# Sedge Island Marine Conservation Zone Biological Survey

Save Barnegat Bay Student Grant Program

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Prepared and submitted by

Kate Killian, Stevens Institute of Technology, NJ

Brady Nichols, Bowdoin College, ME

Sarah Quigley, Berry College, GA

Advisor

Jason Kelsey, MATES, NJ

## Table of Contents

**Abstract**

The Sedge Island Marine Conservation Zone (SIMCZ) in Ocean County, New Jersey is the first and only marine conservation zone established in the state, in order to provide a protected habitat for estuarine species in Barnegat Bay. The SCIMZ is also naturally protected from meteorological fluctuations because of the sinuous water trails and abundance of tidal saltmarsh. Thanks to the protection the SIMCZ provides, species within the area are able to prosper without the hindrance of anthropogenic or naturally occurring threats. For ten nonconsecutive days in July, 2020, students in affiliation with Save Barnegat Bay surveyed species both inside and outside the SIMCZ, spending five sampling days in the zone and five sampling days at Tices Shoal, a site approximately three kilometers north. Species were counted and measured in order to compare species diversity inside and outside of the conservation zone, as well as in the habitats provided by three different kinds of bottom substrate — submerged aquatic vegetation (SAV), mixed macroalgae, and bare bottom. Population analysis found that there were significantly more organisms in macroalgae than in bare surface, but there were no significant differences when comparing SAV to the other substrates. Significantly less shrimp were found at bare surface compared to both SAV and macroalgae. No significant differences were observed when analyzing populations of fish found within the three substrates. Significantly more crabs were found in SAV than in bare bottom. Shore shrimp were determined to be significantly larger in SAV compared to macroalgae and Atlantic silversides were significantly smaller at bare surface compared to both SAV and macroalgae, but no other significant differences were seen in size data. Each substrate inside of the SIMCZ had a higher biodiversity than the bare surface outside of the zone. SIMCZ macroalgae had the highest diversity followed by SIMCZ SAV, SIMCZ bare, and finally bare surface outside the zone. The bare substrate outside of the zone had the highest species evenness, followed by SIMCZ SAV, SIMCZ bare, and SIMCZ macroalgae. There was found to be a 57% similarity between the species found in the bare substrates inside and outside of the SIMCZ. No significant correlation was found between percent algal coverage and the amount of species caught. No significant difference was found between the water temperatures at the bare substrates, nor between the dissolved oxygen values at these locations. Sediment analyses of the bare bottom found that sediment at Tices Shoal consisted largely of coarse particles, while sediment within the SIMCZ consisted largely of medium particles.

## Introduction

The Sedge Island Marine Conservation Zone (SIMCZ) is located just off Island Beach State Park in Ocean County, New Jersey (**Figure 1**). The state's first and only marine conservation zone, it was established in 2001 in part by the efforts of Paul D. "Pete" McLain to minimize anthropogenic impacts on the area so while many recreational activities such as birding, kayaking, and recreational fishing are allowed, commercial fishing and the use of personal watercraft is not. As a result, the area is minimally impacted compared to the rest of Barnegat Bay and consists mostly of natural saltmarsh habitat. Abiotically, this habitat is important for the area because of the sponge-like properties of wetlands that protect the shoreline from some major weather effects (U.S. Environmental Protection Agency, 2018). The zone is also important ecologically due to this protection and its ability to support a wide variety of habitats.

There are three primary bottom habitats that make up the conservation zone—bare surface, mixed macroalgae, and submerged aquatic vegetation (SAV) (**Figure 2**). Bare surface substrate is sand with no macroflora present, mixed macroalgae substrate is composed of macroalgae such as red algae (*Agardhiella sp.*) and sea lettuce (*Ulva lactuca*), and SAV substrate is primarily eelgrass (*Zostera marina)* or widgeon grass (*Ruppia maritima)* grasses. The overall habitat diversity in the SIMCZ increases the potential for faunal biodiversity because it can serve a variety of different organisms as well as multiple stages of the life cycles of species whose habitat preferences change over time (Vasconcelos et al., 2014). The six most common animal species found in the SIMCZ include Atlantic silversides (*Menidia menidia*), four-spined sticklebacks (*Apeltes quadracus*), shore shrimp (*Palaemonetes sp.*), sand shrimp (*Crangon septemspinosa*), blue crabs (*Callinectes sapidus*), and black-fingered mud crabs (*Panopeus herbstii*).

Tices Shoal is a recreational area located about three kilometers north of the Sedge Island Marine Conservation Zone sampling sites, also located just off Island Beach State Park in Ocean County, New Jersey (**Figure 3**). Due to its location outside of the conservation zone, it has minimal restrictions in terms of human presence, so potentially ecologically-damaging activities such as recreational fishing, personal watercraft use, and large gatherings of boats are commonplace. The area does not include the diverse array of bottom habitats found in the SIMCZ with only the aforementioned bare surface habitat being present throughout the area.

Variations of this study on biodiversity in the SIMCZ have been conducted since 2012, originating from former New Jersey governor Chris Christie's 10-point Plan for Barnegat Bay and have received funding from the New Jersey Division of Fish and Wildlife. Since 2017, studies have been funded by Save Barnegat Bay as part of their Student Grant Program. Results of past studies have shown that there is no significant difference in species diversity when taking into account richness and evenness (Jivoff et al., 2013) and that the sizes of organisms of a species within the SIMCZ tend to be smaller when compared to sizes in areas outside the zone (Orndoff et al, 2017). As the sites both support a similar diversity of species and the SIMCZ contains smaller organisms overall, there is a potential for the conservation zone to act as a nursery for young fish thus adding to its ecological importance. This study was conducted to add to the biodiversity dataset of shrimp, fish, and crabs within the Sedge Island Marine Conservation Zone while studying different habitat types and diversity between sample sites inside and outside the zone. While previous studies have compared the SIMCZ to areas outside of the conservation zone with similar bottom substrates, the COVID-19 pandemic limited resources and site selection, therefore Tices Shoal was chosen as a comparison site despite the lack of SAV or macroalgae because of the notable difference in anthropogenic activity. Though the data focuses on just three groups of organisms (shrimp, fish, crabs), the results can assist in the understanding of organisms at all trophic levels as population flux of organisms anywhere in the food web can have a cascading effect on the ecosystem (**Figure 4**) (Silliman & Angelini 2012). Therefore, it is important to ensure the health of populations of organisms in lower trophic levels such as these fish, shrimp, and crabs because their stability means the stability of the area's ecosystem as a whole.

## Methodology

*Study Sites:*

Sampling occurred both inside and outside of the Sedge Island Marine Conservation Zone (SIMCZ) in Barnegat Bay, New Jersey (**Figures 5 and 6**). Outside of the SIMCZ, sampling occurred at Tices Shoal, which is located about three kilometers north of the SIMCZ sites in Barnegat Bay (**Figures 5 and 7**). Sampling at the sites within the SIMCZ was conducted on three different substrates: SAV, macro-algae, and bare bottom. Sampling began in the mornings on days spread out between July 8, 2020 and July 29, 2020. Inside of the SIMCZ, two of each type of bottom substrate (SAV, macroalgae, and bare) were selected for each of the five sampling days in the zone. At Tices Shoal, six sites with bare bottom substrates were selected for each of the five sampling days outside of the zone.

*Protocol:*

Sites were selected based on bottom substrate and percent coverage. A $1m^3$ metal encapsulation cylinder was then dropped onto the study area in order to isolate the species within (**Figure 8**). Inside of the zone, the cylinder was dropped from the gunnel of the sampling boat two times at each habitat type. At Tices Shoal, the cylinder was carried by hand and subsequently dropped six times to account for human presence and it's potential to disturb the bottom fauna. Conditions about the site were then monitored, including time of study, GPS location, weather, tidal flow, and water depth. Wind velocity was measured using a Kestrel, and current was measured using a flowmeter. Using a YSI 85, dissolved oxygen (DO) (mg/L), salinity (ppt), and water temperature (˚C) were noted. Once these initial measurements were taken, D-nets were used to scoop species out of the cylinder and into sorting bins (**Figure 8**). The first 20 of each species were measured for length and identified. Population counts greater than 20 were tallied and applied to the species population for the site. After five consecutive empty scoops, the cylinder was considered depleted and sampling of the second cylinder began. Soil samples were collected inside the SIMCZ at bare substrate sites only, as well as at Tices Shoal for comparison. These samples were later dried and sieved using a Ro-Tap (**Figure 9**). One hundred grams each from four random soil samples were analyzed from both inside and outside the SIMCZ. The sieves that were used were mesh sizes 20, 35, 40, 60, 70, and 150. These sieves separated the sand into the categories very coarse (20), coarse (35), medium (40 and 60), fine (70), very fine (150), and less than very fine (bottom). After being separated by particle size, the sand was measured using an analytical balance to acquire percent composition.

*Statistical Analysis:*

ANOVA tests were run on the data from the years 2016 to 2020 to test for significant differences between the average amount of species caught each day (**Figures 10a-f**). This population data was split into the populations of the six most common species and analyzed on a species-specific basis. Then for each sampling date, the number of organisms found at each substrate was totaled and the five dates were averaged to find a mean number of organisms found at each substrate per day (**Figure 11**). This process was then repeated to further break down the organisms into groups of shrimp, fish, and crabs (**Figures 12-14)**. Size data was also averaged by substrate in order to compare the average size of the six most prevalent species in each substrate (**Figures 15-20**). For species population and species size data, Tukey's HSD Post Hoc analyses were used to compare the three substrate averages and determine which substrates were significantly different from the others. In order to quantify species diversity, a Simpson's Diversity Index (**Figure 21**) was conducted. A Shannon-Wiener Index (**Figure 21**) was also conducted to analyze species evenness. Additionally, a Jaccard Index (**Figure 21**) was conducted in order to analyze the similarity of species found in the bare substrate both inside and outside of the SIMCZ. A t-test was conducted to test for significant correlations between percent algal coverage and number of species found. T-tests were also run to determine significance between both the average water temperature per day and average dissolved oxygen per day at the bare substrates inside and outside of the zone (**Figure 22**).

An alpha of 0.05 or less was used to determine significance for all tests and error bars of 5% from the mean were used in displaying any values involving averages.

## Results

Inside the SIMCZ, the highest total count of specimens (947) was found at the macroalgae substrate, followed closely by the SAV substrate with 878 specimens, and the least amount of specimens found in the bare substrate, with 88 specimens (**Figure 23)**. Among the six most prevalent species, which were shore shrimp, sand shrimp, Atlantic silversides, four-spined stickleback, blue crabs, and black-fingered mud crabs, three of them — Atlantic silversides, blue crabs, and black-fingered mud crabs — preferred the SAV substrate, while the other three — shore shrimp, sand shrimp and four-spined sticklebacks — showed preference of the macroalgae substrate. Species composition in SAV substrate showed 77.7% Atlantic silversides, 67.5% blue crabs, and 70.4% black-fingered mud crabs, while compositions of 59.1% of shore shrimp, 67.9% of sand shrimp, and 89.7% four-spined stickleback were found in macroalgae substrates (**Figures 24a-f**). Comparing the average amount of all organisms found in different substrates, significantly more organisms were located in macroalgae compared to bare surface (P=0.0365) while the SAV average was not significantly different from SAV (P=0.9000) or macroalgae (P=0.0629) (**Figure 11**). Analyzing the shrimp data, there are significantly more shrimp in both SAV (P=0.0253) and macroalgae (P=.0010) compared to bare surface but there is no significant difference between SAV and macroalgae (P=.0593) (**Figure 12**). No significant difference was found between the average amount of fish comparing SAV and macroalgae (P=0.9000), SAV and bare surface (P=0.2651), or macroalgae and bare surface (P=0.4538) (**Figure 13**). There were significantly more crabs in SAV than bare surface (P=0.0066) with no significant difference between macroalgae and SAV (P=0.1049) or bare surface (P=.2974) (**Figure 14**).

When analyzing the population data within the SIMCZ from 2016 through 2020, it can be seen that the shore shrimp, Atlantic silverside, and blue crab populations followed an upward trend over the years, while the sand shrimp, four-spined stickleback, and black-fingered mud crab populations followed a downward trend. There was no significant difference amongst the species populations from 2016 to 2020 (P=0.6190) (**Figures 10a-f**).

Analyzing average size for the six most common species at each SIMCZ substrate, the only case in which any substrate was significantly different from both other substrates was for Atlantic silversides, where they were significantly smaller at the bare substrate compared to both

SAV (P=0.0033) and macroalgae (P=0.0020), but there was no difference between SAV and macroalgae (P=0.8829) (**Figure 17**). Additionally, there was a significant difference between shore shrimp sizes at SAV and macroalgae substrates (P=0.0010) but no difference between SAV and bare surface (P=0.6657) or macroalgae and bare surface (P=0.9000) (**Figure 15**). There was no significant difference in sand shrimp size data between SAV and macroalgae (P=0.9000), SAV and bare surface (P=0.6093), or macroalgae and bare surface (P=0.2840) (**Figure 16**). There was no significant difference in four-spined stickleback size data between SAV and macroalgae (P=0.5986), the only two substrates where the species was found (**Figure 18**). There was no significant difference in blue crab size data between SAV and macroalgae (P=0.8375), SAV and bare surface (P=0.9000), or macroalgae and bare surface (P=0.9000) (**Figure 19**). There was also no significant difference in black-fingered mud crab size data between SAV and macroalgae (P=0.0590), SAV and bare surface (P=0.0835), or macroalgae and bare surface (P=0.5024) (**Figure 20**).

Each substrate inside of the SIMCZ had a higher biodiversity than the bare substrate outside of the zone. The macroalgae substrate had the highest diversity with a Simpson's Diversity Index value of 0.6904, followed by SAV (0.6823), then bare (0.6000), and finally by the bare substrate outside of the zone (0.5714). Alternatively, the bare substrate outside of the zone had the highest species evenness according to the Shannon-Wiener Index with a value of 0.7149. SAV (0.6555), bare inside of the zone (0.5713), and macroalgae (0.5629) followed respectively. The Jaccard Index revealed a 57.0% similarity between the species found in the bare substrates inside and outside of the SIMCZ.

No significant correlation was found between percent algal coverage and the amount of species caught (P=0.0574). When comparing the water quality between the sites within the SIMCZ and outside the SIMCZ, there was no significant difference between the water temperatures at the bare substrates (P=0.0580) nor between the DO at these locations (P=0.0981) (**Figure 22**). The majority of sand particles from samples taken within the SIMCZ were classified as medium, while the majority of sand particles from samples taken outside the SIMCZ were classified as coarse. Samples taken within the SIMCZ had an average composition of 17.3% coarse particles, 60.4% medium particles, and 9.1% fine particles, while samples taken outside the conservation zone had an average composition of 7.8% very coarse particles, 28.5% coarse particles, and 17.8% medium particles (**Figures 25 and 26**).

**Discussion**

Overall there were significantly more organisms found in macroalgae than in bare surface with no significant difference between SAV and macroalgae or SAV and bare surface, though each group of organisms (shrimp, crabs, fish) follow a different trend. It is likely that the most amount of organisms were found in macroalgae because it provides a good mix of shelter and food for many organisms. There were significantly less shrimp found at bare surface compared to both SAV and macroalgae, but no significant difference between the amount of shrimp found at SAV and macroalgae substrates. This is likely a result of shrimp preferring vegetative habitats due to the fact that they feed partially on algae, small epifaunal organisms, and decaying animals that may have been caught in the flora, as well as the added protection of the aquatic vegetation in which shrimp tend to blend in well due to their transparency (Barnegat Bay Partnership, 2020). No significant differences arose when analyzing populations of fish found at SAV, macroalgae, and bare surface substrates. The lack of significance is likely due to their schooling behavior causing a large variance between dates as the sampling cylinder sometimes landed on a large school of silversides and other times only captured stragglers. There was a significant difference in crab population data comparing SAV and bare surface with more crabs being found in SAV, but no significant difference was found between macroalgae and SAV or macroalgae and bare surface. Crabs likely prefer SAV because it provides the most cover from larger predator organisms such as birds along with a steady supply of food, like smaller prey organisms such as shrimp (Barnegat Shellfish, 2019).

There were species population variations over the course of the years analyzed in this project, but the fluctuations were not significant. While some species were more prevalent in certain years and less in others, there were no drastic changes. The randomness of survey protocol allows for some variability in these readings. Further study could shed additional light on the population changes.

The only cases in which there was a significant difference between the average size of organisms between substrates was shore shrimp being significantly larger at SAV compared to macroalgae and Atlantic silversides being significantly smaller at bare surface compared to both SAV and macroalgae. The lack of significance throughout these comparisons is likely due to the presence of organisms in various stages of life at each site, causing a wide range of size and therefore a larger variance in the data making significance harder to show.

It is likely that the macroalgae substrate showed the most diversity because macroalgae sites were chosen for their coverage with none of the sites having under 50% coverage. This may have caused the macroalgae sites to be more favorable because they offered more food and better protection from predators, so more species would prefer it over bare surface. The bare substrate outside of the conservation zone was found to have the most evenness because there were not many organisms located in these areas, so no one species was driven to dominate over any others in addition to the low sample size.

Percent algal coverage did not have a significant effect on the number of species caught due to the low sample size of sites with varying algal coverage and large variety in the amount of organisms found at each site. The water quality between the two sites was not found to be significantly different, so although Tices Shoal is impacted by anthropogenic activities, the water quality is similar enough to sites within the SIMCZ to allow for the same species found within the conservation zone to also thrive at Tices Shoal. Analysis of sediment particle sizes in soil samples from both inside and outside the conservation zone, showed that the sand particles tended to be larger at Tices Shoal than within the SIMCZ.

**Conclusion**

The Sedge Island Marine Conservation Zone successfully sustains a diverse ecosystem across the various habitats it contains, as well as fosters the growth of the individuals that reside there. Alternatively, areas outside of the conservation zone such as Tices Shoal are prone to many more disturbances and are unable to support an abundance of life. The information gained from this study continues the long term survey of biodiversity in the conservation zone. This data will facilitate the analysis of the conservation zone and determine its success.

**Acknowledgements**

Thank you to Save Barnegat Bay for the opportunity to conduct this study. Also, thanks to the Marine Academy of Technology and Environmental Science (MATES) as part of the Ocean County Vocational Technical Schools for the use of their equipment, the New Jersey Division of Fish and Wildlife, the New Jersey Division of Parks and Forestry, and Kelley Scott from Island Beach State Park.

**References**

Barnegat Bay Partnership. (2020). Barnegat Bay Species Archive Database.

Barnegat Shellfish, LLC. (2019). Barnegat Bay Shellfish information Blue Crabs.

Jivoff, D., Bilinski, J., Belton T., & Ferko M. (2013, August 21). Ecological Evaluation of Sedge Island Marine Conservation Zone. New Jersey Department of Environmental Protection.

Orndorff, S., DeGennaro N., & Pobok, V. (2017, August 14). Ecological Evaluation: The Sedge Island Marine Conservation Zone. Save Barnegat Bay.

Silliman, B. R. & Angelini, C. (2012) Trophic Cascades Across Diverse Plant Ecosystems. *Nature Education Knowledge* 3(10):44

United States Environmental Protection Agency. (2018, June 13). *Why are Wetlands Important?* Retrieved from https://www.epa.gov/wetlands/why-are-wetlands-important

Vasconcelos, R. P., Eggleston, D. B., Pape, O. L., & Tulp, I. (2014). Patterns and processes of habitat-specific demographic variability in exploited marine species. *ICES Journal of Marine Science, 71*(3), 638-647. doi:10.1093/icesjms/fst136

**Figures**


**Figure 1:** The Sedge Island Marine Conservation Zone (SIMCZ), in Barnegat Bay in Ocean County, New Jersey. The conservation zone is located just off of Island Beach State Park, near the Barnegat Inlet. Map courtesy of Save Barnegat Bay.


**Figure 2:** Inside the SIMCZ, there were three different types of bottom substrate: submerged aquatic vegetation (SAV) (left), macroalgae (center), and bare (right).



**Figure 3:** Tices Shoal is located in Barnegat Bay in Ocean County, New Jersey. This site is approximately 3 miles north of the SIMCZ, and is also located just off of Island Beach State Park.

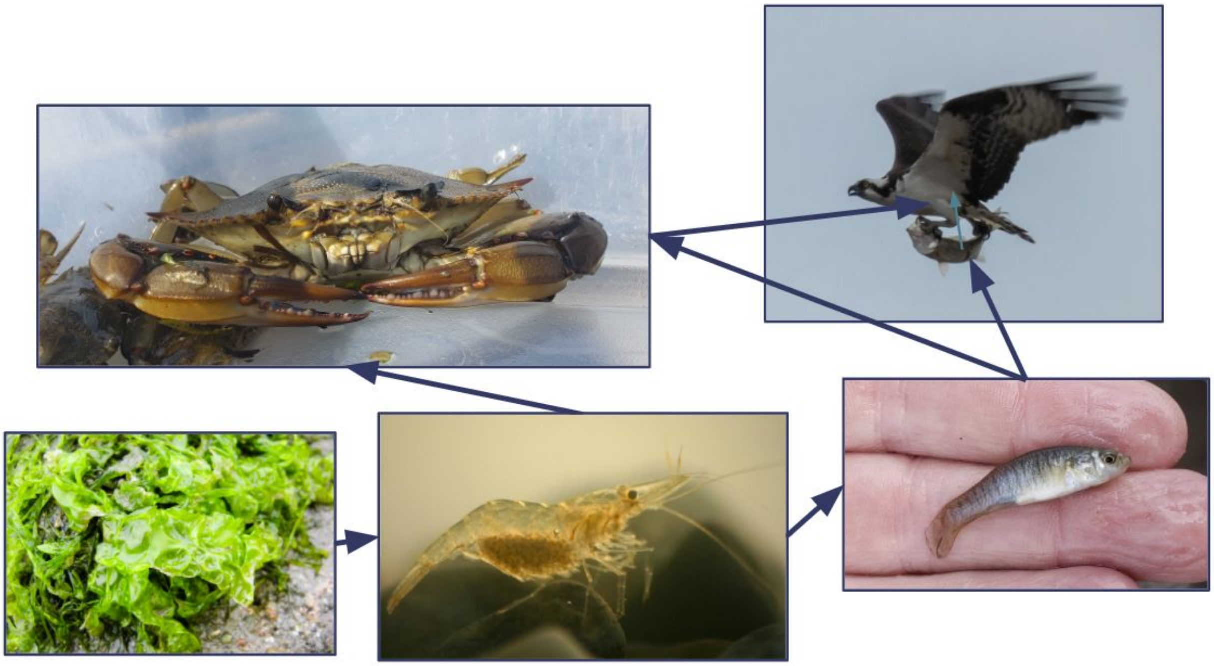

**Figure 4:** Simplified food web of the Barnegat Bay ecosystem. Sea lettuce is at the lowest trophic level as a producer and is eaten by shore shrimp, which become food for higher trophic level organisms including small fish and crabs. The small fish are food for the larger fish which are, along with crabs, eaten by ospreys, the apex predator here. As a result of the interconnectedness of the food web, fluctuations in the populations of one species can cause many other parts of the chain to become unstable. Sea lettuce photo courtesy of Chesapeake Bay Program; shore shrimp photo courtesy of Barnegat Bay Partnership.


**Figure 5:** Over 10 nonconsecutive days in the summer of 2020, 30 sites were sampled inside the SIMCZ and 30 sites were sampled outside the SIMCZ, approximately three kilometers north, at Tices Shoal.


**Figure 6:** Five days between July 8, 2020 and July 29, 2020 were spent collecting samples in the SIMCZ dropping two cylinders in each of three substrates (bare, macroalgae, and SAV) for a total of six sites per day in the conservation zone (n=30).


**Figure 7:** Five days between July 8, 2020 and July 29, 2020 were spent collecting samples at Tices Shoal where the cylinder was dropped six times on the bare surface substrate in order to account for the lack of SAV and macroalgae substrates, the fact that the cylinder was walked out instead of dropped from a boat, and that species may have been scared off by the extra movement in the water (n=30).

**Figure 8:** Study areas were isolated using a 1m³ metal encapsulation cylinder that was dropped onto the study area. D-nets were then used to scoop species out of the study area and into sorting bins, where the organisms would then be counted and measured.

**Figure 9:** The Ro-Tap machine was used to separate sediment samples by particle sizes. The copper tins are loaded into the machine with the sediment sample inside, and the machine rotates and taps the tins that contain mesh to sort the differently sized particles.

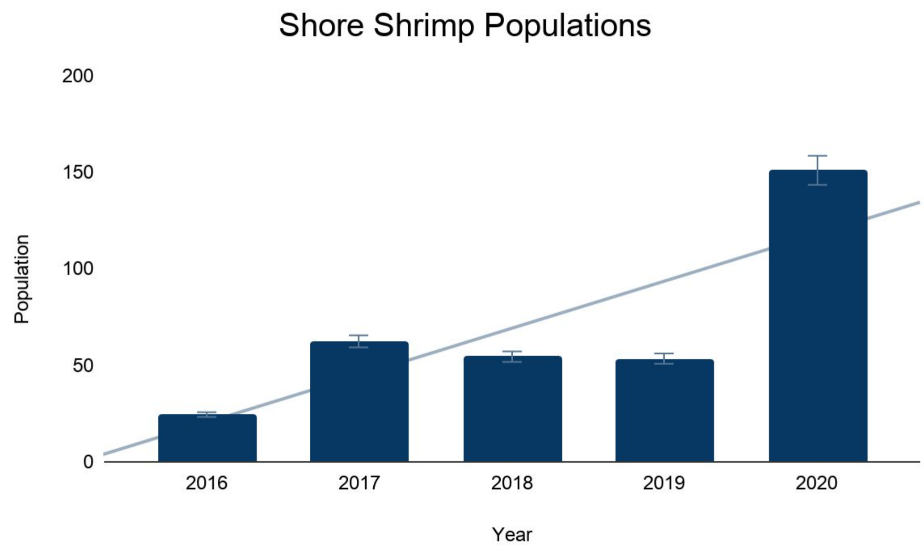


**Figure 10a**

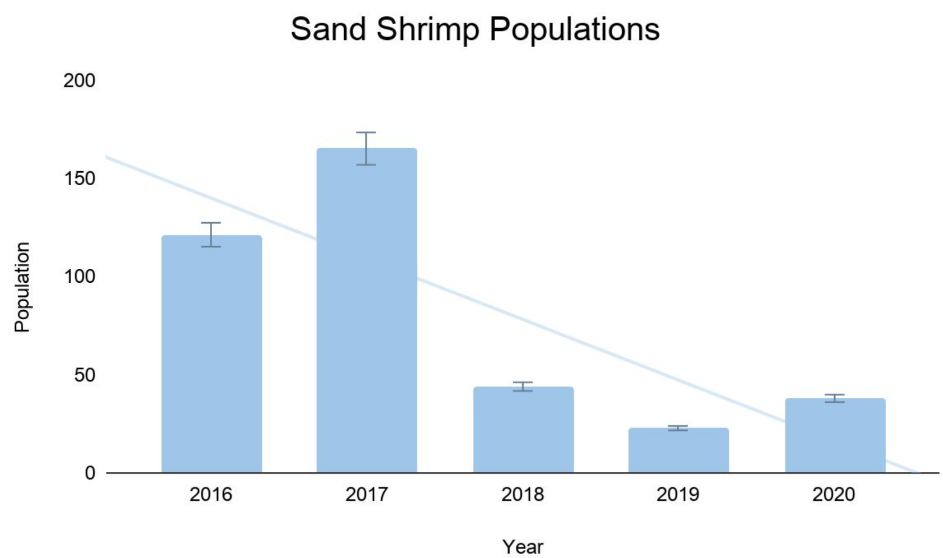


**Figure 10b**

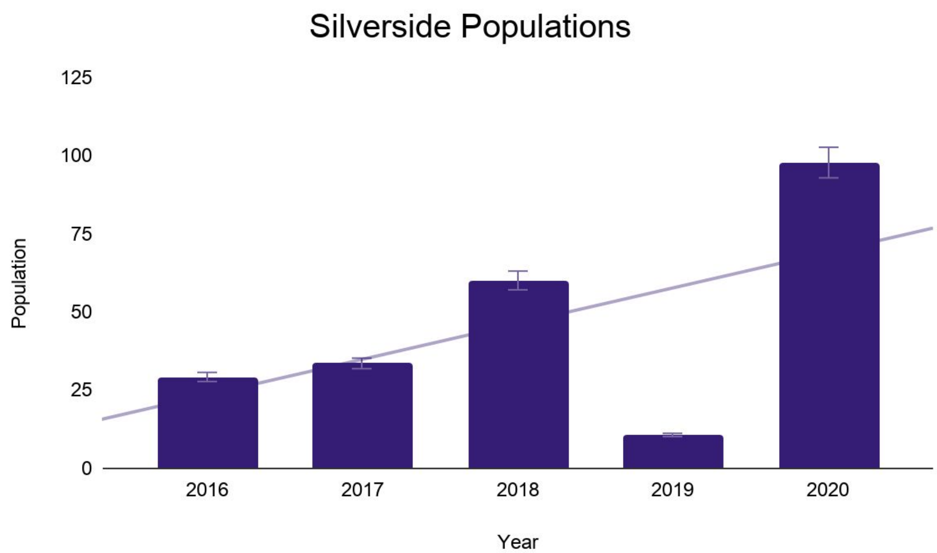


**Figure 10c**

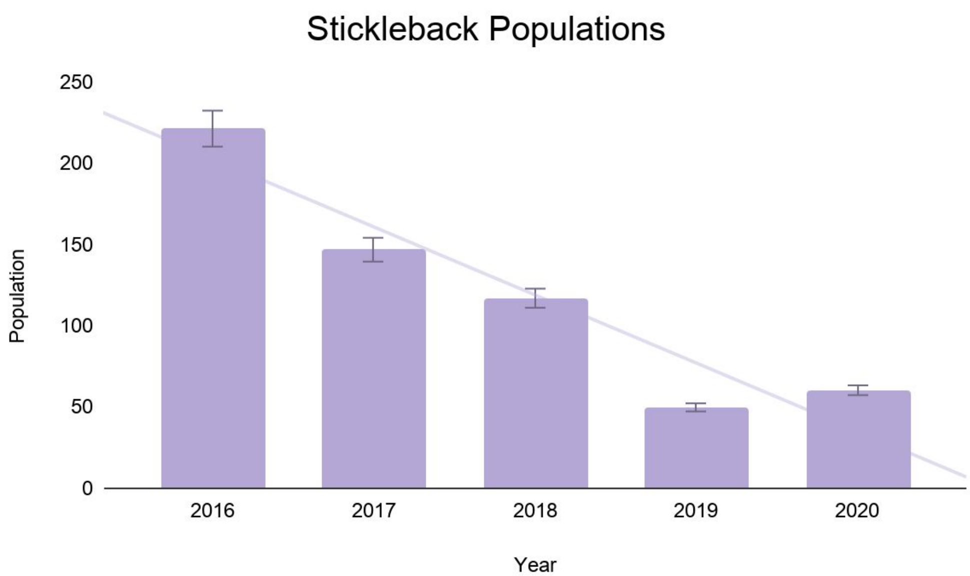


**Figure 10d**

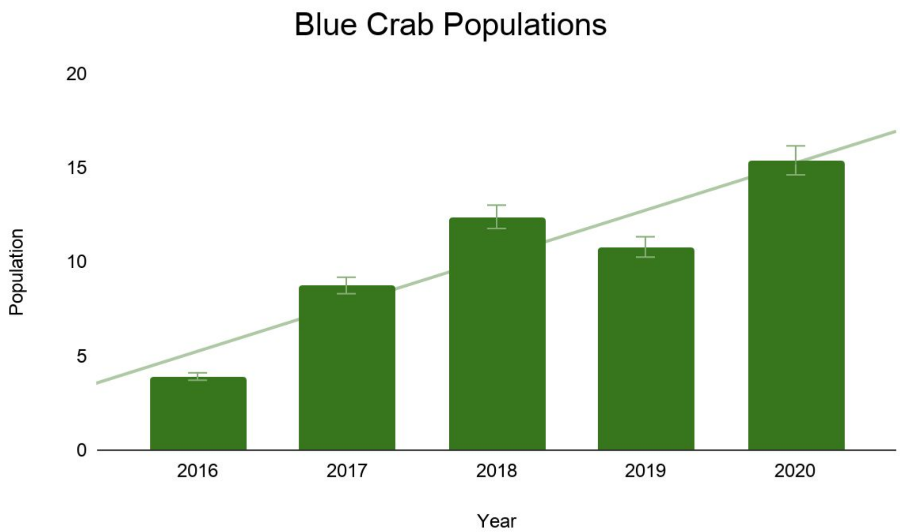


**Figure 10e**

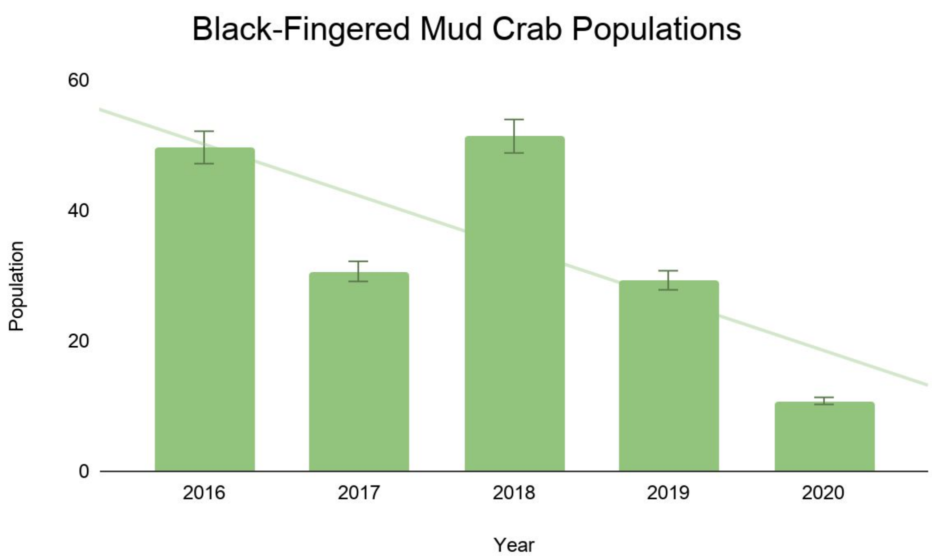


**Figure 10f**

**Figures 10a-f:** Population data from the years 2016-2020 was split into the populations of the six most common species and analyzed on a species-specific basis. ANOVA tests were run on the data to test for significant differences between the average amount of species caught each day. There was no significant difference amongst the overall species populations from 2016-2020 (P=0.6190).

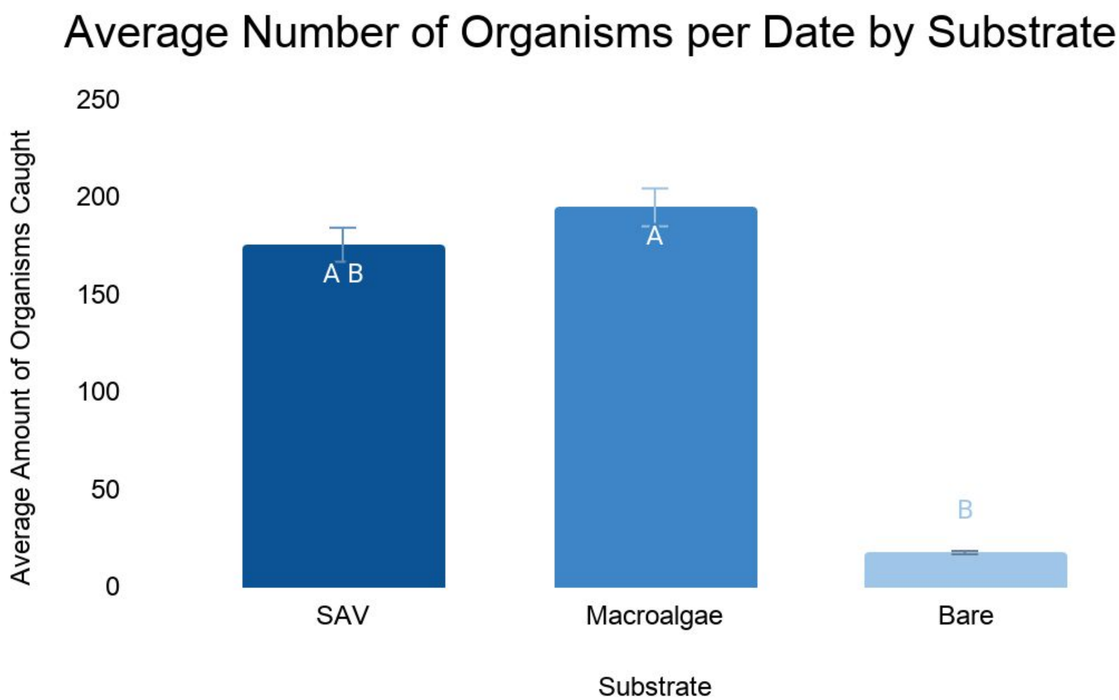


**Figure 11:** Comparison of the average number of organisms per sample found at each substrate within the SIMCZ (n=1940). The Tukey's HSD Post Hoc showed macroalgae to be significantly different from bare surface (P=0.0365) with neither being significantly different from SAV (P=0.9000 for macroalgae and P=0.0629 for bare surface). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where A is different from B but neither is different from AB.

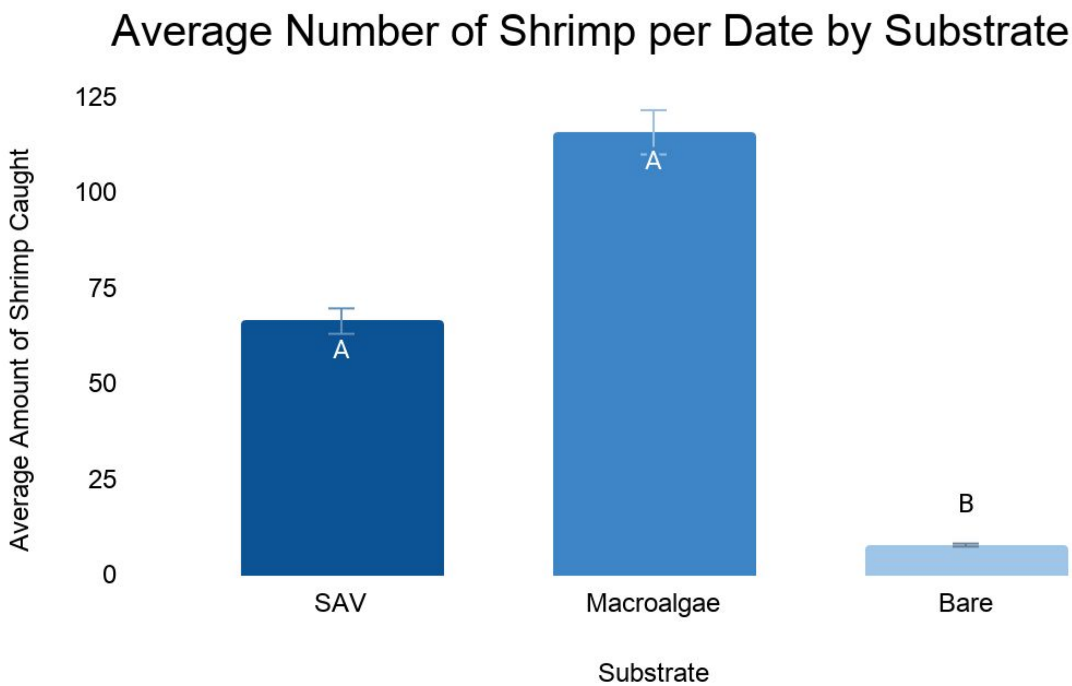


**Figure 12:** Shrimp found per sample at each substrate in the SIMCZ (n=950). Tukey's HSD Post Hoc analysis showed the amount of shrimp found in bare surface substrate to be significantly different from SAV (P=0.0253) and macroalgae (P=0.0010) and the amount found in SAV and macro to not be significantly different (P=0.0593). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where A is different from B.

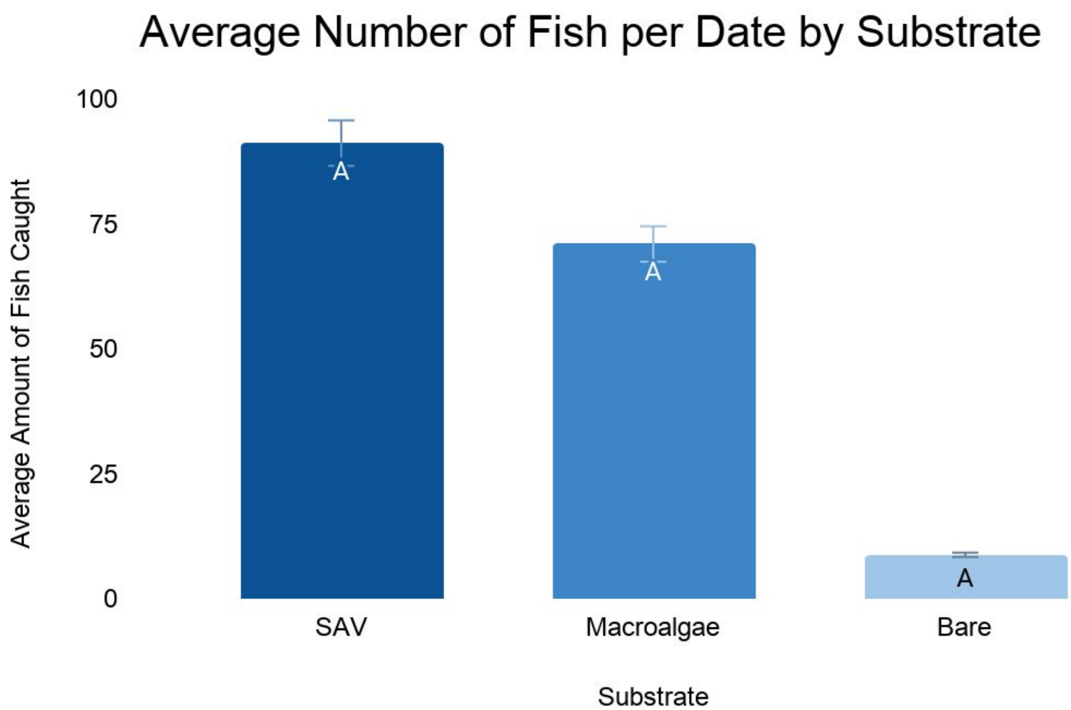


**Figure 13:** Fish found per sampling date at each of the three substrates at the SIMCZ (n=855). Tukey's Post Hoc Analysis found there to be no significant difference between any of the averages (SAV-macroalgae: P=0.9000; SAV-bare: P=0.2651; macroalgae-bare: P=0.4538). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where they are all A since there are no significant differences.

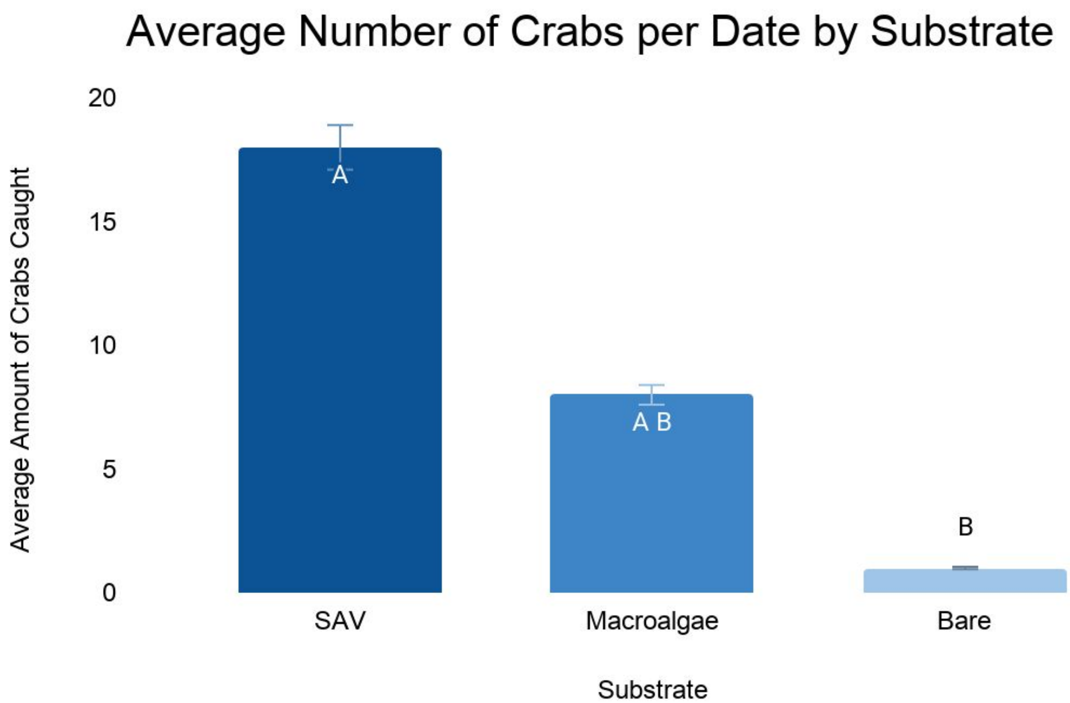


**Figure 14:** Average number of crabs per sampling date found at each substrate of the SIMCZ (n=135). Tukey's HSD Post Hoc analysis showed there to be a significant difference between the number of crabs found at SAV and bare surface (P=0.0066) but not between SAV and macro (P=0.1049) or macroalgae and bare (P=0.2974). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where A is different from B but neither is different from AB.

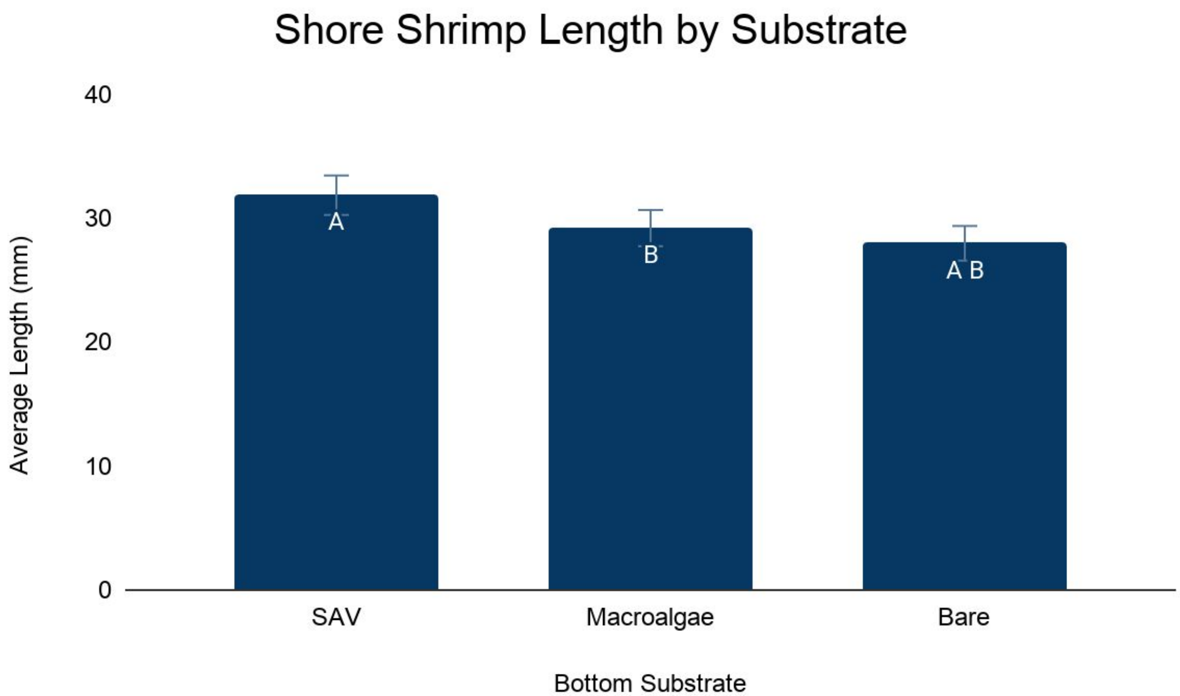


**Figure 15:** Average length of shore shrimp (*Palaemonetes sp.*) by bottom substrate at SIMCZ (n=755). Tukey's HSD Post Hoc analysis showed none of the groups to be significantly different from the other two (SAV-bare: P=0.6657; macroalgae-bare: P=0.9000), though there was a significant difference between SAV and macroalgae (P=0.0010). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where A is different from B but neither is different from AB.

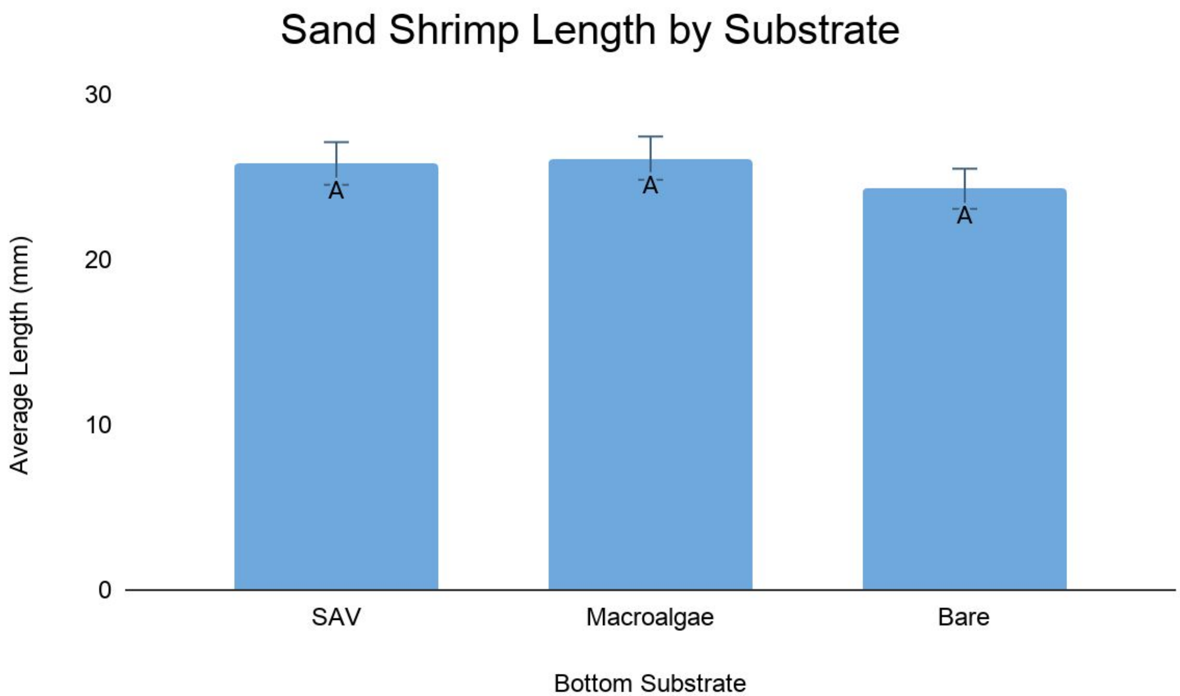


**Figure 16:** Average length of sand shrimp (*Crangon septemspinosa*) by bottom substrate at SIMCZ (n=190). Tukey's HSD Post Hoc analysis showed none of the groups to be significantly different (SAV-macroalgae: P=0.9000; SAV-bare: P=0.6093; macroalgae-bare: P=0.2840). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where they are all A since there are no significant differences.

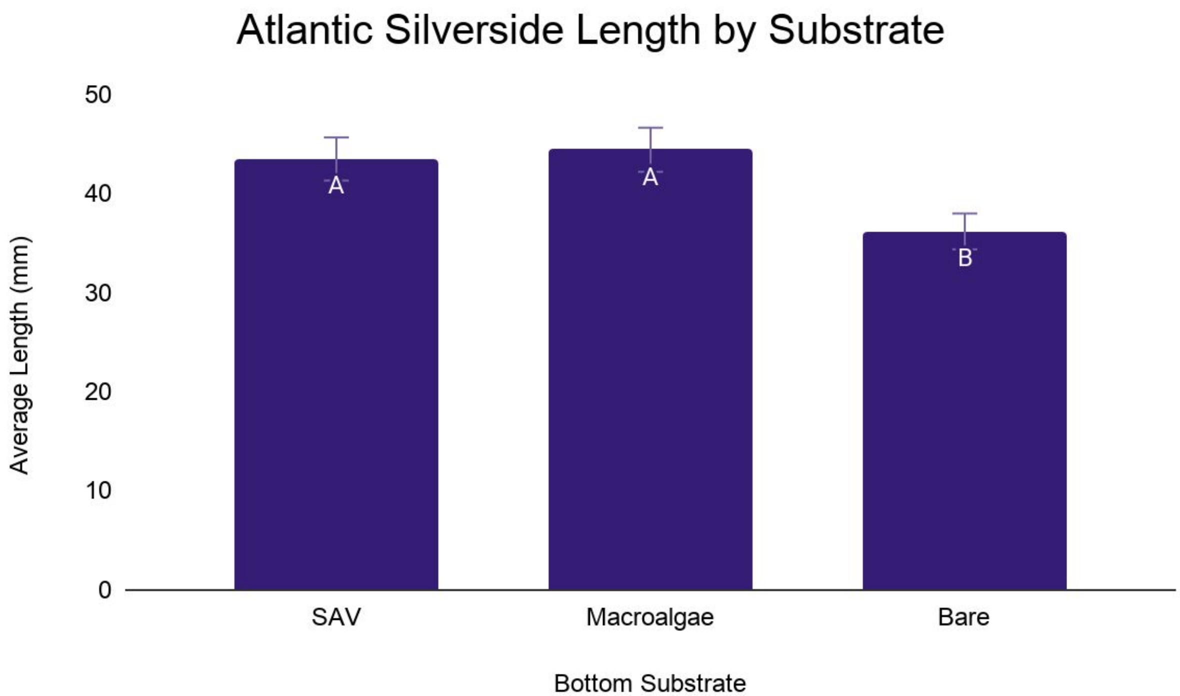


**Figure 17:** Average length of Atlantic silversides (*Menidia menidia*) by bottom substrate at SIMCZ (n=489). Tukey's HSD Post Hoc analysis showed bare surface to be significantly different from SAV (P=0.0033) and macroalgae (P=0.0020) but SAV and macroalgae to be not significantly different (P=0.8829). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where A is different from B.

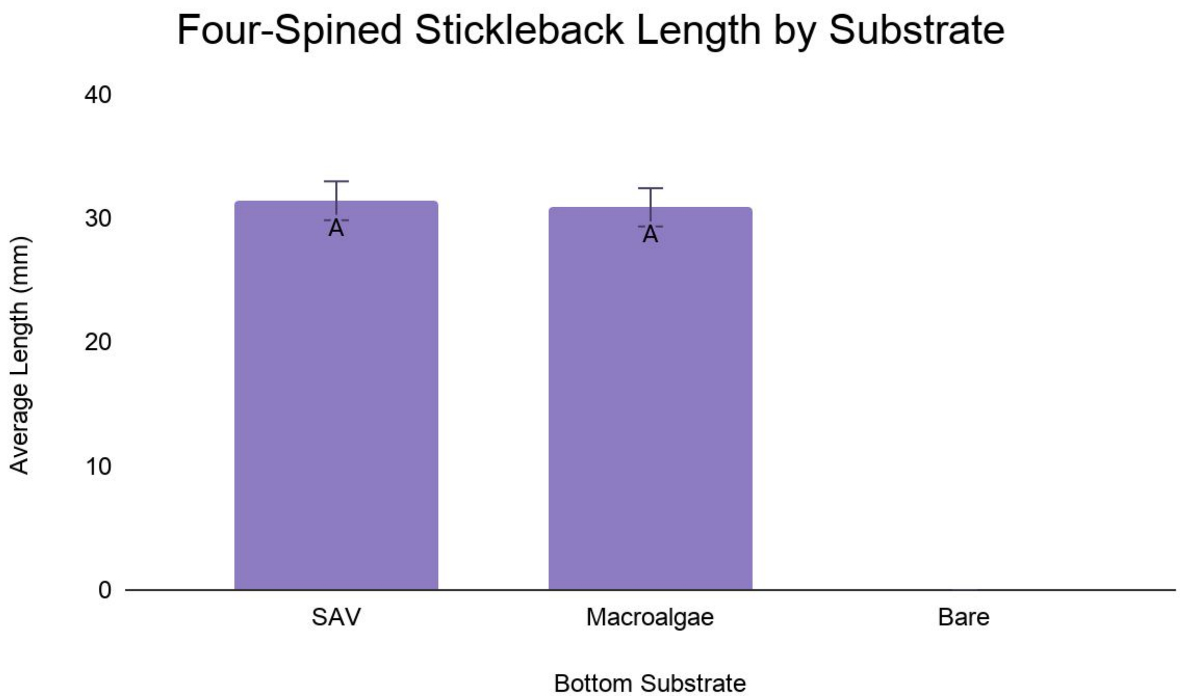


**Figure 18:** Average length of four-spined sticklebacks (*Apeltes quadracus*) at the two substrates they were found in at SIMCZ (n=302). A one-way ANOVA showed that there was not a significant difference between the two substrates in terms of size (P=0.5986). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where they are both A since there is not a significant difference.

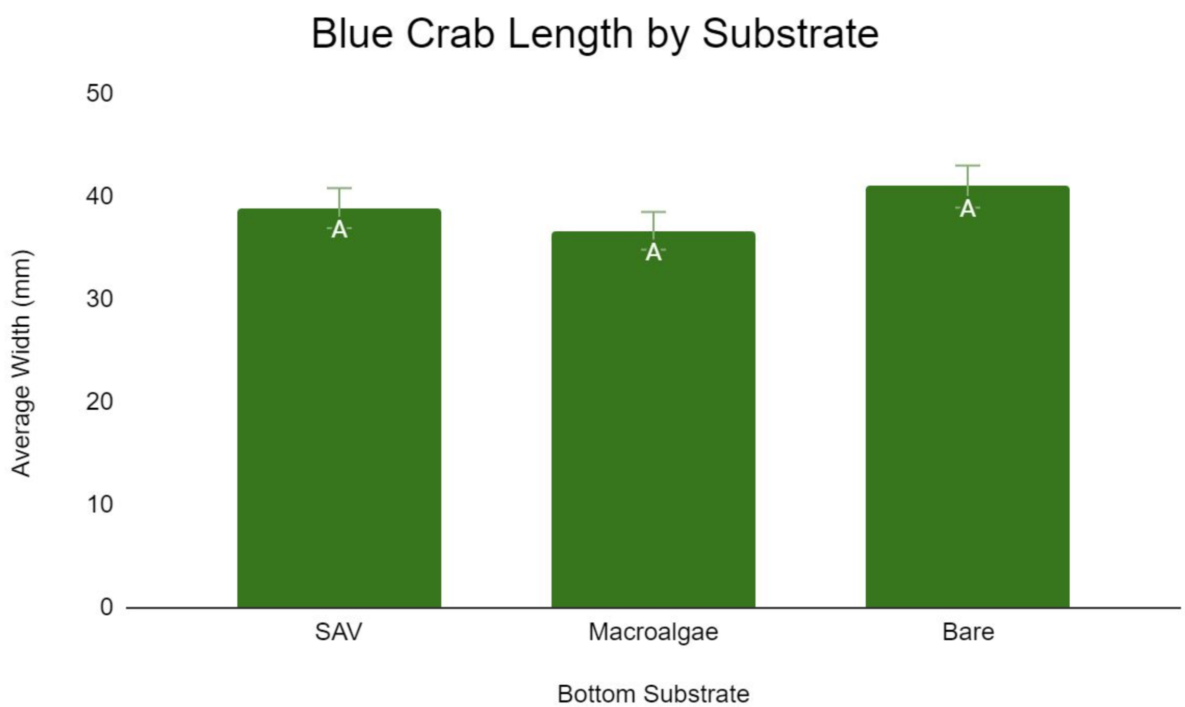


**Figure 19:** Average length of blue crabs (*Callinectes sapidus*) by bottom substrate at SIMCZ (n=77). Tukey's HSD Post Hoc analysis showed none of the groups to be significantly different (SAV-macroalgae: P=0.8375; SAV-bare: P=0.9000; macroalgae-bare: P=0.9000). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where they are all A since there are no significant differences.

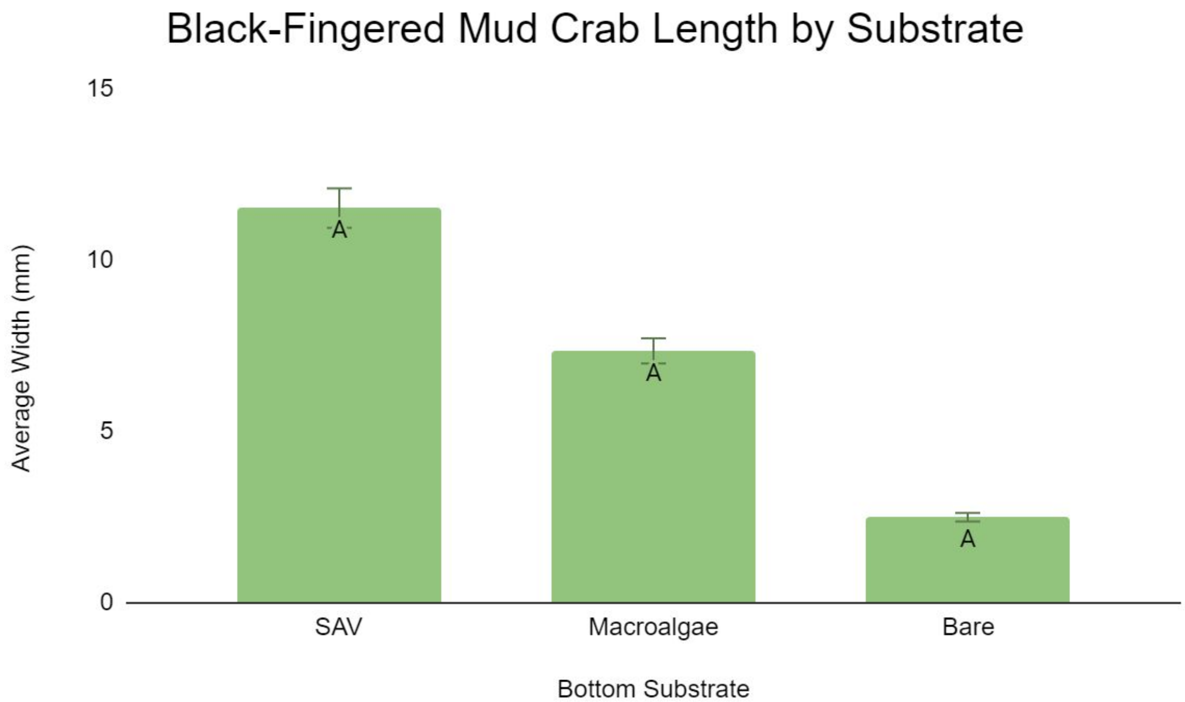


**Figure 20:** Average length of black-fingered mud crabs (*Panopeus herbstii*) by bottom substrate at SIMCZ (n=54). Tukey's HSD Post Hoc analysis showed none of the groups to be significantly different (SAV-macroalgae: P=0.0589; SAV-bare: P=0.0835; macroalgae-bare: P=0.5024). Error bars show 5% from the mean and the letters in each bar show where the significant differences lie where they are all A since there are no significant differences.

$$D = \frac{N(N-1)}{\sum n(n-1)} \quad H' = -\sum_{i=1}^{S} p_i \ln p_i \quad J(A,B) = \frac{|A \cap B|}{|A \cap B|}$$

**Figure 21:** Formulas used to calculate Simpson's Diversity (left), Shannon-Wiener values (center), and Jaccard similarity values (right).

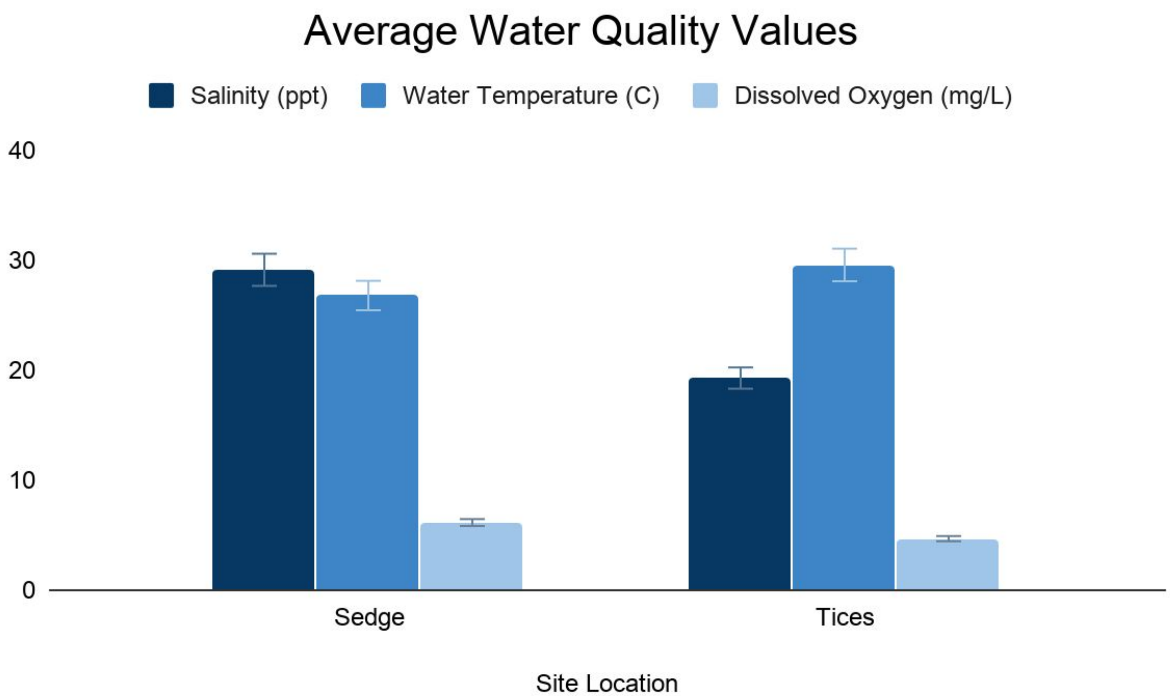


**Figure 22:** Water quality values for sites both within the SIMCZ and outside the SIMCZ were collected. This table displays the average salinity (ppt), water temperature (˚C), and dissolved oxygen (DO) (mg/L) for inside and outside of the SIMCZ. When comparing water quality between the sites within the conservation zone and outside the conservation zone, there was no significant difference between the water temperatures at the bare substrates (P=0.0580) nor between the DO at these locations (P=0.0981).

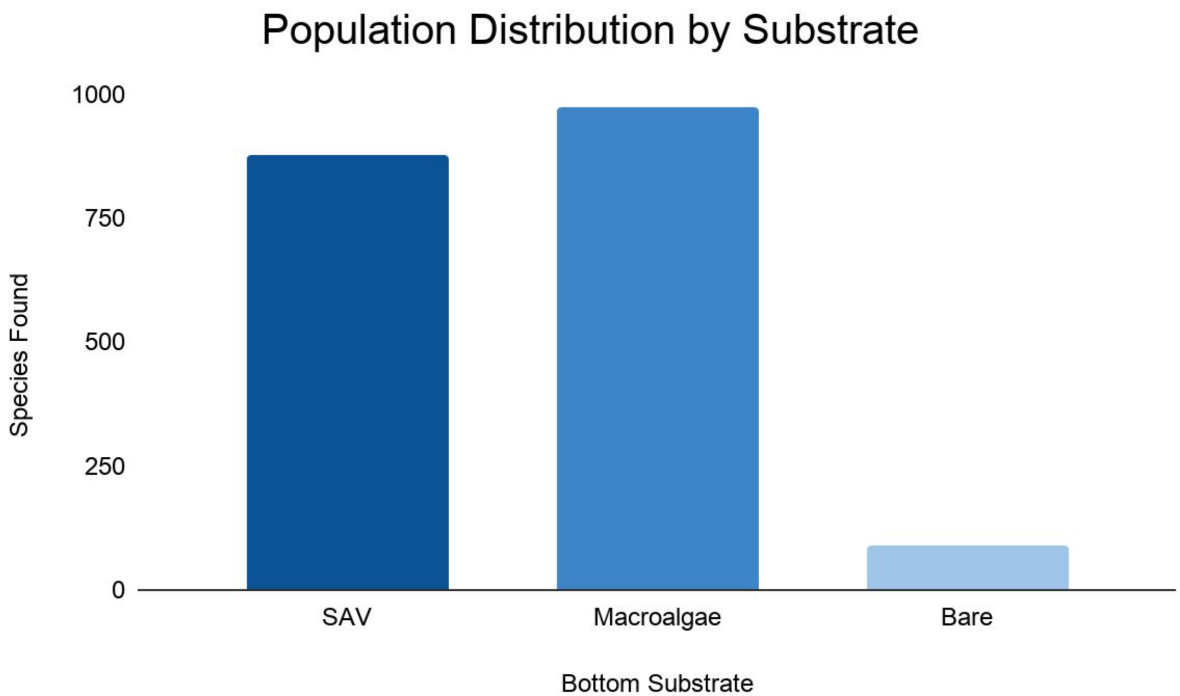


**Figure 23:** Inside the SIMCZ, the most amount of specimens, 974, were found at the macroalgae substrate, followed closely by the SAV substrate with 878 specimens, and the least amount of specimens found at the bare substrate, with 88 specimens

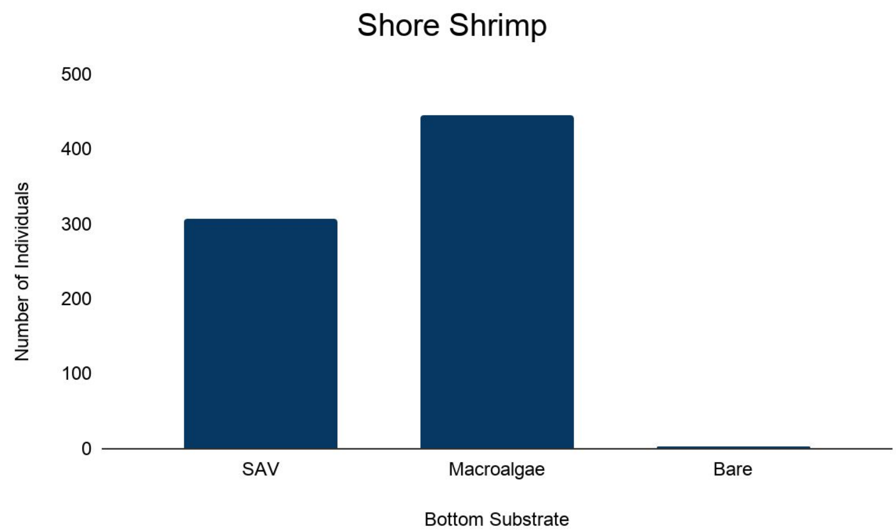


**Figure 24a**

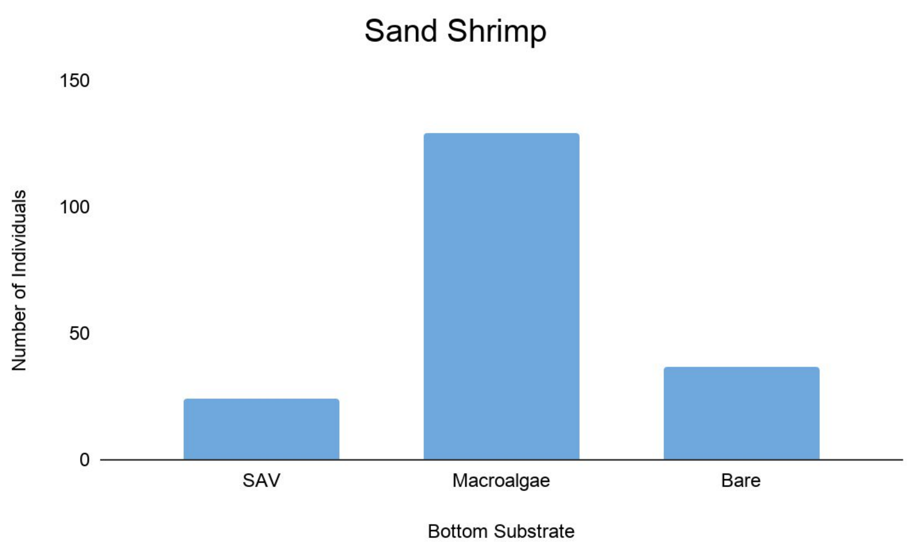


**Figure 24b**

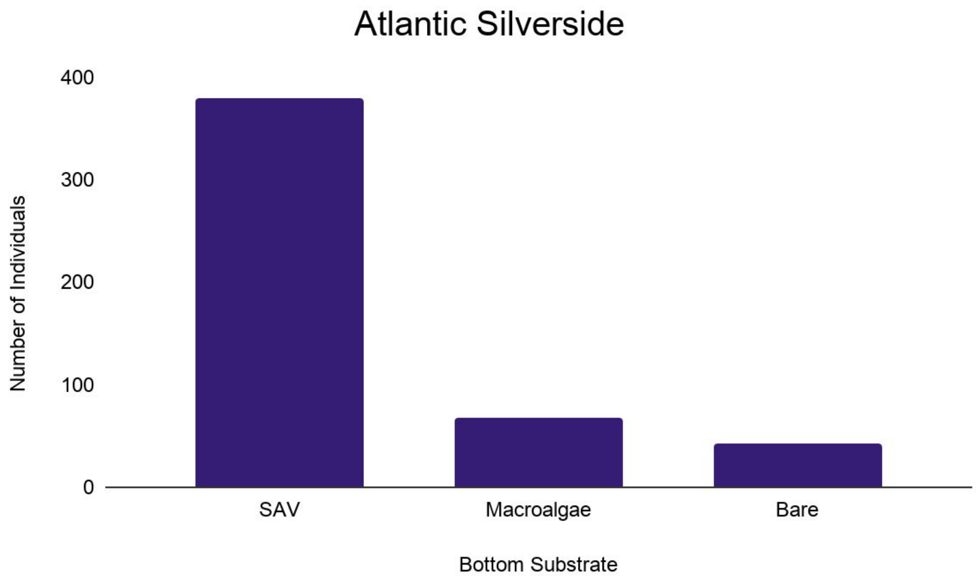


**Figure 24c**

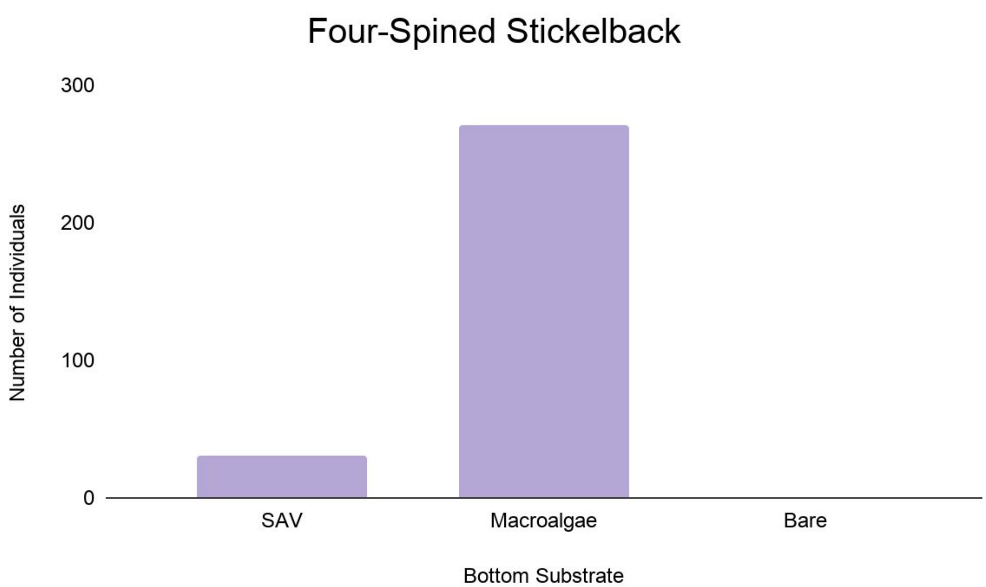


**Figure 24d**

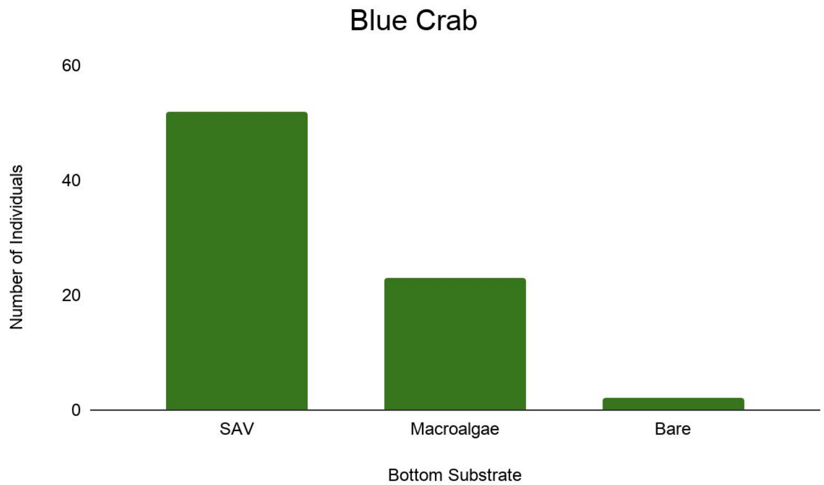


**Figure 24e**

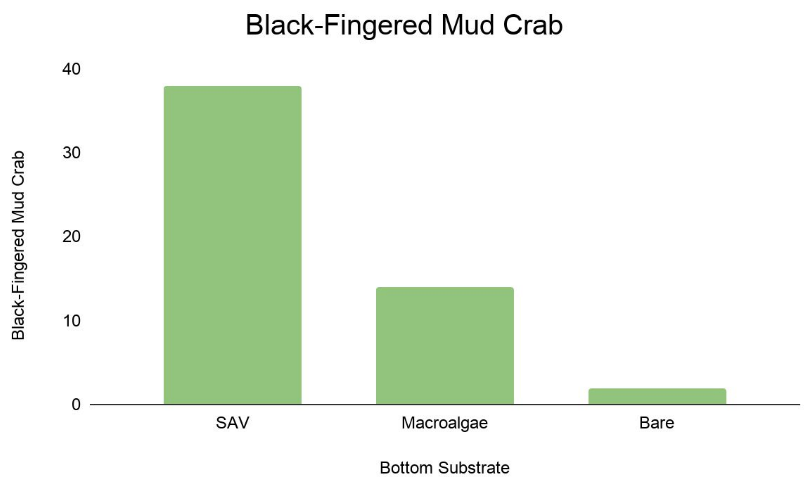


**Figure 24f**

**Figures 24a-f:** Among the six most prevalent species, which were shore shrimp, sand shrimp, Atlantic silversides, four-spined stickleback, blue crabs, and black-fingered mud crabs, three of them — Atlantic silversides, blue crabs, and black-fingered mud crabs — preferred the SAV substrate, while the other three — shore shrimp, sand shrimp and four-spined sticklebacks — preferred the macroalgae substrate. 77.7% of Atlantic silversides, 67.5% of blue crabs, and 70.4% black-fingered mud crabs were found in SAV substrates, while 59.1% of shore shrimp, 67.9% of sand shrimp, and 89.7% four-spined stickleback were found in macroalgae substrates.

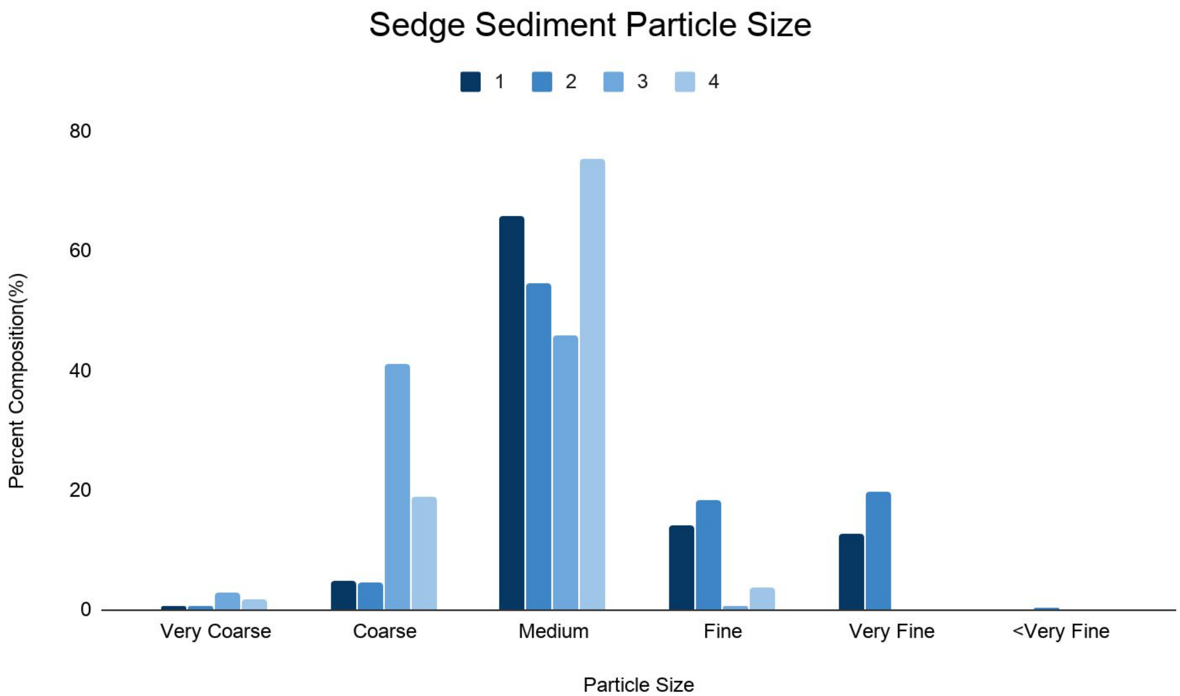


**Figure 25:** The majority of sand particles from samples taken within the SIMCZ were classified as medium. Samples taken within the SIMCZ had an average composition of 17.3% coarse particles, 60.4% medium particles, and 9.1% fine particles.

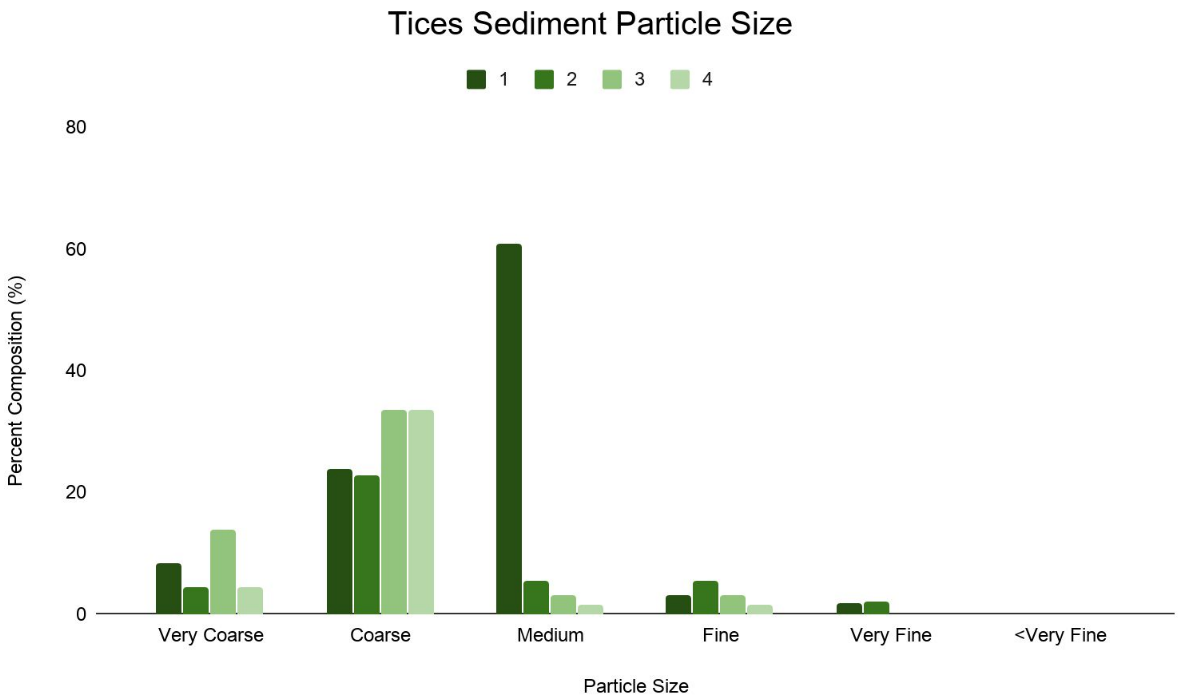


**Figure 26:** The majority of sand particles from samples taken outside the SIMCZ were classified as coarse. Samples taken outside the conservation zone had an average composition of 7.8% very coarse particles, 28.5% coarse particles, and 17.8% medium particles.

**Appendix** - 2020 SIMCZ Sampling Team

## KATE KILLIAN

Stevens Institute of Technology, Sophomore
Naval Engineering Major, Coastal Engineering Minor

## SARAH QUIGLEY

Berry College, Sophomore
Biochemistry Major, Spanish Minor

## BRADY NICHOLS

Bowdoin College, Freshman
Biology Major, Math Minor