petchey, O. L., & Gaston, K. J. (2006). Functional diversity: back to basics and looking forward. *Ecology Letters*, *9*(6), 741–758.

Phenix, L. M., Tricarico, D., Quintero, E., Bond, M. E., Brandl, S. J., & Gallagher, A. J. (2019). Evaluating the effects of large marine predators on mobile prey behavior across subtropical reef ecosystems. *Ecology and Evolution*, *9*(24), 13740–13751.

Price, D. M., Felgate, S. L., Huvenne, V. A., Strong, J., Carpenter, S., Barry, C., Lichtschlag, A., Sanders, R., Carrias, A., Young, A., & Andrade, V. (2022). Quantifying the intra-habitat variation of seagrass beds with unoccupied aerial vehicles (UAVs). *Remote Sensing*, *14*(3), 480.

Raulerson, G. E., Robison, D. E., Beck, M. W., Burke, M. C., Ries, T. F., Saarinen, J. A., Sciarrino, C. M., Sherwood, E. T., & Tomasko, D. A. (2020). Seizing diminishing habitat conservation and restoration opportunities in the Tampa Bay, FL watershed: An urban estuary in recovery. *BioRxiv*.

Reis-Filho, J. A., Schmid, K., Harvey, E. S., & Giarrizzo, T. (2019). Coastal fish assemblages reflect marine habitat connectivity and ontogenetic shifts in an

estuary-bay-continental shelf gradient. *Marine environmental research*, *148*, 57-66.

Reynolds, P. L., Duffy, E., & Knowlton, N. (2018). Seagrass and seagrass beds. *Ocean Portal*, *16*(10).

Rolim, F. A., Langlois, T., Motta, F. D. S., Castro, G. M. D., Lester, E., Abieri, M. L., ... & Moura, R. L. D. (2022). Habitat and marine reserve status drive reef fish biomass and functional diversity in the largest south Atlantic coral reef system (Abrolhos, Brazil). *Frontiers in Marine Science*, *9*, 701244.

Scott, M. E., Tebbett, S. B., Whitman, K. L., Thompson, C. A., Mancini, F. B., Heupel, M. R., & Pratchett, M. S. (2022). Variation in abundance, diversity and composition of coral reef fishes with increasing depth at a submerged shoal in the northern Great Barrier Reef. *Reviews in Fish Biology and Fisheries*, *32*(3), 941-962.

Sherwood, E., & Kaufman, K. (2016). Summary report for the Tampa Bay region. In L. Yarbro & P. R. Carlson Jr. (Eds.), *Seagrass Integrated Mapping and Monitoring Report No. 1.1* (pp. xx–xx) (Fish and Wildlife Research Institute Technical Report TR-17, version 2.0). Florida Fish and Wildlife Conservation Commission.

Shrivastava, V., Lende, S. R., Mahida, P. J., Yusufzai, S. I., & Jha, A. K. (2014). An Introduction to Underwater Video Technique: Scope, Constraints and Future Prospects. *INDIAN FARMER*, 140.

Smith, T. M., Hindell, J. S., Jenkins, G. P., & Connolly, R. M. (2008). Edge effects on fish associated with seagrass and sand patches. *Marine Ecology Progress Series*, *359*, 203–213.

Smith, T. M., Hindell, J. S., Jenkins, G. P., Connolly, R. M., & Keough, M. J. (2011). Edge effects in patchy seagrass landscapes: the role of predation in determining fish distribution. *Journal of Experimental Marine Biology and Ecology*, *399*(1), 8–16.

Stiles, M. L., Stockbridge, J., Lande, M., & Hirshfield, M. F. (2010). *Impacts of bottom trawling*. Oceana.

Tampa Bay Estuary Program. (2006). *Charting the course: the comprehensive conservation and management plan for Tampa Bay*. Tampa Bay Estuary Program.

Tampa Bay Estuary Program. (2020). *Habitat Master Plan Update*.

Taylor, M. D., Baker, J., & Suthers, I. M. (2013). Tidal currents, sampling effort and baited remote underwater video (BRUV) surveys: are we drawing the right conclusions?. *Fisheries Research*, *140*, 96-104.

Thomas, M. R., & Betancur-R, R. (2020). Ariidae: Sea Catfishes. In *Freshwater Fishes of North America: Volume 2: Characidae to Poeciliidae* (p. 101).

Unsworth, R. F. K., & Cullen-Unsworth, L. C. (2014). Biodiversity, ecosystem services, and the conservation of seagrass meadows. *Coastal Conservation*, *19*, 95.

Unsworth, R. K., & Cullen-Unsworth, L. C. (2017). Seagrass meadows. *Current Biology*, *27*(11), R443–R445.

Vandermeer, J. H. (1972). Niche theory. *Annual review of Ecology and Systematics*, 107-132.

Vetter, E. W. (1998). Population dynamics of a dense assemblage of marine detritivores. *Journal of Experimental Marine Biology and Ecology*, *226*(1), 131-161.

Vettori, D., & Marjoribanks, T. I. (2021). Temporal variability and within-plant heterogeneity in blade biomechanics regulate flow-seagrass interactions of Zostera marina. *Water Resources Research*, *57*(3), e2020WR027747.

Watson, D. L., Harvey, E. S., Fitzpatrick, B. M., Langlois, T. J., & Shedrawi, G. (2010). Assessing reef fish assemblage structure: how do different stereo-video techniques compare? *Marine Biology*, *157*(6), 1237–1250.

Whitmarsh, S. K., Fairweather, P. G., Brock, D. J., & Miller, D. (2014). Nektonic assemblages determined from baited underwater video in protected versus unprotected shallow seagrass meadows on Kangaroo Island, South Australia. *Marine Ecology Progress Series*, *503*, 205–218. https://doi.org/10.3354/meps10733

Whitmarsh, S. K., Fairweather, P. G., & Huveneers, C. (2017). What is Big BRUVver up to? Methods and uses of baited underwater video. *Reviews in Fish Biology and Fisheries*, *27*, 53–73.

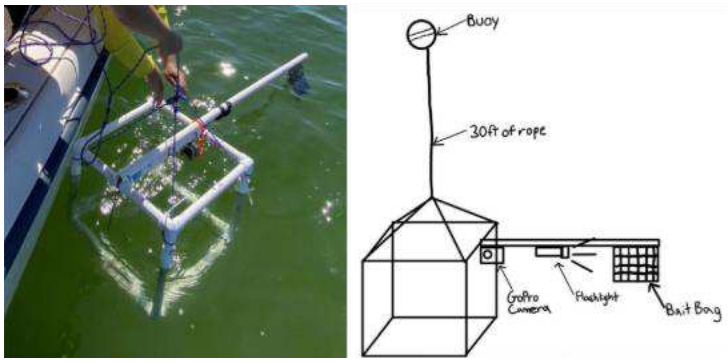
Zaima, L. (2014). *Commercial Shrimp Trawling: the profit does not out weigh the damaging effects on rest of the ecosystem*.

APPENDIX A:

BRUV Unit Materials and Construction

How to build a Baited Remote Underwater Video (BRUV) unit

Designed by: Dr. Heather Mason, William Love, Ben Share, and Georgia Ambrose from The University of Tampa



Materials for 1 BRUV unit

- 1 inch PVC (Total 25 ft) (get extra)
  - 20-inch segments (11 total)
  - 10-inch segments (4 total)
  - 60-inch segment (1 total)
- 1 inch PVC Elbow Joints (8 total)
- 1 inch PVC T-Joints (2 total)
- 1 Pack of Heavy Duty Zip Ties (Need at least 10 total)
- ½ inch Nylon rope (50 ft, depends on deployment depth)
- 1 Bag of Concrete
- 1 Role of Black Plastic Hardware Netting
- 1- 8oz Oatey PVC Purple Primer
- 1- 8oz Oatey PVC Cement
- 1 GoPro Camera and the waterproof housing
- 1 GoPro Pole Attachment
- 1 Small Floating Buoy
- 1 Dive Flashlight (optional)

Materials Needed for Construction

- PVC pipe cutter
- Scissors (to cut rope)
- 5 – gallon bucket for mixing cement
- Tarp (for mess)
- Funnel (to pour cement)
- ¼ inch Drill bit

- Handheld Drill

Steps for Main Body of BRUV Unit

1. Take the 1-inch PVC and cut it into the segments listed above in the materials (10 – 20-inch segments, 4 – 10-inch segments, and 1 – 60 inch segment)
2. Once the segments are cut grab 4, 20-inch segments and 4 Elbow Joints. With these pieces you will place the segments on the ground in a square shape and place 1 Elbow joint at each of the 4 corners of the square you laid out.
3. Now to connect the 4 - 20-inch segments and the 4 elbow joints, first use the Oatey PVC primer and put primer on the first 1 inch of the 20 –inch PVC on the outside and primer on the inside of the inside 1 corner of the elbow joint and then do the same thing with the Oatey PVC cement and connect the segments (you should now have a square with 4 opens at the top of each corner)
4. Next, grab 4 – 20 inch PVC segments and the square you previously made. Put PVC primer in each of the 4-corner openings in the top of the square made previously. Then, put primer and then cement on the outside of the 1 – 20-inch segment and place into 1 of openings in the square previously made and repeat for the other 3 – 20-inch segments. (you should now have a square with 4 PVC segments straight up or upside-down table)
5. Take a 5-gallon bucket and mix up the concrete to be poured into the bottom section of the BRUV unit.
6. Once the concrete is mixed, take a funnel and pour the concrete into the top of the 4 PVC "legs" until full.
7. Let the cement dry and cure.
8. While the concrete is curing in the bottom section of the BRUV, the next step is to build the top.
9. To build the top section, take 2 10-inch segments, 2 elbow joints, and 1 T-joint. Prime and cement the 2 10-inch segments and connect to the T- joint. At the end of this new segment PVC prime and PVC cement each of the elbow joints and connect them to the new segment. (Make sure the corner opening are in line (parallel) with each other)
10. Repeat step 9 to create the same segment (2 total: 10 and 10 inch segments connected with a T-joints and 2 elbow joints on each end)
11. Next, take the 2 segments you made in the previous step and lay them on the ground with the T-joint openings facing each other.
12. Take 3 20-inch segments of PVC, PVC prime and cement 3 parallel openings of the 1 T-joint and PVC prime and cement one end of each of the 3 20-inch segments and place in the 3 openings. (You should have an "E" shape)
13. Next, take the second T-joint segment and connect it to the "E" shape segment. PVC prime and cement the second T-joint segment and PVC prime and cement the 3 ends of the "E" shape segment. (You should now have a square with 2 sections and 4 corner openings all facing up.

14. Take the top square and PVC prime and cement the 4 corner openings and connect to the top PVC section with the cured concrete to create a cube.
15. Next, with the drill, drill 2 holes straight though the PVC in the top part of the cube (the part with not concrete) This is for air to escape the PVC in order for the BRUV to sink to the benthos.
16. Next, take the 1 60 inch PVC segment and lay it parallel directly on top of the T-joints section of the BRUV unit. 20 inches of the 60-inch section will line up with the BRUV cube section, and the other 40 inches will be protruding from the cube, acting as the arm for the bait bag.
17. Attach the 60-inch segment with 2 zip ties around the 1 T-joint section (long arm) around both the 60-inch segment and the T-joint creating an "X" pattern on the top with 2 zip tips or as many as needed
18. On the other end of the 60-inch segment that is in line with the cube drill a hole through both sides and will line up parallel with the T- joint section. Put aa ziptie through this hole and connect it the middle T-joint section of the BRUV cube.
19. Drill a hole all the way through the other end of the 60-inch PVC (this is where the bait bag will be attached via and zip tie)

Bait Bag and GoPro Attachment

Bait Bag

1. Take the Black Plastic Hardware Netting and cut a piece (8 x 12 inches)
2. Fold the netting, 8-inch end to 8-inch end
3. Fold the netting so there is 1-inch of access netting (so there is a flap)
4. Zip tie the 2 sides together (As many zip tie as needed) (Now, you will have and bag with an opening in the top)

GoPro Attachment

1. Attach the pole GoPro attachment to the cube off set from the T-joint segment of the BRUV cube (long arm section) (refer to photo above)
2. Attach the GoPro with housing right before deployment

Rope

1. Tie nylon rope around the top 4 corner of the BRUV units (make each rope section 24 inches long)
2. Create loops at the end of each of the sections and connect together in the middle, like a pyramid
3. Next, cut a long section of rope (depends on BRUV deployment depth (3 to 30 ft) and tie this section together with the 4 loops at the top of the pyramid of rope sections.
4. Finally, at the other end of the rope attach the floating buoy (this is so you can spot the BRUV at the surface of the water for retrieving)

APPENDIX B:

Functional Group Distinctions

Trophic Level Distinctions:

Not in successful deployments

Trophic Level	Organisms
Carnivore	• Atlantic Stingray (*Dasyatis sabina*) (Florida Musuem of Natural History, 2025) • Southern Stingray (*Hypanus americanus)* (Florida Musuem of Natural History, 2025) • Cownose Ray *(Rhinoptera bonasus)* (Florida Musuem of Natural History, 2025) • Florida Crown Conch *(Melongena corona)* (Florida Fish and Wildlife Conservation Commission, 2025) • Lighting Whelk (*Busycon perversum)* (Florida Fish and Wildlife Conservation Commission, 2025) • Pear Whelk (*Fulguropsis spirata*) (Vanderbilt Museum, 2020) • Lined Sea Star (*Luidia clathrate*) (Animal Diversity Web, 2002) • Gulf Flounder (*Paralichthys albiguttata*) (Smithsonian Tropical Research Institute, 2024) • Unknown Flounder Species (medium) (Smithsonian Tropical Research Institute, 2024) • Spiny Searobin *(Prionotus alatus)* (Kells and Carpenter, 2011) • Sand Perch (*Diplectrum formosum*) (Florida Museum of Natural History, 2025) • Bluntnose Jack (*Hemicaranx amblyrhynchus*) (Smithsonian Tropical Research Institute, 2024) • Gafftop Sail Catfish (*Bagre marinus*) (Rudershausen and Locascio, 2001) • Striped Burrfish (*Chilomycterus schoepfi*) (National Aquarium, 2025) • Bull Shark (Large Unknown Shark Species) (*Carcharhinus leucas*) (Florida Museum of Natural History, 2025) • Either Double-Crested or Anhinga (Order Suliformes) (Animal Diversity Web, 2025) • Sparidae sp. (Taieb et al., 2013) • Gerreidae sp. (Gning et al., 2008) • Silver Jenny (*Eucinostomus gula*) (Taieb et al., 2013) • Ladyfish *(Elops saurus)* (Florida Museum of Natural History, 2025) • Lettered Olive Snail *(Oliva sayana)* (Leal, 2018) • Nudibranch sp. (Florida Fish and Wildlife Conservation Commission, 2025) • Sharksucker (*Echeneis naucrates*) (Florida Museum of Natural History, 2025)
Herbivore	• Sea Hare sp. (unknown) (National Marine Sanctuary Foundation, 2020) • Green Sea Turtle *(Chelonia mydas)* (NOAA Fisheries, 2025) • Arrow shrimp *(Tozeuma carolinense)* (Cournoyer & Cohen, J ,2011) • West Indian Manatee (*Trichechus manatus*)(National Wildlife Federation, 2025)
Omnivore	• Hardhead Catfish (*Ariopsis felis)* (Osowski et al., 2023) • Southern Pufferfish *(Sphoeroides nephelus)* (Shipp & Yerger 1969) • Horseshoe Crab (*Limulus*) (Florida Fish and Wildlife Conservation Commission, 2025) • Pinfish (*Lagodon rhomboides)* (Allan, 1980) • Scrawled Cowfish (*Acanthostracion quadricornis*) (Mote Marine Laboratory and Aquarium, 2025)

	• Orange Filefish (*Aluterus schoepfii*) (Florida Museum of Natural History, 2025) • Unknown Filefish Species (Monacanthidae family) (Florida Museum of Natural History, 2025) • Tomtate (*Haemulon aurolineatum*) (Sedberry, 1985) • Haemulidae (Grunt sp. unknown) (Limeira et al., 2022) • Bonnethead Shark (*Sphyrna tiburo*) (Florida Muesum of Natural History, 2025) • Atlantic Spadefish (Chaetodipterus faber) (Florida Muesum of Natural History, 2025) • Sheepshead *(Archosargus probatocephalus)* (Florida Muesum of Natural History, 2025)
Planktivory	• Comb Jelly sp. (Ctenophora) (Aquarium of the Pacific, 2025) • Pipefish sp. (Smithsonian Tropical Research Institute, 2024) • Bait Fish Sp. (less than 1 ft) (Sealey et al. 1998) • Small Minnow type sp. (Sealey et al. 1998) • Atlantic Thread Herring (*Opisthonema oglinum*) (Finucane & Shaffer, 1986) • Scaled Sardine (*Harengula jaguana*) (Motta et al., 1995) • Clupeidae (Herring species) (Sealey et al., 1998) • Unknown Fish Species Grey (medium) (Clupediae sp. 1) (Sealey et al., 1998) • Unknown Fish Species 15 inches Sliver (Clupeidae sp. 2) (Sealey et al., 1998)
Detritivore	• Dwarf Hermit Crab (*Pagurus longicarpus*) (Whitman et al., 2001) • Large Hermit Crab (unknown) (Paguridae family) (Whitman et al., 2001) • Spider Crab (*Libinia emarginata*) (Chesapeake Bay Program, 2025) • Tube Building Amphipod (Moore & Eastman, 2015) • Blenny sp. (Wilson et al., 2009) • Snail Small (Heard & Lutz, 1982) • Unknown Small (>2cm) Snail (Heard & Lutz, 1982)
Unknown	Unknown

References for Functional Group Distinctions

Allan, W. (1980). Feeding ecology of *Lagodon rhomboides* (Pisces: Sparidae): variation and functional responses. *Fishery Bulletin*, *78*(2), 337.

Aquarium of the Pacific. (2025). *Comb Jelly (Sea Walnut)*. https://www.aquariumofpacific.org/onlinelearningcenter/species/comb_jelly

Chesapeake Bay Program. (2025). *Common spider crab: Libinia emarginata*. https://www.chesapeakebay.net/discover/field-guide/entry/common-spider-crab

Cournoyer, B. L., & Cohen, J. H. (2011). Cryptic coloration as a predator avoidance strategy in seagrass arrow shrimp colormorphs. *Journal of Experimental Marine Biology and Ecology*, *402*(1-2), 27-34.

Finucane, J. H., & Shaffer, R. N. (1986). *Species profile of Atlantic thread herring, Opisthonema oglinum* (Lesueur 1818).

Florida Fish and Wildlife Conservation Commission. (2025). *Facts About Horseshoe Crab and FAQ*. https://myfwc.com/research/saltwater/crustaceans/horseshoe-crabs/facts/

Florida Fish and Wildlife Conservation Commission. (2025). *Sea Snails*. https://myfwc.com/research/saltwater/mollusc/other-molluscs/sea-snails/

Florida Fish and Wildlife Conservation Commission. (2025). *Sea Slugs*. https://myfwc.com/research/saltwater/mollusc/other-molluscs/sea-slugs/

Florida Museum of Natural History. (2025). *Discover Fishes: Atlantic Spadefish*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/atlantic-spadefish/

Florida Museum of Natural History. (2025). *Discover Fishes: Atlantic Stingray*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/atlantic-stingray/

Florida Museum of Natural History. (2025). *Discover Fishes: Bonnethead*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/bonnethead/

Florida Museum of Natural History. (2025). *Discover Fishes: Bull Shark*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/bull-shark/

Florida Museum of Natural History. (2025). *Discover Fishes: Cownose Ray*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/cownose-ray/

Florida Museum of Natural History. (2025). *Discover Fishes: Lady Fish*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/ladyfish/

Florida Museum of Natural History. (2025). *Discover Fishes: Sand Perch*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/sand-perch/

Florida Museum of Natural History. (2025). *Discover Fishes: Sharksucker*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/sharksucker/

Florida Museum of Natural History. (2025). *Discover Fishes: Sheepshead*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/sheepshead/

Florida Museum of Natural History. (2025). *Discover Fishes: Southern Stingray*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/southern-stingray/

Gning, N., Vidy, G., & Thiaw, O. T. (2008). Feeding ecology and ontogenic diet shifts of juvenile fish species in an inverse estuary: The Sine-Saloum, Senegal. *Estuarine, Coastal and Shelf Science*, *76*(2), 395–403.

Heard, R. W., & Lutz, L. B. (1982). Guide to common tidal marsh invertebrates of the northeastern Gulf of Mexico.

Howard, L. (2003). *Pelecaniformes*. Animal Diversity Web. https://animaldiversity.org/accounts/Pelecaniformes/

Jud, Z. R., Layman, C. A., & Shenker, J. M. (2011). Diet of age-0 tarpon (*Megalops atlanticus*) in anthropogenically-modified and natural nursery habitats along the Indian River Lagoon, Florida. *Environmental Biology of Fishes*, *90*, 223–233.

Kells, V., & Carpenter, K. (2011). *A field guide to coastal fishes from Maine to Florida*. The John Hopkins University Press.

Leal, J. (2018, December 14). *The eclectic food habits of lettered olives*. Bailey-Matthews National Shell Museum and Aquarium. https://www.shellmuseum.org/post/2018/12/14/the-eclectic-food-habits-of-lettered-olives

Limeira, Á. G. C., Frédou, T., Soares, A. P. C., Lira, A. S., Viana, G. F. S., Rosa-Filho, J. S., Munaron, J. M., & Lucena-Frédou, F. (2022). Trophic ecology and resource partitioning of Haemulidae species along the Northeastern Brazilian continental shelf. *Neotropical Ichthyology*, *20*(e220001).

Moore, P. G., & Eastman, L. B. (2015). The tube-dwelling lifestyle in crustaceans and its relation to feeding. *The natural history of the Crustacea*, *2*, 35-77.

Mote Marine Laboratory and Aquarium. (2025). *Scrawled Cowfish: Acanthostracion quadricornis*. https://mote.org/animal-encyclopedia/scrawled-cowfish/

Motta, P. J., Clifton, K. B., Hernandez, P., Eggold, B. T., Giordano, S. D., & Wilcox, R. (1995). Feeding relationships among nine species of seagrass fishes of Tampa Bay, Florida. *Bulletin of Marine Science*, *56*(1), 185-200.

National Aquarium. (2025). *Animals: Striped Burrfish (Chilomycterus schoepfi)*. https://aqua.org/explore/animals/striped-burrfish

National Marine Sanctuary Foundation. (2020). *Sea Wonder: Sea Hare*. https://marinesanctuary.org/blog/sea-wonder-sea-hare/

National Wildlife Federation. (2025). *Mammals: West Indian Manatee*. https://www.nwf.org/Educational-Resources/Wildlife-Guide/Mammals/West-Indian-Manatee

NOAA Fisheries. (2025). *Species Directory: Green Turtle*. https://www.fisheries.noaa.gov/species/green-turtle

Osowski, A. R., Jargowsky, M. B., Cooper, P. T., Powers, S. P., & Drymon, J. M. (2023). Dietary Habits of Hardhead (*Ariopsis felis*) and Gafftopsail (*Bagre marinus*) Catfish revealed through DNA Barcoding of stomach contents. *Fishes*, *8*(11), 539.

Rudershausen, P. J., & Locascio, J. V. (2001). Dietary habits of the Gafftopsail Catfish, *Bagre marinus*, in Tarpon Bay and Pine Island South, Florida. *Gulf of Mexico Science*, *19*(2), 2.

Sealey, W. M., Davis, J. T., & Gatlin III, D. M. (1998). *Feeding Practices for Baitfish* (Southern Regional Aquaculture Center).

Sedberry, G. R. (1985). Food and feeding of the tomatate, Haemulon aurolineatum (Pisces, Haemulidae), in the South Atlantic Bight. *Fishery Bulletin*, *83*(3), 461-466.

Shipp, R. L., & Yerger, R. W. (1969). Status, characters, and distribution of the northern and southern puffers of the genus *Sphoeroides*. *Copeia*, 425–433.

Smithsonian Tropical Research Institute. (2024). *Species: Hemicaranx amblyrhynchus, Bluntnose Jack*. https://biogeodb.stri.si.edu/caribbean/en/thefishes/species/3645

Smithsonian Tropical Research Institute. (2024). *Species: Paralichthys albigutta, Gulf Flounder*. https://biogeodb.stri.si.edu/caribbean/en/thefishes/species/4303

Smithsonian Tropical Research Institute. (2024). *Species: Syngnathus scovelli, Gulf Pipefish*. https://biogeodb.stri.si.edu/caribbean/en/thefishes/species/3408

Taieb, A. H., Sley, A., Ghorbel, M., & Jarboui, O. (2013). Feeding habits of *Sparus aurata* (Sparidae) from the Gulf of Gabes (central Mediterranean). *Cahiers de Biologie Marine*, *54*, 263–270.

Vanderbilt Museum. (2020). *Whelks*. https://www.vanderbiltmuseum.org/wp-content/uploads/2020/04/whelk-fact-sheet.pdf

Waldrop, J. (2002). *"Luidia ciliaris"*. Animal Diversity Web. https://animaldiversity.org/accounts/Luidia_ciliaris/

Whitman, K. L., McDermott, J. J., & Oehrlein, M. S. (2001). Laboratory studies on suspension feeding in the hermit crab Pagurus longicarpus (Decapoda: Anomura: Paguridae). *Journal of Crustacean Biology*, *21*(3), 582-592.

Wilson, S. K., Patzner, R. A., Gonçalves, E. J., Hastings, P. A., & Kapoor, B. G. (2009). Diversity in the diet and feeding habits of blennies. *The biology of blennies. Science Publishers, Enfield, NH*, 139-162.

APPENDIX C:

Normality (Shapiro-Wilks), Histograms of Normality and Variance (Levene's Test) (Seagrass P/A, Tide Status, and Season) of Numeric Variables

Variable (Numeric)	**Normality (Shapiro-Wilks)**	**Variance (Levene's Test)**
Distance from SG	p-value = 1.907e-10 W = 0.8677 Non-parametric	Seagrass P/A: df = 1, F-value = 55.955, p-value = 7.051e-12 *** Tide Status: df = 2, F-value = 0.5874, p-value = 0.5571 Season: df = 1, F-value = 4.8367, p-value = 0.02948 * Treatment: df = 2, F-value = 36.961, p-value= 1.108e-13 ***
Total Time Deployed	W = 0.90829 p-value = 5.117e-08 Non-Parametric	Seagrass P/A: df =1, F-value = 3.3919, p-value = 0.06756 Tide Status: df = 2, F-value = 8.5872, p-value = 0.0002998 *** Season: df= 1, F-value = 0.0014, p-value = 0.9699
Total Survey Time	W = 0.98277 p-value = 0.06232 Non-Parametric	**Median:** Seagrass P/A: df = 1, F-value = 5.5653, p-value = 0.01965 * Tide Status: df = 2, F-value = 4.9019, p-value = 0.008719 ** Season: df = 1, F-value = 1.2335, p-value= 0.2686 **Mean:** Seagrass P/A: df = 1, F-value = 5.6794, p-value= 0.01846 * Tide Status: df = 2, F-value = 5.4711, p-value = 0.005127 ** Season: df = 1, F-value = 1.0214, p-value = 0.3139
MaxestN	W = 0.439 p-value < 2.2e-16	Seagrass P/A: df = 1, F-value = 7.9281, p-value = 0.005545 **

	Non-Parametric	Tide Status: df = 2, F-value = 0.3871, p-value= 0.6797 Season: df = 1, F-value = 0.3439, p-value = 0.5585
Total Species Observed	W = 0.92508 p-value = 5.74e-07 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.1789, p-value= 0.6729 Tide Status: df = 2, F-value = 0.3454, p-value= 0.7085 Season: df = 1, F-value = 2.4691, p-value= 0.1183
Total Time of Activity	W = 0.81235 p-value = 1.908e-12 Non-Parametric	Seagrass P/A: df = 1, F-value = 22.279, p-value = 5.502e-06 *** Tide Status: df = 2, F-value= 2.3398, p-value = 0.1 Season: df = 1, F-value = 0.0166, p-value= 0.8977
Total Time of IE	W = 0.22704 p-value < 2.2e-16 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.1276 p-value = 0.7214 Tide Status: df = 2, F-value = 0.1807, p-value= 0.8348 Season: df = 1, F-value = 0.004, p-value= 0.9499
Total Time of IA	W = 0.52799 p-value < 2.2e-16 Non-Parametric	Seagrass P/A: df = 1, F-value =19.494, p-value = 1.96e-05 *** Tide Status: df = 2, F-value = 2.8206, p-value = 0.06287 Season: df = 1, F-value = 2.1793, p-value = 0.142
Total Time of IB	W = 0.42048 p-value < 2.2e-16 Non-Parametric	Seagrass P/A: df = 1, F-value = 37.981, p-value = 6.699e-09 *** Tide Status: df = 2, F-value = 0.1759, p-value = 0.8389

		Season: df = 1, F-value = 3.7611, p-value = 0.0544
pH	W = 0.86341 p-value = 1.503e-09 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.0305, p-value = 0.8617 Tide Status: df = 2, F-value = 5.1746, p-value = 0.006922 ** Season: df = 1, F-value = 1.7319, p-value= 0.1905
Salinity	W = 0.93067 p-value = 1.372e-06 Non-Parametric	Seagrass P/A: df = 1, F-value = 6.418, p-value= 0.01236 * Tide Status: df = 2, F-value = 1.472, p-value = 0.2329 Season: df = 1, F-value = 6.0425, p-value = 0.01514 *
Phosphate	W = 0.91413 p-value = 1.872e-07 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.0169, p-value = 0.8967 Tide Status: df = 2, F-value = 0.0599, p-value = 0.9419 Season: df = 1, F-value = 1.575, p-value = 0.2116
Nitrite	W = 0.92048 p-value = 2.875e-07 Non-Parametric	Seagrass P/A: df = 1, F-value = 1.1348, p-value = 0.2885 Tide Status: df = 2, F-value = 0.3677, p-value= 0.6929 Season: df = 1, F-value= 0.0172, p-value = 0.8957
Average Turbidity	W = 0.70957 p-value = 1.217e-15 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.9723, p-value = 0.3257 Tide Status: df = 2, F-value = 14.404, p-value = 2e-06 *** Season: df = 1, F-value = 6.8128,

		p-value = 0.01001 *
Depth	W = 0.89004 p-value = 4.92e-09 Non-Parametric	Seagrass P/A: df = 1, F-value= 32.926, p-value = 5.389e-08 *** Tide Status: df = 2, F-value = 1.6705, p-value = 0.1918 Season: df = 1, F-value = 1.047, p-value = 0.3079
Temperature	W = 0.92867 p-value = 1.077e-06 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.0037, p-value = 0.9515 Tide Status: df = 2, F-value = 13.611, p-value = 3.88e-06 *** Season: df = 1, F-value= 7.0878, p-value= 0.008644 **
Carnivore	W = 0.74701 p-value = 1.264e-14 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.3746, p-value = 0.5415 Tide Status: df = 2, F-value = 0.3529, p-value = 0.7032 Season: df = 1, F-value = 0.399, p-value = 0.5286
Herbivore	W = 0.14991 p-value < 2.2e-16 Non-Parametric	Seagrass P/A: df = 1, F-value = 1.3399, p-value = 0.249 Tide Status: df = 2, F-value = 1.0861, p-value = 0.3403 Season: df = 1, F-value = 1.2294, p-value = 0.2694
Omnivore	W = 0.8367 p-value = 1.688e-11 Non-Parametric	Seagrass P/A: df = 1, F-value= 1.8378, p-value = 0.1773 Tide Status: df = 2, F-value = 0.0014, p-value = 0.9986 Season: df = 1, F-value = 2.5738, p-value = 0.1108

Planktivory	W = 0.46645 p-value < 2.2e-16 Non-Parametric	Seagrass P/A: df = 1, F-value = 0.4758, p-value = 0.4914 Tide Status: df = 2, F-value = 2.3474, p-value = 0.09926 Season: df = 1, F-value = 7.802, p-value = 0.005924 **
Detritivore	W = 0.72802 p-value = 3.503e-15 Non-Parametric	Seagrass P/A: df = 1, F-value = 4.698, p-value= 0.03183 * Tide Status: df = 2, F-value = 6.5064, p-value = 0.001971 ** Season: df = 1 F-value = 2.8551 p-value = 0.09323

Histograms of Distribution of Normality (Shapiro-Wilks) (Figure 1 to 18)

Figure 1: Distance from Seagrass

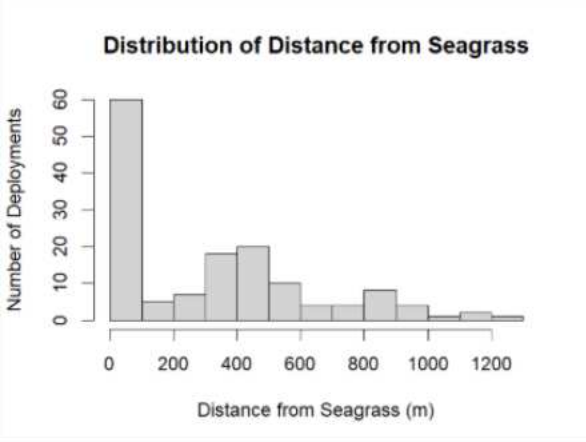


Figure 1: Visualization of the distribution of the BRUV Deployments and their Distance from Seagrass. The distribution is skewed to the left, and most of the BRUV deployments were less than 200 meters from the seagrass. Therefore, this data is non-parametric. (p-value = 5.114e-10, W = 0.8677)

Figure 2: Total Time Deployed

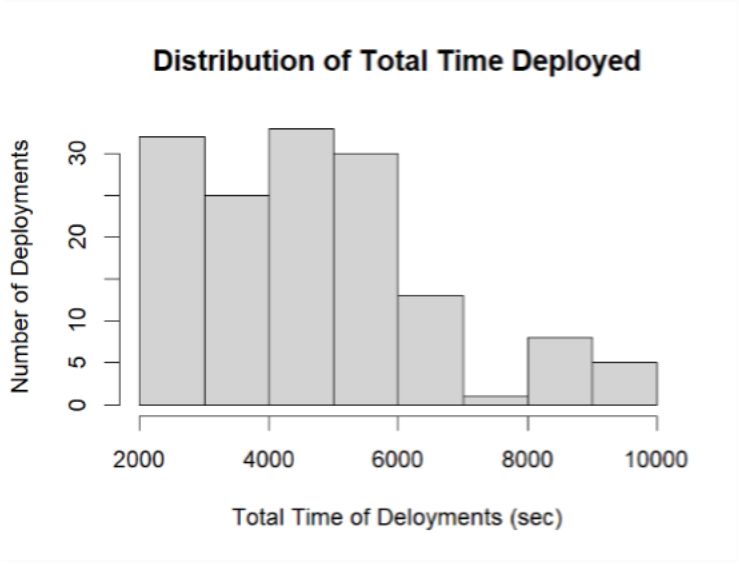


Figure 2: Visualization of the distribution of the successful BRUV Deployments and the Total Time Deployed in seconds (W = 0.90829, p-value = 5.117e-08)

Figure 3: Total Survey Time

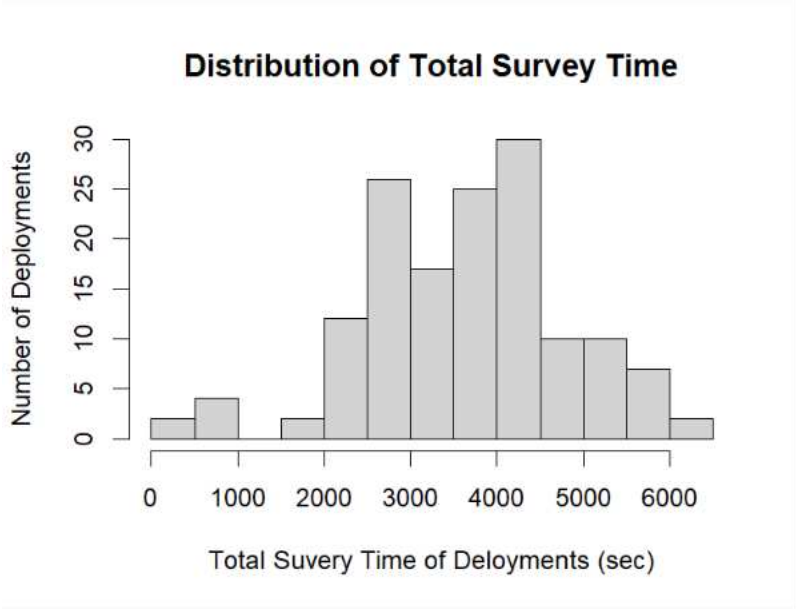


Figure 3: Visualization of the distribution of successful BRUV Deployments and their Total Survey Time (sec) (W = 0.98277, p-value = 0.06232)

Figure 4: Maxest N

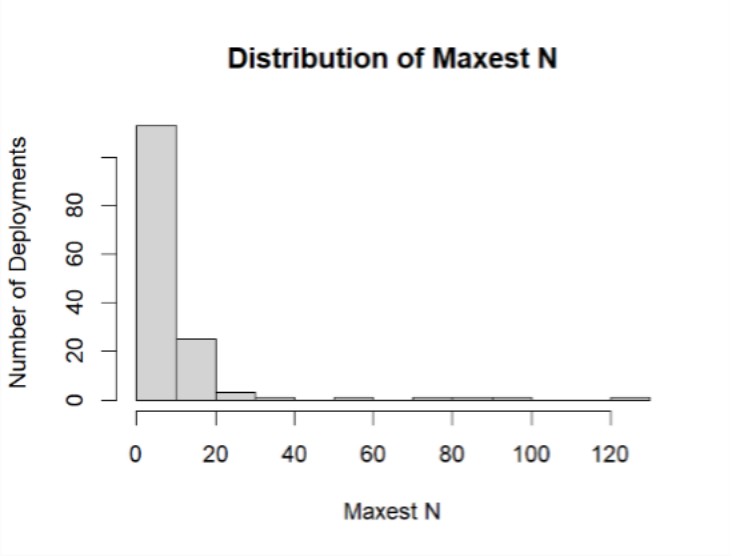


Figure 4: Visualization of the distribution of successful BRUV Deployments and the Maxest N (W = 0.439, p-value < 2.2e-16)

Figure 5: Total Species Observed

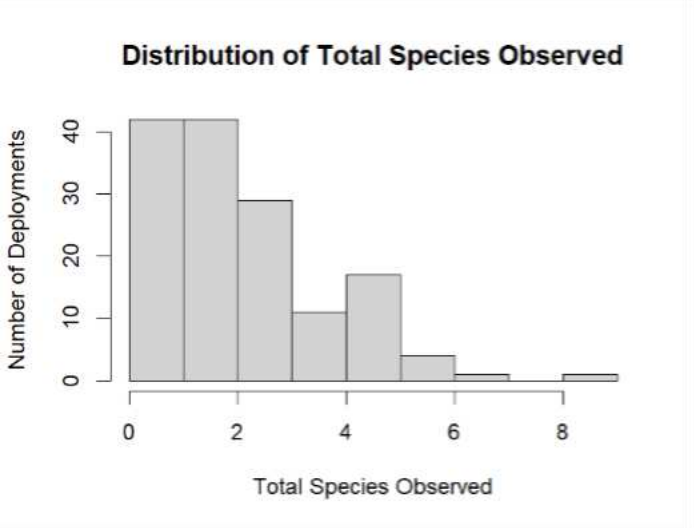


Figure 5: Visualization of the distribution of the Total Species Observed across the successful BRUV Deployments (W = 0.92508, p-value = 5.74e-07)

Figure 6: Total Time of Activity

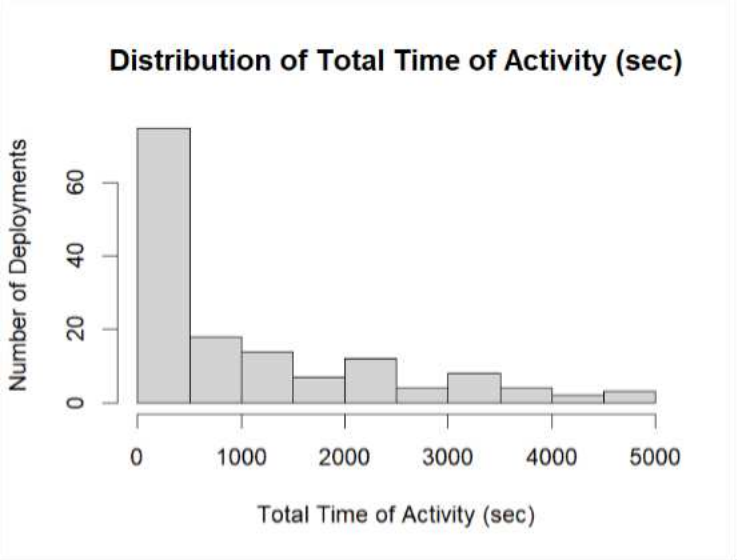


Figure 5: Visualization of the distribution of the Total Time of Activity across the successful BRUV Deployments (W = 0.81235, p-value = 1.908e-12)

Figure 6: Total Time of Interspecies Interactions

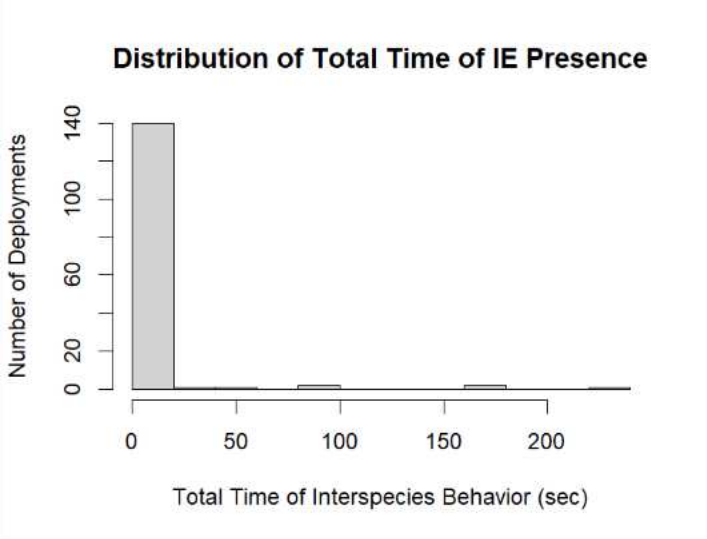


Figure 6: Visualization of the distribution of the Total Time of Interspecies Behavior Presence across the successful BRUV Deployments (W = 0.22704, p-value < 2.2e-16)

Figure 7: Total Time of Intraspecies Behavior Presence

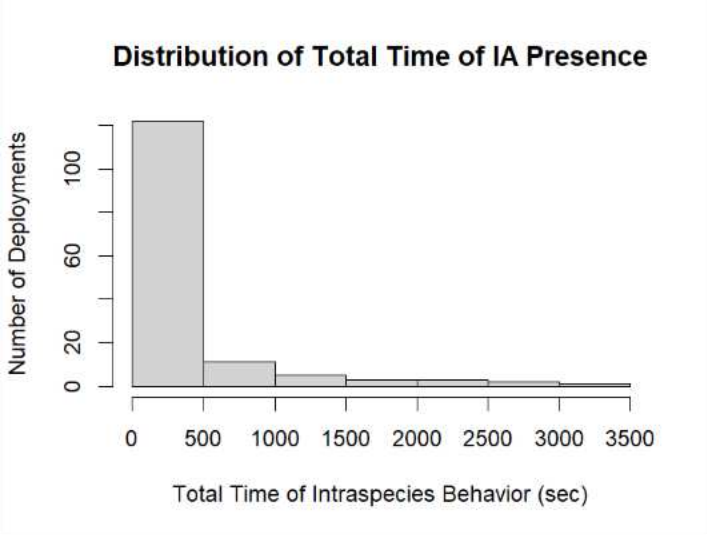


Figure 7: Visualization of the distribution of the Total Time of Intraspecies Behavior Presence across the successful BRUV Deployments (W = 0.52799, p-value < 2.2e-16)

Figure 8: Total Time of Both Intra- and Interspecies (Mixed) Behavioral Presence

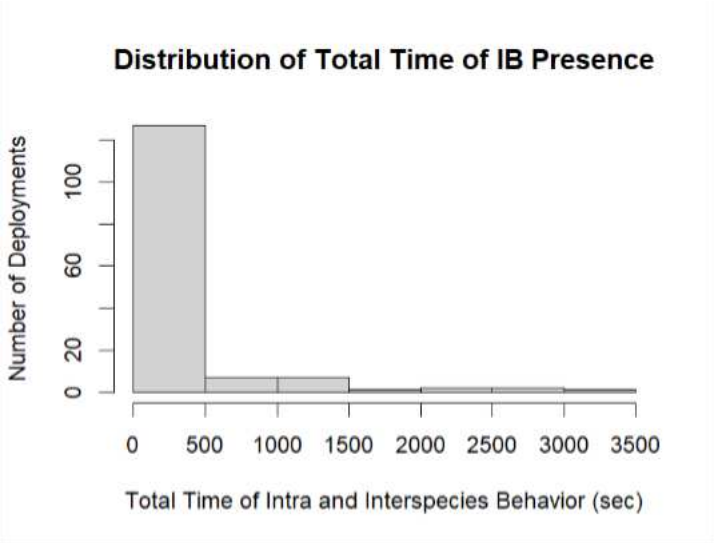


Figure 8: Visualization of the distribution of the Total Time of Intra- and Interspecies Behavior Presence across the successful BRUV Deployments (W = 0.42048, p-value < 2.2e-16)

Figure 9: pH

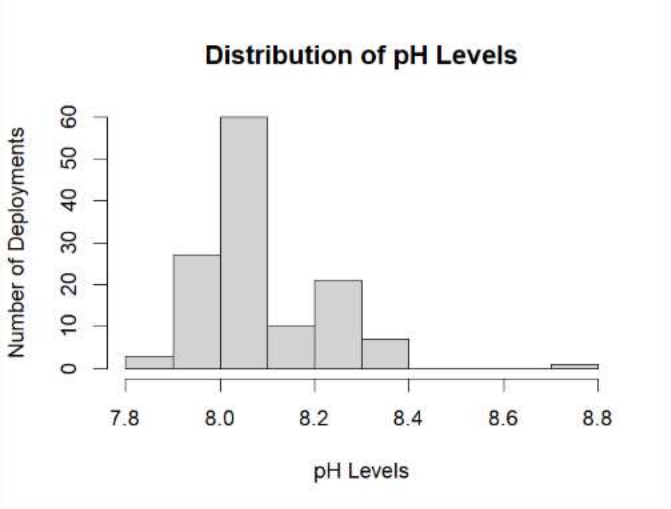


Figure 9: Visualization of the distribution of pH levels across the successful BRUV Deployments (W= 0.86341, p-value = 1.503e-09)

Figure 10: Salinity

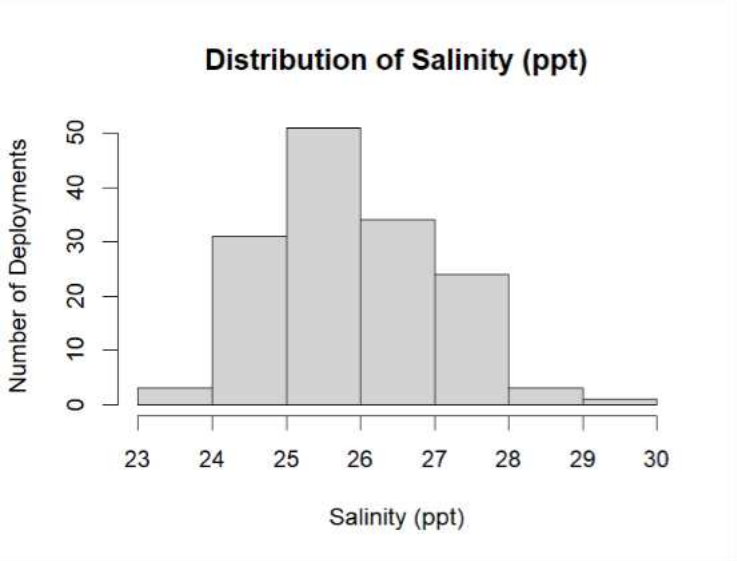


Figure 10: Visualization of the distribution of Salinity (ppt) levels across the successful BRUV Deployments (W = 0.93067, p-value = 1.372e-06)

Figure 11: Phosphate

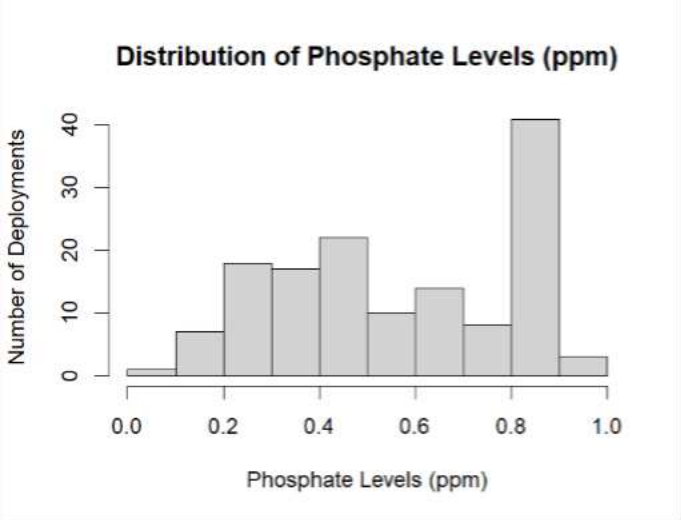


Figure 11: Visualization of the distribution of Phosphate (ppm) levels across the successful BRUV Deployments (W = 0.91413, p-value = 1.872e-07)

Figure 12: Nitrite

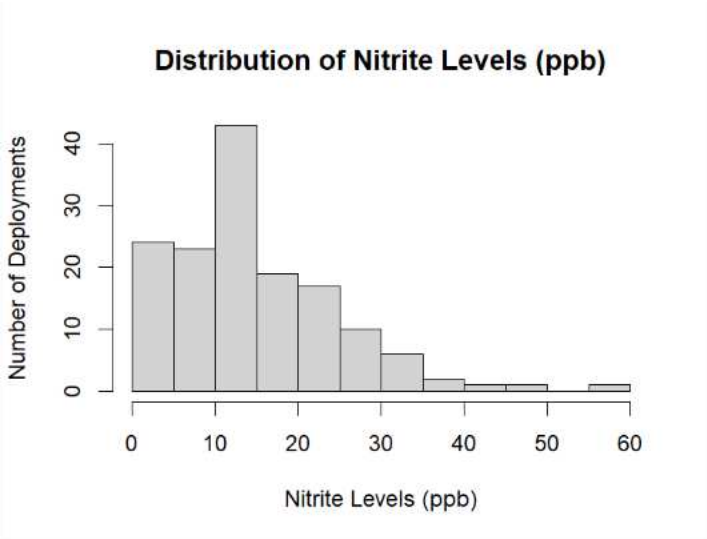


Figure 12: Visualization of the distribution of Nitrite (ppb) levels across the successful BRUV Deployments (W = 0.92048, p-value = 2.875e-07)

Figure 13: Average Turbidity

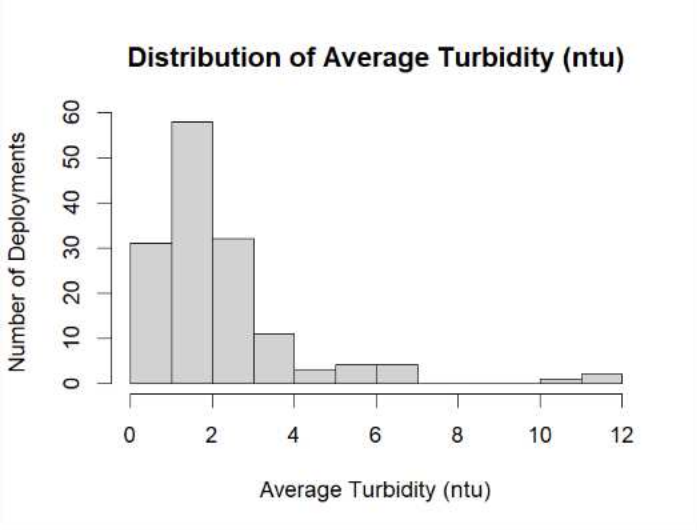


Figure 12: Visualization of the distribution of Average Turbidity (ntu) across the successful BRUV Deployments (W = 0.70957, p-value = 1.217e-15)

Figure 13: Depth (m)

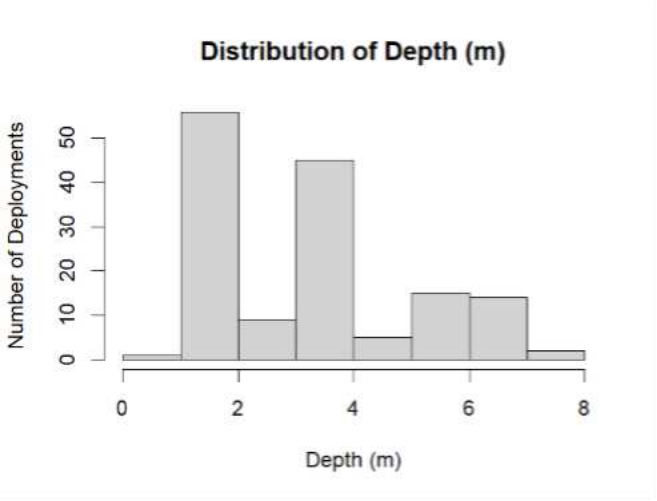


Figure 13: Visualization of the distribution of Depth (m) across the successful BRUV Deployments (W = 0.89004, p-value = 4.92e-09)

Figure 14: Temperature (C)

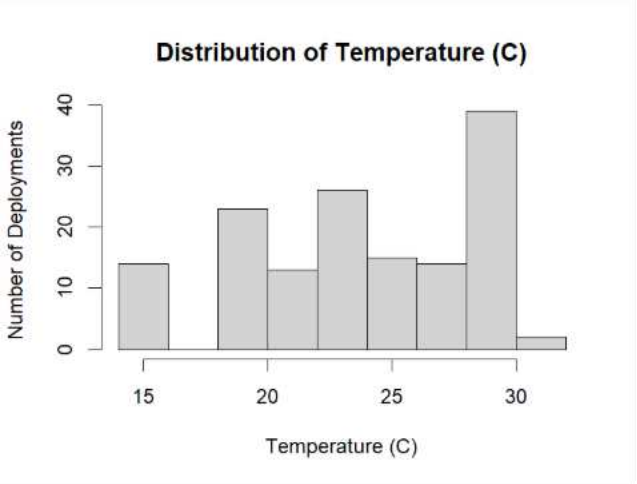


Figure 14: Visualization of the distribution of Temperature (C) across the successful BRUV Deployments (W = 0.92867, p-value = 1.077e-06)

Figure 15: Carnivore

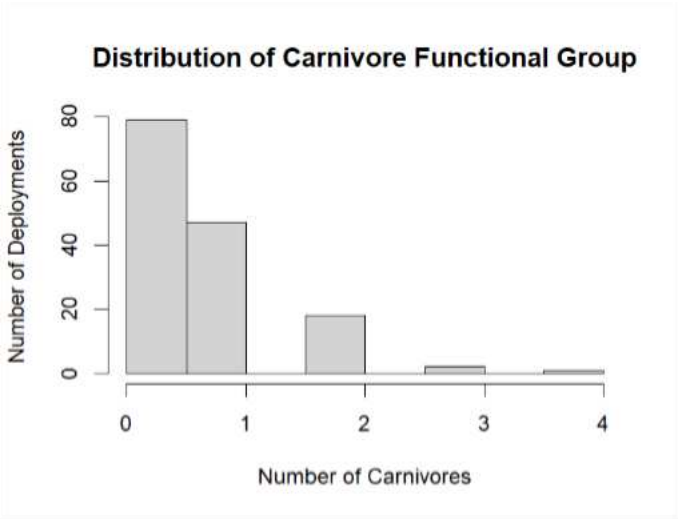


Figure 15: Visualization of the distribution of Carnivore functional Group across the successful BRUV Deployments (W = 0.74701, p-value = 1.264e-14)

Figure 16: Herbivore Functional Group

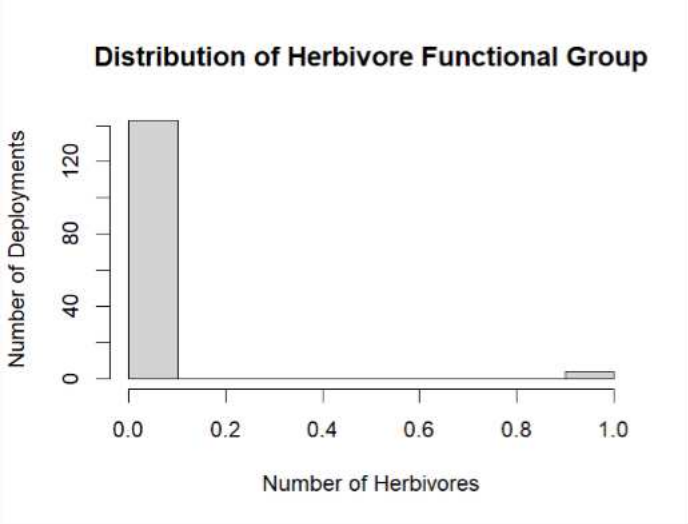


Figure 16: Visualization of the distribution of Herbivore functional Group across the successful BRUV Deployments (W = 0.14991, p-value < 2.2e-16)

Figure 17: Omnivore Functional Group

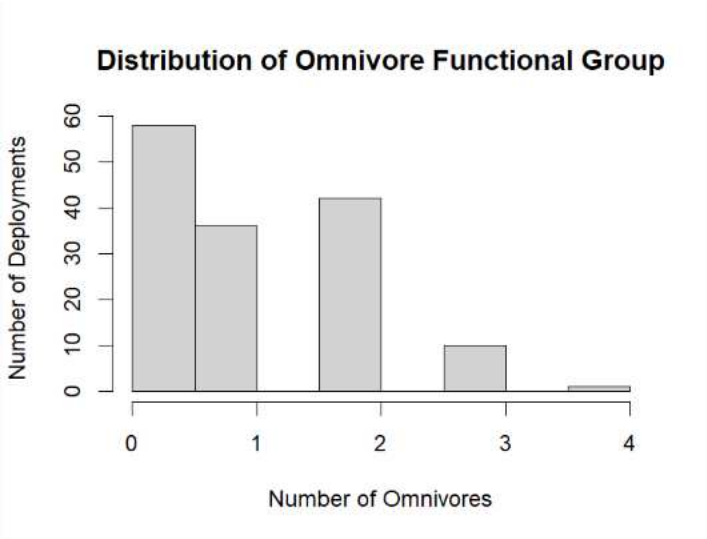


Figure 16: Visualization of the distribution of Omnivore functional Group across the successful BRUV Deployments (W = 0.8367, p-value = 1.688e-11)

Figure 17: Planktivory Functional Group

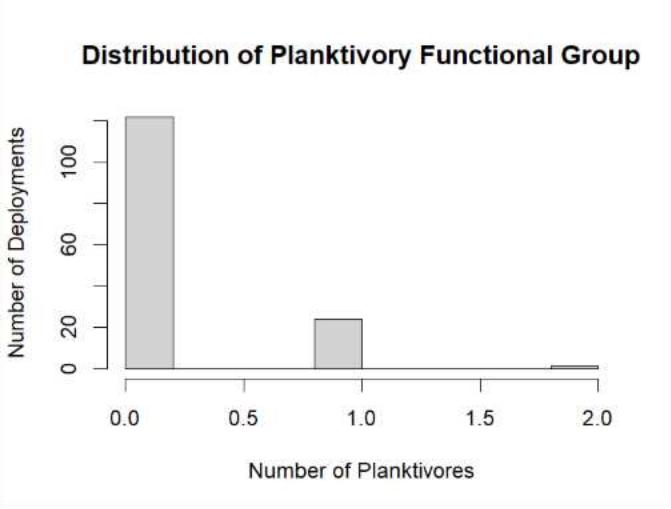


Figure 17: Visualization of the distribution of Planktivory functional Group across the successful BRUV Deployments (W = 0.46645, p-value < 2.2e-16)

Figure 18: Detritivore Functional Group

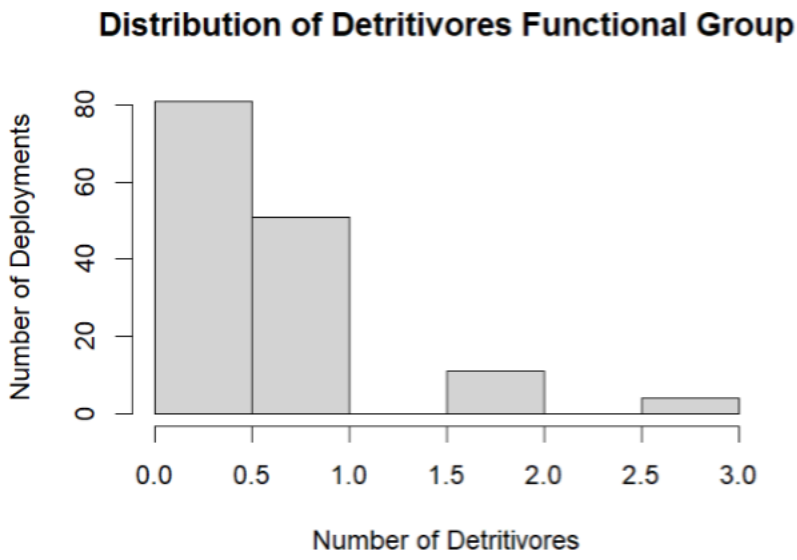


Figure 18: Visualization of the distribution of Detritivore functional Group across the successful BRUV Deployments (W = 0.72802, p-value = 3.503e-15)

APPENDIX D:

Means, Standard Error, and Standard Deviation of Numeric Variables

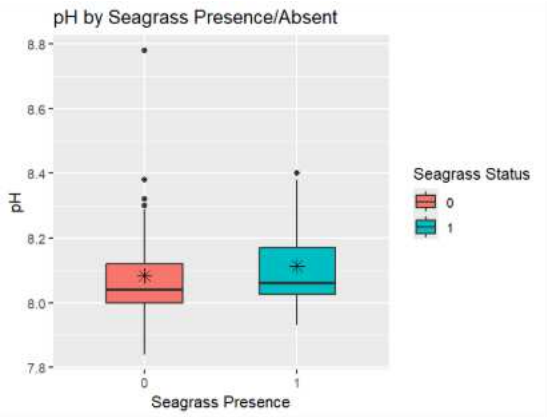
Variable	Mean	Standard Error (SE)	Standard Deviation (SD)
Distance from Seagrass (m)	307.0697	± 26.39659	316.5006
Total Time Deployed (seconds)	4687.755	± 147.9695	1794.035
Total Survey Time (seconds)	3658.592	± 96.73725	1172.877
Maxest N	8.047619	± 1.395018	16.91369
Total Species Observed	2.503401	± 0.1383416	1.677303
Total Time of Activity (seconds)	1062.184	± 102.6732	1244.847
Total Time of IE (seconds)	6.44898	± 2.466554	29.90537
Total Time of IA (seconds)	271.4286	± 49.31343	597.8936
Total Time of IB (seconds)	211.6122	± 48.48614	587.8632
pH (n = 129)	8.090698	± 0.01203706	2.664304
Salinity (ppt) (n = 147)	26.37755	± 0.09624289	1.166883
Phosphate (ppm) (n = 141)	0.5819858	± 0.02180396	0.2786211
Turbidity (ntu) (n = 146)	2.198801	± 0.1567714	1.896469
Depth (m) (n = 147)	3.223208	± 0.1386535	1.681084
Temperature (C) (n = 146)	24.19384	± 0.3686142	4.866621
Nitrite			

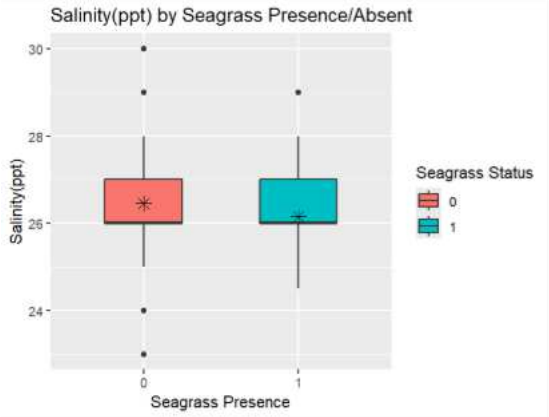
Table 1: Mean, standard error, and standard deviation regardless of the categorical variables

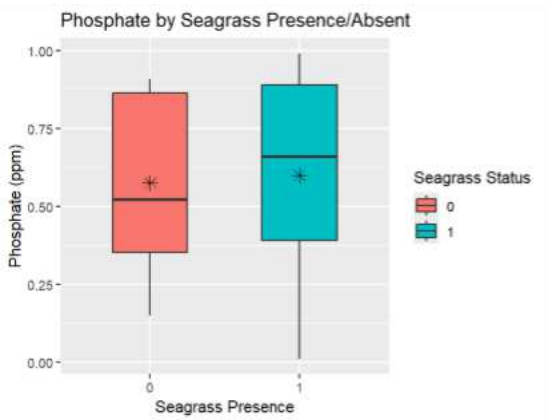
APPENDIX E:

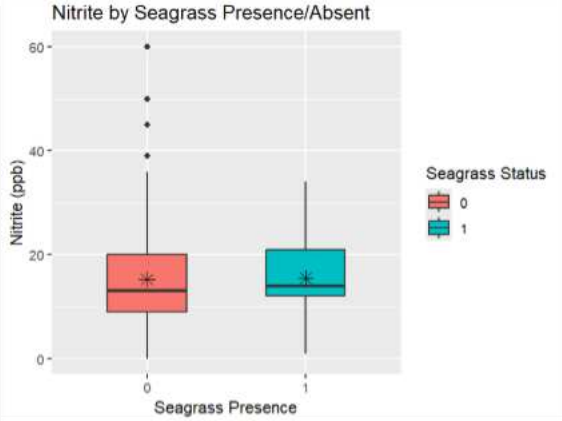
Boxplots of environmental parameters by seagrass presence, tide status, and season

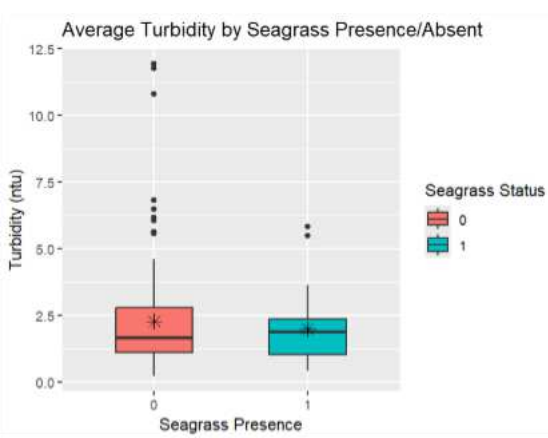
Boxplots of Environmental Parameters by Seagrass P/A

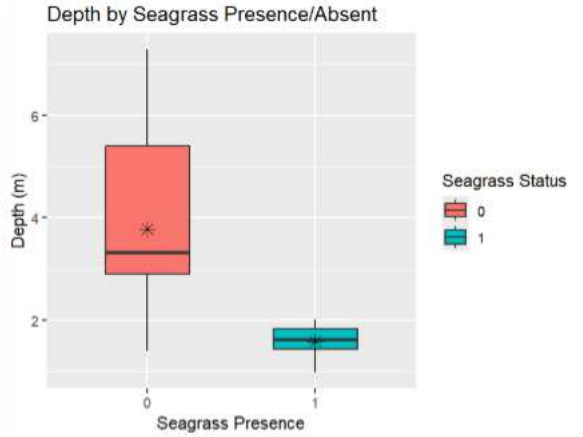


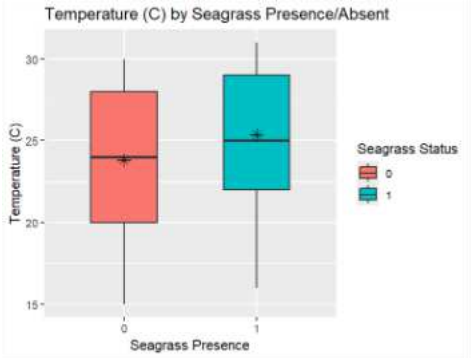






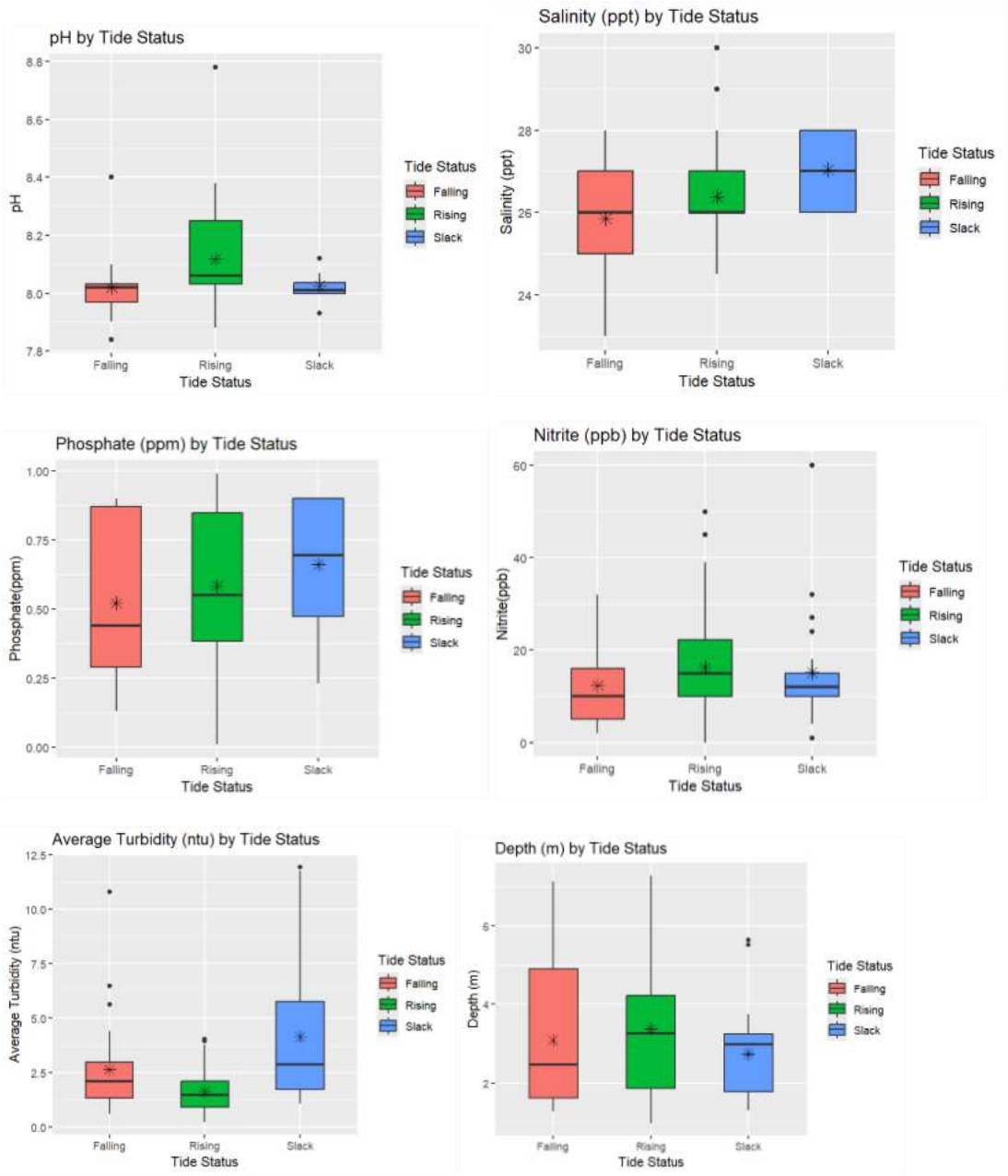


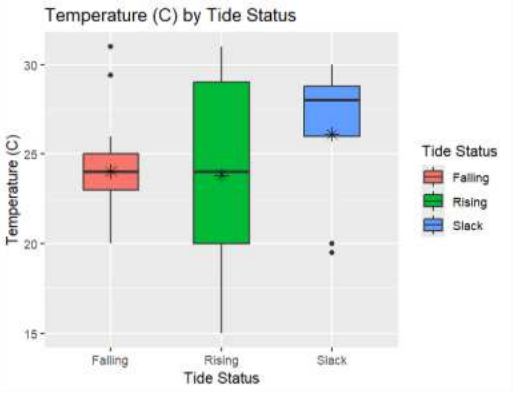




These are a series of boxplots that show the distribution of the data (pH, salinity, phosphate, nitrite, turbidity, depth and temperature) in seagrass presence and absence. The means are depicted by the star (*) and medians by the solid black line.

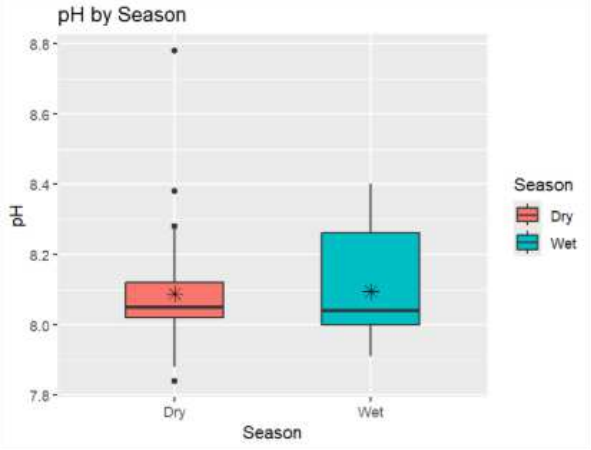
Boxplots of Environmental Parameters by Tide Status

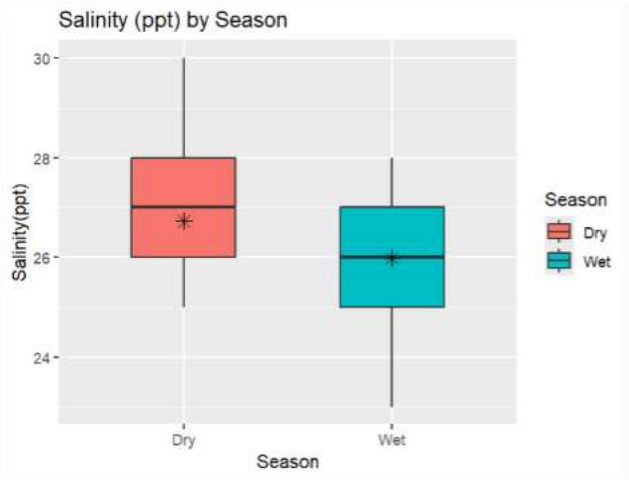


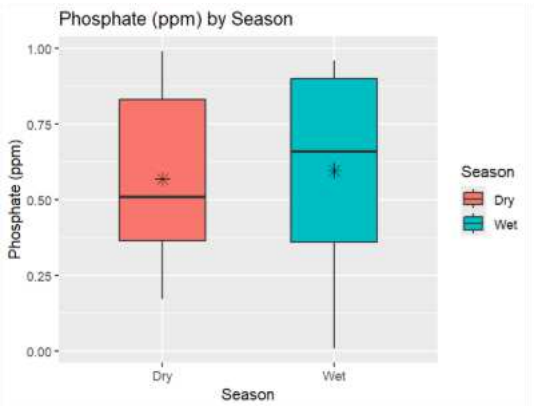


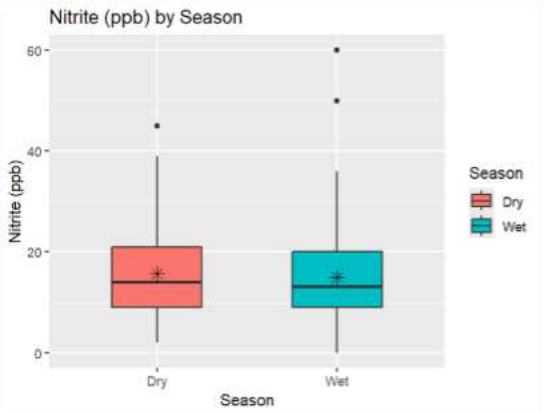
These are a series of boxplots that show the distribution of the data (pH, salinity, phosphate, nitrite, turbidity, depth and temperature) by tide status (falling, rising, and slack) . The means are depicted by the star (*) and medians by the solid black line.

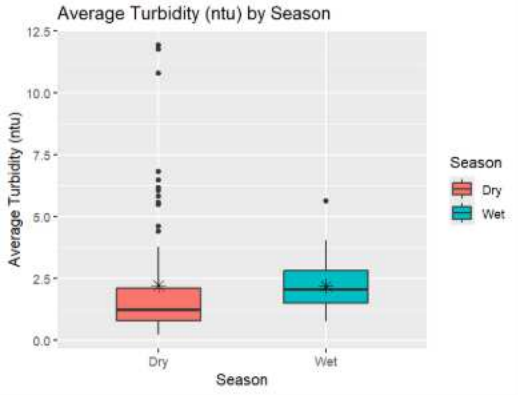
Boxplots of Environmental Parameters by Season

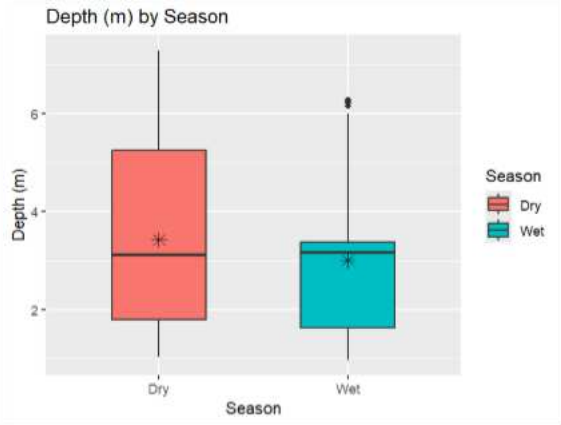


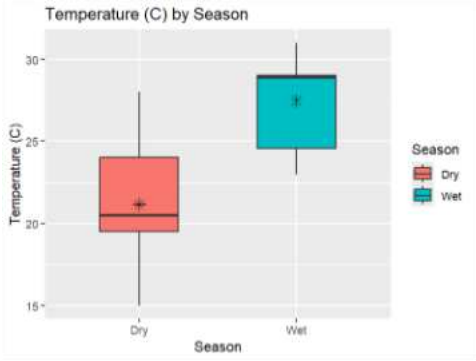








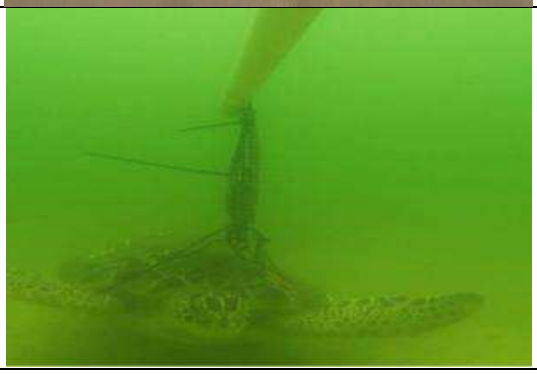




These are a series of boxplots that show the distribution of the data (pH, salinity, phosphate, nitrite, turbidity, depth and temperature) by season (wet and dry). The means are depicted by the star (*) and medians by the solid black line.

APPENDIX F:

Example of species identified in successful BRUV deployments including the common name and the functional group they were placed into

Photo	Identification
	Hardhead Catfish (*Ariopsis felis)* Omnivore
	Bonnethead Shark (*Sphyrna tiburo)* Omnivore
	Green Sea Turtle *(Chelonia mydas)* Herbivore