2024 Sedge Island Marine Conservation Zone Biological Survey

Barnegat Bay, New Jersey

Samantha Arbeit, Katelyn Seay, Victoria Yakes
Advisor: Jason Kelsey
Save Barnegat Bay: Matt McCurdy Student Grant
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Abstract

The Sedge Island Marine Conservation Zone (SIMCZ), situated east of Ocean County, New Jersey, within Barnegat Bay, is the first marine conservation zone established in the state. SIMCZ was created to safeguard natural habitats and encourage species growth. Organisms within SIMCZ thrive due to the strict fishing and recreational regulations, as well as the area's extensive marshlands and winding water trails. Within the zone, migrating and breeding patterns are minimally affected by anthropogenic or meteorological threats. To study the biodiversity of the zone, students partnered with Save Barnegat Bay to collect and analyze species within SIMCZ over two nonconsecutive five-day periods in June and July 2024. Fish, shrimp, and crabs were counted and measured to identify significant differences in biodiversity and species size. Additionally, the study examined three types of substrates—submerged aquatic vegetation (SAV), macroalgae, and bare surface—to assess species diversity across different habitats. The Simpson's index supports that all substrates of SIMCZ provide adequate habitats for a variety of species. No significant long-term trends were found for the blue crab, mud crab, and shore shrimp populations, indicating a healthy and stable ecosystem. Data collected in June and July were analyzed for species abundance for comparison purposes to previous years. This year, there was a decrease in the species population attributed to the nursery nature of the zone. The majority of species count was found in macroalgae and SAV beds influenced by the abundant food source and protection the dense vegetation provides. Overall, data collected during the 2024 sampling supports that SIMCZ is a diverse and abundant ecosystem that properly sustains nursery and growth habitats.

Introduction

The Sedge Island Marine Conservation Zone, hereon known as SIMCZ, is a vital habitat for a variety of marine life. SIMCZ is located bayside at the southern end of Island Beach State Park, New Jersey, and is 1,900 acres in total (*State/Commonwealth/Territory*, 2023). Since SIMCZ is located within the Barnegat Bay, which is an estuary, its water is brackish and fluctuates in concentration depending on if the tide is outgoing or incoming. SIMCZ has remained the sole marine conservation zone in New Jersey since its establishment in 2001 by the New Jersey Department of Environmental Protection (*Marine Conservation Zone*, 2020). As defined by the National Oceanic and Atmospheric Administration (NOAA), a marine protected area is a "defined region designated and managed for the long-term conservation of marine resources, ecosystems services, or cultural heritage" (NOAA, 2019). In marine conservation zones, which are a type of marine protected area, commercial crabbing, fishing, or clamming are prohibited (Luell et. al, 2020). Additionally, the use of personal water vehicles, i.e. waverunners or jet skis, within 300 feet of SIMCZ is banned (NOAA, 2019). However, recreational activities are permitted. Some include clamming, boating, kayaking, fishing, or crabbing. Recreation within the zone is economically and ecologically beneficial; for example, the zone results in increased tourism and natural barriers from severe winds and stormwater.

Resulting from the strict fishing policies, SIMCZ is home to an abundance of species such as sea stars, clams, snails, crabs, and small sharks etc. Specifically though, this study is looking at crabs, shrimp, and fish found in SIMCZ in three main substrate types. Those substrate types are: bare surface, mixed macroalgae, and submerged aquatic vegetation (SAV). Bare surface consists of sand with little to no vegetation or algae present. Macroalgae consists mainly of sea lettuce (*Ulva lactuca*) and red algae (*Agardhiella sp.*). SAV is mostly comprised of eelgrass (*Zostera marina*) and widgeon grass (*Ruppia maritima*). The diversity in habitats allows for a wide variety of fauna to populate SIMCZ. Additionally, some key species in SIMCZ are Blue Crab (*Callinectes sapidus*), Shore Shrimp (*Palaemonetes sp.*), and Black-Fingered Mud Crab (*Panoeius herbstii*). These can be used as indicator species, meaning they show the overall health of SIMCZ.

In 2010, New Jersey Governor Chris Christie unveiled his 10-Point Plan to “address the ecological health of the 660-square-mile Barnegat Bay watershed” (*Governor’s Ten-Point Plan*, 2023). In addition to the various infrastructure upgrades and policy updates, his 10-Point Plan funded ten research projects focusing on Barnegat Bay. Research conducted in 2013 and 2017 concluded that there was no significant difference in biodiversity inside vs outside SIMCZ. But, they found that species physical size was smaller inside SIMCZ, implying that the conservation zone is a fish nursery.

Presently, these projects are funded by Save Barnegat Bay and the New Jersey Department of Environmental protection. Due to the longevity of the SIMCZ studies, the data can now be used to measure biodiversity trends over time, as well as to predict future trends that will be influenced by climate change and other external factors. The objective of this study is to record the quantity and size of crabs, fish, and shrimp species found in the three substrate types in SIMCZ. The purpose of this study is to contribute to the comprehensive, long-term trends within SIMCZ which can serve as a basis for future studies.

Methodology

Sample Sites

Samples were retrieved within SIMCZ, located bayside at the southern end of Island Beach State Park, New Jersey *(Figures 1 & A1*). Two samples were retrieved from each of three substrates: bare, macroalgae, and SAV, for a total of six samples, each day for a period of five days. Sampling occurred in mid-morning to early-afternoon during the week of June 24, 2024 and repeated the week of July 22, 2024.

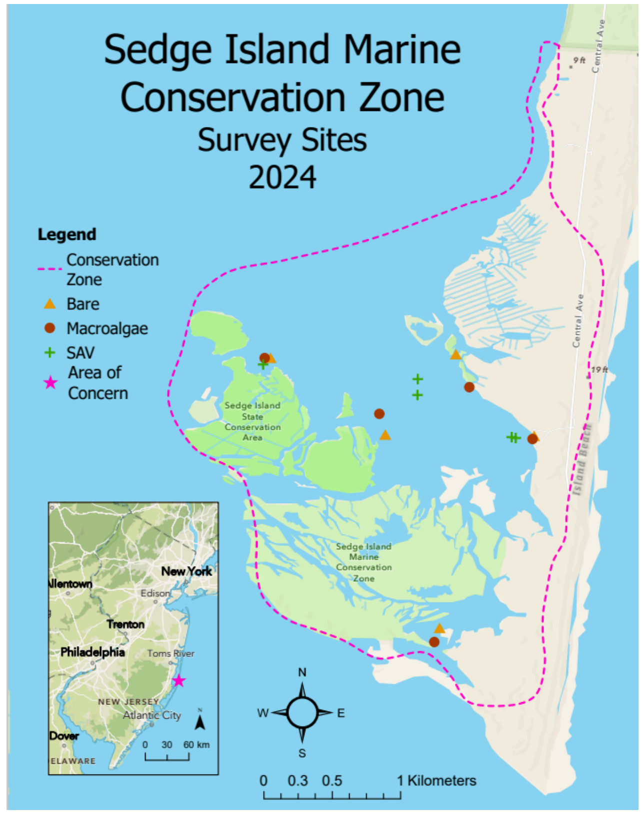

Figure 1: Survey sites in the 2024 SIMCZ Biological Survey, located bayside at the southern end of Island Beach State Park, New Jersey. Three site types are represented: bare surface, macroalgae, and submerged aquatic vegetation (SAV) within the conservation zone, for a total of 30 samples from 15 sites. See *Figure A1* for exact coordinates.

Procedure

One main piece of equipment used in this study was a 1 meter (diameter) stainless steel, encapsulation cylinder. The cylinder was used to encapsulate vegetation, species, and substrate while data collection occurred (*Figure 2*). Thus, ensuring that no marine life can enter or exit the surveying site while data is being collected, therefore preventing a species being repeatedly measured. Prior to dropping the cylinder in the water, an optimal spot is Selected. For the SAV and the macroalgae, a spot was selected with at least 50% cover of vegetation. For the bare surface there was minimal vegetation so there was no need to select a specific spot. The encapsulation cylinder was dropped off at each of the three sites twice, carefully aiming for the optimal spot. A handheld multimeter by Yellow Springs International (YSI) was used to measure various water parameters including salinity (ppt), water temperature (℃), and dissolved oxygen concentration (mg/L). Time, GPS coordinates (decimal degrees), depth (m), weather conditions, air temperature (℃), wind speed (kn), and tidal flow were also recorded for each site. A standard D-frame net was used to scoop the substrate out of the cylinder and place it into plastic bins. The bins were then combed through and the fish, shrimp, and crabs caught were placed into a container with bay water, while the vegetation was placed into a measuring container. After there were five consecutive scoops from the cylinder with no marine life in them, then the crabs, shrimp, and fish were inventoried. The first 20 of each fish and shrimp species were measured, the remaining were counted. For crabs, the first 20 were measured and the sex were recorded, as well as if the female crabs had an egg sponge. The recorded species were kept in a bin filled with bay water until the cylinder was dropped for the second time at the site, then they were released. Thus, preventing any marine life from being measured twice. The volumetric vegetation was measured for the macroalgae and SAV sites as well.

Figure 2: The metal cylinder, 1 m in diameter, once placed into the bay. Species were collected using a D-frame net (pictured), measured, and counted for data analysis.

Results

SIMCZ featured a diverse range of species, with a total of 21 different species identified across the entire zone. The most caught species was the Shore Shrimp which encompassed 55% of the whole catch throughout June and July and was caught most abundantly in macroalgae. The second highest species caught was the Three-spined Stickleback (*see Table A2 for all scientific names*) which encompassed 16.3% of the whole catch and was found only in macroalgae and SAV. Species overlapped in the substrates as well, all three substrates had Shore Shrimp, Sand Shrimp, Stickleback, Winter Flounder, Atlantic Silverside, Blue Crab, Mud Crab, and European Green Crab. SAV and bare surface shared no species; whereas, macroalgae and bare surface shared Lady Crab. SAV and macroalgae shared Grass Shrimp, American Eel, Northern Pipefish, and Tautog. SAV alone had Mantis Shrimp, Mummichog, and Black Sea Bass. Macroalgae alone had Skillet Fish, Nakey Goby, Rainwater Killifish, Jonah Crab, and Spider Crab (*Figure A1*). Overall, 2767 individuals were caught with 38.2% found in SAV, 57.6% found in macroalgae, and 4.2% found in bare surface. In June, a total of 1707 individuals were caught with 37.8% found in SAV, 55.8% found in macroalgae, and 6.37% found in bare surface (*Figure 3*). In July, a total of 1060 individuals were caught with 38% found in SAV, 61.1% found in macroalgae, and 0.85% found in bare surface. There were a couple species that preferred macroalgae as a home

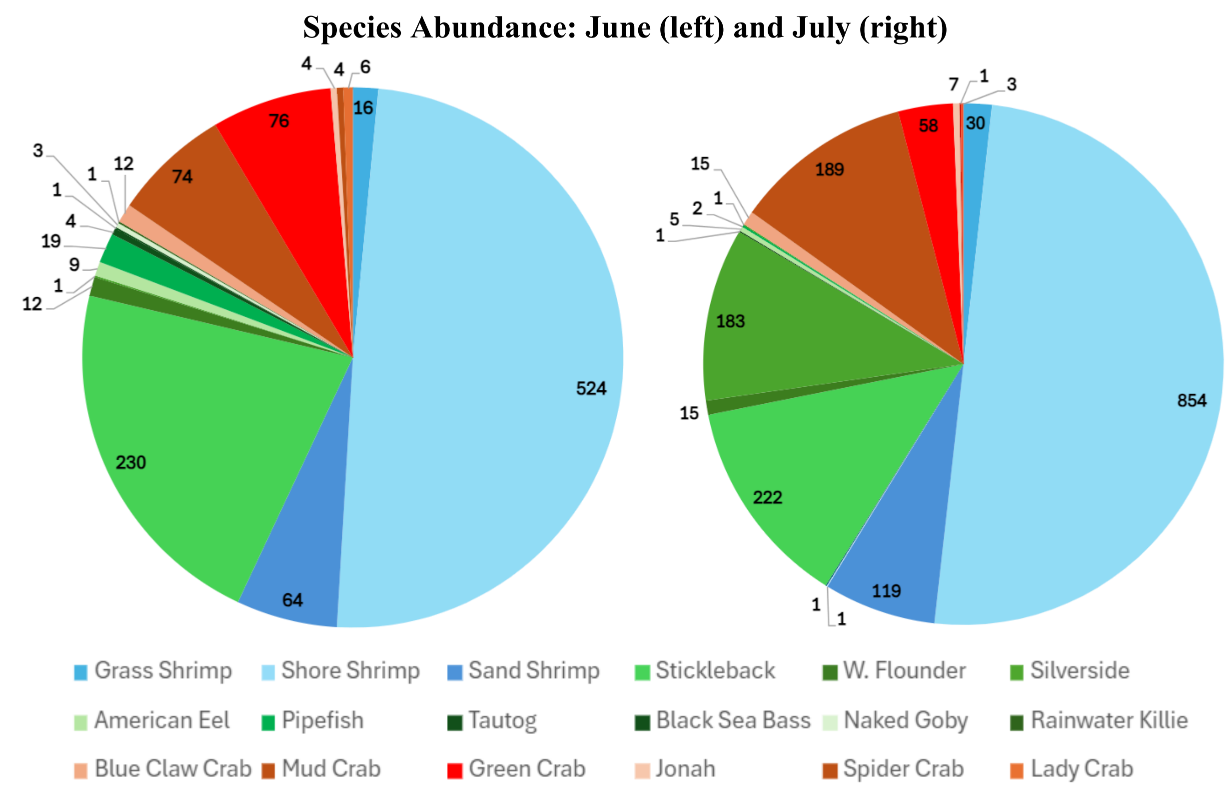

Figure 3: June (left) and July (right) fish, crab, and shrimp abundance from the 2024 SIMCZ Biological Survey. Species were collected during two nonconsecutive five-day periods. Specific species denoted with general colored categories: fish (green), crabs (red), and shrimp (blue). [n_{JUNE}=1707; n_{JULY}=1060]

over SAV beds. There was no species that preferred bare surface over SAV or macroalgae. Shore Shrimp and American Eel preferred macroalgae over SAV the most. A Student's t-test indicated no significant difference in species quantity between substrates in June and July (p=0.0895). To determine if there was a significant difference among the substrates, an analysis of variance (single-factor ANOVA) test was run for June and July separately (α=0.05). This statistical analysis showed that there was at least one significant difference among the means of substrates in both June (p=0.0016) and July (p=0.0027). To figure out exactly which substrates were significantly different, a Post-Hoc Tukey HSD test was run for both months (*Figure A2*). In both of these tests, treatments were A for SAV, B for macroalgae, and C for bare surface. The June test found that there is no significant difference between macroalgae and SAV (p=0.2360), significant difference between macroalgae and bare surface (p=0.001), and a significant difference between SAV and bare surface (p=0.0270). The July test found that there was no significant difference between macroalgae and SAV (p=0.2400), significant difference between macroalgae and bare surface (p=0.0020), and a significant difference between SAV and bare surface (p=0.0440).

To measure species diversity, a Simpson's Diversity Index (AKA Gini-Simpson index) was calculated (*Figures A3 and A4*). The Gini-Simpson index ranges from 0 to 1, where a higher value reflects greater diversity and a lower value indicates less diversity (Singh, 2024). As species numbers increase and their population distribution becomes more even, the diversity index approaches one. Additionally, a Shannon Diversity Index was used to assess species evenness (*Figure A3*). This index reflects the diversity of species within a community, increasing with both the number of species and the evenness of their distribution (Rain, 2024). Among the three substrates combined from June and July, macroalgae has the most diversity and most eveness among species, followed by SAV then bare surface (*Table A3*).

Long term trends for Blue Crab, Mud Crab, Shore Shrimp, and American Eel were conducted and depicted in line graphs (*Figures 4, 5, A5, and A6*). Correlations over time are as follows: Blue Crab (R^2=0.0996), Mud Crab (R^2=0.0389), Shore Shrimp (R^2=0.6684), and American Eel (R^2=0.3037).

Discussion

Biodiversity is an important factor to the health and integrity of an ecosystem. SIMCZ is home to many species of fish, crab, and shrimp that constitute a diverse and complex food web. A main objective of the SIMCZ project was to assess species diversity and dictate any trends that would indicate the health and prosperity of the environment.

The Gini-Simpson's index was utilized to observe the biodiversity within each substrate type, with values closer to 1 depicting high diversity and 0 for no diversity. All substrates had an index value greater than 0.6400, suggesting some level of diversity. The macroalgae had the highest index with a value of 0.7143 while also consisting of 57.6% of the total species collected. There was a significant difference in species quantity among substrates, supported with a p-value less than 0.05 for both weeks of sampling. Based on the Post-HOC Tukey analysis, bare surface accounts for the significant difference in species abundance, with p-values of less than 0.05 when compared to either SAV or macroalgae (*Figure A2*). Unique species were not found on bare surfaces, but found in each of the other habitat types (*Figure A1*). This was anticipated as the bare surface had much less species abundance compared to the two other substrates. The lack of food and protection from vegetation makes an inadequate habitat for many marine species, explaining the lack of organisms. Meanwhile, macroalgae and SAV is a primary producer of the marine food chain, sustaining several benthic animal communities such as crabs (Chodhary, 2021 and Perkinds-Visser, 1999). Macroalgae provides a good food source for many organisms whilst also providing shelter due to the dense vegetation, similar to the benefits provided by tall seagrass in the SAV substrate.

Sampling took place over two nonconsecutive weeks to provide data that could compare early summer to mid-summer biodiversity. Summer is a vital time for many marine organisms as it is the period after many reproductive cycles from spring. Due to the quick increase in spawning during the spring and early summer, it is expected to discover differences between June and July caused by the changes in species abundance and richness. There was a decrease in overall species count from June, 1707 organisms, to July, 1060 organisms. However, there was no significant difference between species quantity in each substrate for June and July based on the Student's t-test. Species distribution was even for both months with the largest category being shrimp located in SAV and Macroalgae habitats (*Figure 3*).

The SIMCZ Biological Survey is an ongoing project that has resulted in a database of species' abundance since 2016. The 2024 SIMCZ Biological Survey aimed to analyze the dataset for any distinct trends between a handful of key species: Blue Crab (*Callinectes sapidus*), Shore Shrimp (*Palaemonetes sp.*), and Black-Fingered Mud Crab (*Panoeius herbstii*). There were no significant trends for any of the looked upon species (*Figures 4, 5, A5, and A6*). The absence of a significant increase or decrease in species provides a positive outlook for the health of the bay ecosystem. The lack of trend indicates a stable ecosystem, where each respective species has reached an equilibrium within the food web to create a stable, but still diverse ecosystem. In a stable food web, as population numbers fluctuate, competition should as well, leading to an ongoing cycle that maintains the entire ecosystem. This is a possible explanation for the rise and fall of species abundance over the past eight years whilst maintaining no significant growth or decline in overall population.

For future studies, it will be important to analyze population numbers with respect to their position in the food web. For example, had there been a significant increase in blue crabs, this might indicate a decrease in the migratory bird population, which would indicate a disturbance in the bay food web. One important factor from the data is the consistent decline in blue crab abundance over the last three years (*Figure 4*). Blue crabs are essential to not only the ecological growth of the bay, but also the economy of the Jersey shore. A focus on the decline of blue crabs in SIMCZ is vital to maintain prosperity in the seafood industry and the marine food web. The abundance of the invasive green crab (*Carcinus maenas*) found during the survey could be an explanation for the decline in the blue crab population due to the increased competition (Smithsonian, 2024).

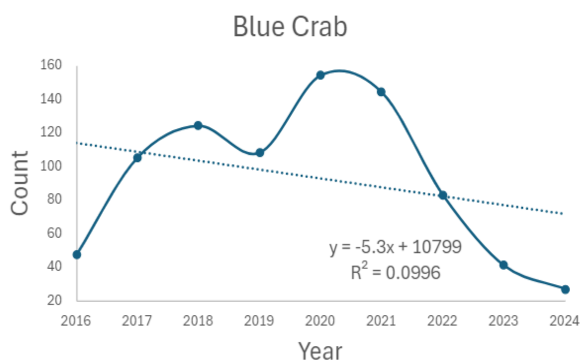

Figure 4: Blue crab (*Callinectes sapidus*) quantity during the 2016-2024 SIMCZ biological surveys. A steady decline from a high of 154 crabs in '20 to 27 crabs '24 was observed, although no significant linear trend was discovered. [R^2=0.0996, n=9]

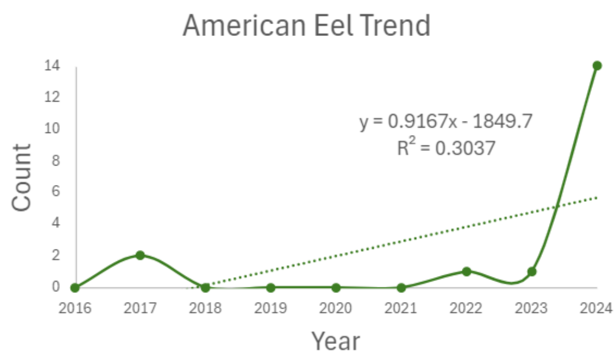

Figure 5: American eel (*Anguilla rostrata*) quantity during the 2016-2024 SIMCZ biological surveys. An increase from a total of 4 eels from '16-'23 to 14 eels in '24 was observed, although no significant linear trend was discovered. [R^2=0.3037, n=9]

A finding of the 2024 survey showed a large increase in American Eels (*Anguilla rostrata*) collected (*Figure 5*). In 2024, 14 eels were collected and, compared to the previous data's mean of 0.5 eels per year, considered an upper outlier as per the Tukey outlier method. This sudden increase could be due to the aforementioned blue crab decline. Blue crabs are a predator of elvers, an early stage eel, and a decrease in the crab population would explain the increase in eel count. Additionally, American Eels rely on the Gulf Stream for migration from the ocean up into inland territories and, with an increase in global warming, the ocean's currents are slowing in certain areas causing a delay in migration patterns (*The Incredible American Eel*, 2022 and Piecuch, 2023). If future SIMCZ surveys propose similar populations for American Eels, it will be important to monitor the long-standing effects of global warming.

Conclusion

In conclusion, the 2024 SIMCZ Biological Survey offers valuable insights into the diverse and stable marine ecosystem within the Sedge Island Marine Conservation Zone. The study confirmed significant species variation across different substrate types, with macroalgae and SAV supporting the greatest biodiversity. The findings suggest that the conservation zone continues to serve as a crucial nursery for marine life, particularly for key species such as Blue Crab, Shore Shrimp, and Black-Fingered Mud Crab. The stability of these species over time indicates a balanced ecosystem, despite seasonal fluctuations in species abundance. The unexpected increase in American Eels highlights increased predators or the potential impact of climate change on migration patterns, warranting further investigation. Overall, the data from this study contribute to the long-term monitoring of SIMCZ, helping to inform future conservation efforts and ensure the ongoing health of this critical marine habitat.

Acknowledgements

All species were collected in accordance with NJDEP Scientific Collecting Permit #2024-1825. We would like to thank Save Barnegat Bay for allowing us to complete this research. We are also grateful to the New Jersey Division of Fish and Wildlife for supporting SIMCZ. Additionally, we would like to thank the Marine Academy of Technology and Environmental Science for providing supplies necessary for this project. Lastly, an immense thank you in honor of Matt McCurdy for allowing this study to continue.

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Appendix

Table A1: Geographic coordinates represented in decimal degrees for all sample sites in the 2024 SIMCZ Biological Survey. Points were logged using a Garmin 73 Handheld. Midpoints calculated as the center point on a linear line between point pairings in June and July. Midpoints are represented in *Figure 1*.

June 2024				July 2024				Midpoint	
Date	Site	LAT	LONG	Date	Site	LAT	LONG	LAT	LONG
	Bare	39.78929	-74.10777		Bare	39.78900	-74.10700	39.789145	-74.107385
	Algae	39.79113	-74.10658		Algae	39.79000	-74.10900	39.790565	-74.107790
24	SAV	39.79171	-74.10537	22	SAV	39.79200	-74.10500	39.791855	-74.105185
	Bare	39.79385	-74.11503		Bare	39.79496	-74.11543	39.794405	-74.115230
	Algae	39.79506	-74.11611		Algae	39.79371	-74.11515	39.794385	-74.115630
25	SAV	39.79391	-74.11530	23	SAV	39.79398	-74.11617	39.793945	-74.115735
	Bare	39.79460	-74.10256		Bare	39.79470	-74.10255	39.794650	-74.102555
	Algae	39.79242	-74.10182		Algae	39.79236	-74.10146	39.792390	-74.101640
26	SAV	39.79293	-74.10516	24	SAV	39.79296	-74.10517	39.792945	-74.105165
	Bare	39.78912	-74.09742		Bare	39.78900	-74.09700	39.789060	-74.097210
	Algae	39.78894	-74.09734		Algae	39.78874	-74.09730	39.788840	-74.097320
27	SAV	39.78887	-74.09947	25	SAV	39.78895	-74.09747	39.788910	-74.098470
	Bare	39.77597	-74.10381		Bare	39.77586	-74.10354	39.775915	-74.103675
	Algae	39.77502	-74.10410		Algae	39.77487	-74.10397	39.774945	-74.104035
28	SAV	39.78901	-74.09879	26	SAV	39.78893	-74.09870	39.788970	-74.098745

Table A2: All species of fish, shrimp, and crabs caught during the 2024 SIMCZ Biological Survey. Species denoted with common name (left) and scientific name (right).

Fish, Shrimp, and Crabs Species List	
Common Name	Scientific Name
American Eel	*Anguilla rostrata*
Atlantic Silverside	*Menidia menidia*
Black Sea Bass	*Centropristis striata*
Black-Fingered Mud Crab	*Panoeius herbstii*
Blue Crab	*Callinectus sapidus*
European Green Crab	*Crancinus maenas*
Grass Shrimp	*Palaemonetes paludosus*
Jonah Crab	*Cancer borealis*
Lady Crab	*Ovalipes ocellatus*
Mantis Shrimp	*Squilla empusa*
Mummichog	*Fundulus heteroclitus*
Naked Goby	*Gabiosoma bosc*
Northern Pipefish	*Syngnathus fuscus*
Rainwater Killifish	*Lucania parva*
Sand Shrimp	*Crangon septemspinosa*
Shore Shrimp	*Palaemonetes sp.*
Skillet Fish	*Gobiesox strumosus*
Spider Crab	*Lbinia emarginata*
Tautog	*Tautog onitis*
Three-Spined Stickleback	*Gasterosteus aculeatus*
Winter Flounder	*Pseudopleuronectes americanus*

Table A3: Shannon and Gini-Simpson diversity indexes found for each substrate calculated by formulas in *Figure A3* and *Figure A4*.

Substrate	Shannon Index	Gini-Simpso
SAV	1.4565	0.646
Macroalgae	1.7105	0.714
Bare surface	1.3287	0.643

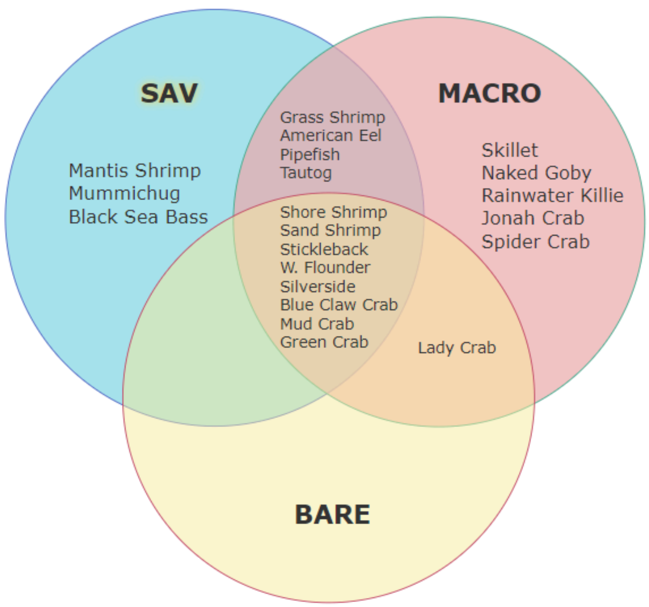

Figure A1: Substrate locations of species appearance during the 2024 SIMCZ Biological Survey. Species were collected during two nonconsecutive five-day periods in June and July.

June 2024

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.4380	0.2364640	insignificant
A vs C	4.2502	0.0273617	* p<0.05
B vs C	6.6882	0.0013083	** p<0.01

July 2024

treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.4099	0.2434545	insignificant
A vs C	3.8696	0.0442073	* p<0.05
B vs C	6.2795	0.0021395	** p<0.01

Figure A2: Post-hoc Tukey HSD for species abundance per substrate type to determine significant difference in 2024 SIMCZ species quantity. Significant difference between bare surface (C) and both SAV (A) and macroalgae (B). [α=0.05]

$$D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

$$H = -\sum[(p_i) \times \log(p_i)]$$

Figure A3: Formulas used to calculate Simpson's index (left) and Shannon's Diversity index (right) (*Singh*, 2024 and *Rain*, 2024).

$$\text{Gini-Simpson index} = (1 - D) = 1 - \left(\frac{\sum n_i(n_i - 1)}{N(N-1)}\right)$$

Figure A4: Gini-Simpson index formula which is used to interpret species diversity in an easier way. The Gini-Simpson index is the complement of the Simpson's index (Singh, 2024).

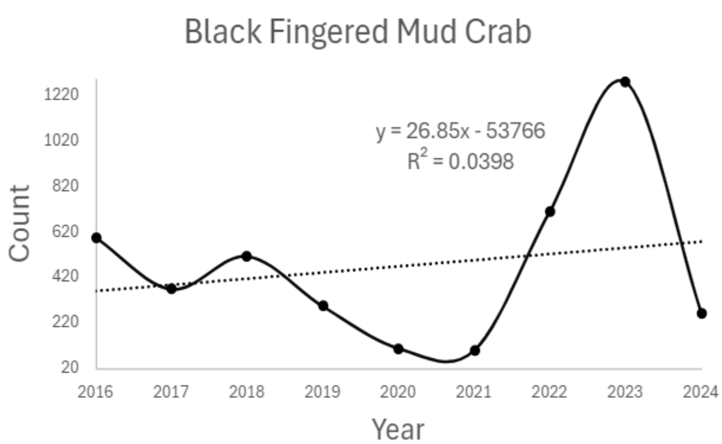

Figure A5: Black Fingered Mud Crab (*Panoeius herbstii*) quantity during the 2016-2024 SIMCZ biological surveys. A decrease from a total of 1281 crabs in '23 to 263 crabs '24 was observed, although no significant linear trend was discovered. [R^2=0.0398, n=9]

Figure A6: Shore Shrimp (*Palaemonetes sp.*) quantity during the 2016-2024 SIMCZ biological surveys. A steady increase from ‘16 to ‘24 was observed. Although there is no significant linear trend, there is mild correlation for the growth of the shore shrimp population over time. [R^2=0.6684, n=9]