US Army Corps
Of Engineers®
Charleston District

Post 45 Mitigation Reef Monitoring
Final Report

April 2024

Executive Summary

In June 2015, the U.S. Army Corps of Engineers (USACE), Charleston District completed an Environmental Impact Statement (EIS) to assess impacts associated with Charleston Harbor (Post 45) Deepening Project. The EIS predicted that up to 28.6 acres of hard bottom habitat may be directly impacted due to the project. The EIS included a 10-year recovery Habitat Equivalency Analysis (HEA) to determine the required compensatory mitigation, approximately 33 acres. As such, USACE proposed to construct eight new artificial reefs using excavated limestone rock material removed from the channel. Six reefs were designated as beneficial use reefs while two reefs (MitReefs) mitigated for the lost ecological function of the hardbottom habitat. As agreed upon with NOAA Fisheries, USACE has coordinated monitoring over the past five years to document recruitment and mitigation success at the two mitigation reefs. This report serves as the fifth and final report to document the success of the mitigation reefs.

Table of Contents

1.0 Background

In accordance with the Charleston Harbor Deepening Project (Post 45) Mitigation Planning and Monitoring and Adaptive Management Plan (USACE 2015), annual mitigation monitoring was conducted annually for five years post reef construction. Bathymetry and multispectral backscatter data was collected to determine relief, rugosity, and interstitial area of the mitigation reefs. Biological monitoring was also conducted annually to assess the fish and invertebrate populations at the mitigation reefs. USACE, NOAA Fisheries, and SCDNR established successful mitigation as fish and invertebrate species similarity between the mitigation reefs and the impact area.

2.0 Summary

The total area identified by the multispectral backscatter classification as hardbottom is 41.2 acres (21.6 acres for MitReef 1 and 19.6 acres for MitReef 2). Overall, MitReef 2 had an average rugosity of 0.948 microns. The average rugosity for MitReef 1 is 0.927 microns. The average relief of MitReef 2 is 5.6 ft. and 6.3 feet for MitReef 1.

Twelve of the 13 (92%) target finfish species seen by divers in the deepening impact area in March 2016 were also seen at MitReef sites during 2019-2023 across survey techniques (success was previously defined at 75%). Target invertebrate taxa at the MitReef sites comprised 37% of all invertebrates, and in order of prevalence were represented by hard corals (43%), sponges (36%), and soft corals (21%). Temporal invertebrate coverage succession was evident at the MitReef sites. Through 2022, sponge and hard coral density at MitReef sites significantly exceeded respective impact area densities; however, species compositions differed. Soft coral density, species ratios, and size distributions were significantly lower at MitReef sites in 2022 than observed at the impact area in 2016. Despite these differences, a more in-depth examination concluded that the MitReef was a success concerning invertebrate colonization.

Based on the above results from the monitoring, the mitigation reefs successfully met the compensatory mitigation requirements of the Charleston Harbor (Post 45) Deepening Project.

References

United States Army Corps of Engineeres, Charleston District (USACE). 29 April 2015. Charleston Harbor Deepening Project (Post 45) Charleston, South Carolina Mitigation Planning and Monitoring and Adaptive Management Plan.

Appendix 1

Post 45 Mitigation Reef Surveys Final Update

Post 45 Mitigation Reef Surveys Final Update

USACE Charleston District

March 26, 2024

Report Prepared by: Jennifer Kist

1. OVERVIEW

In 2018 two mitigation reefs and six beneficial use reefs (Figure 1) were constructed from materials dredged from the Charleston Entrance Channel. Bathymetry and multispectral backscattered data were collected, processed and analyzed to assess any changes to the reefs that could affect their environmental impact. The results of that analysis comparing the before and after construction were provided in a report on January 2019.

This report provides the area of hardbottom as estimated using multispectral multibeam backscatter, as well as the estimated relief and rugosity of the hardbottom area for the two mitigation reefs. Post construction surveys of the mitigation reefs were collected annually (Table 1). The report “Change Analysis for the Post 45 Mitigation and Beneficial Use Reefs Update” written on 10/5/2021 performed an analysis of the pre and post construction conditions of the mitigation reefs and two of the beneficial use reefs.

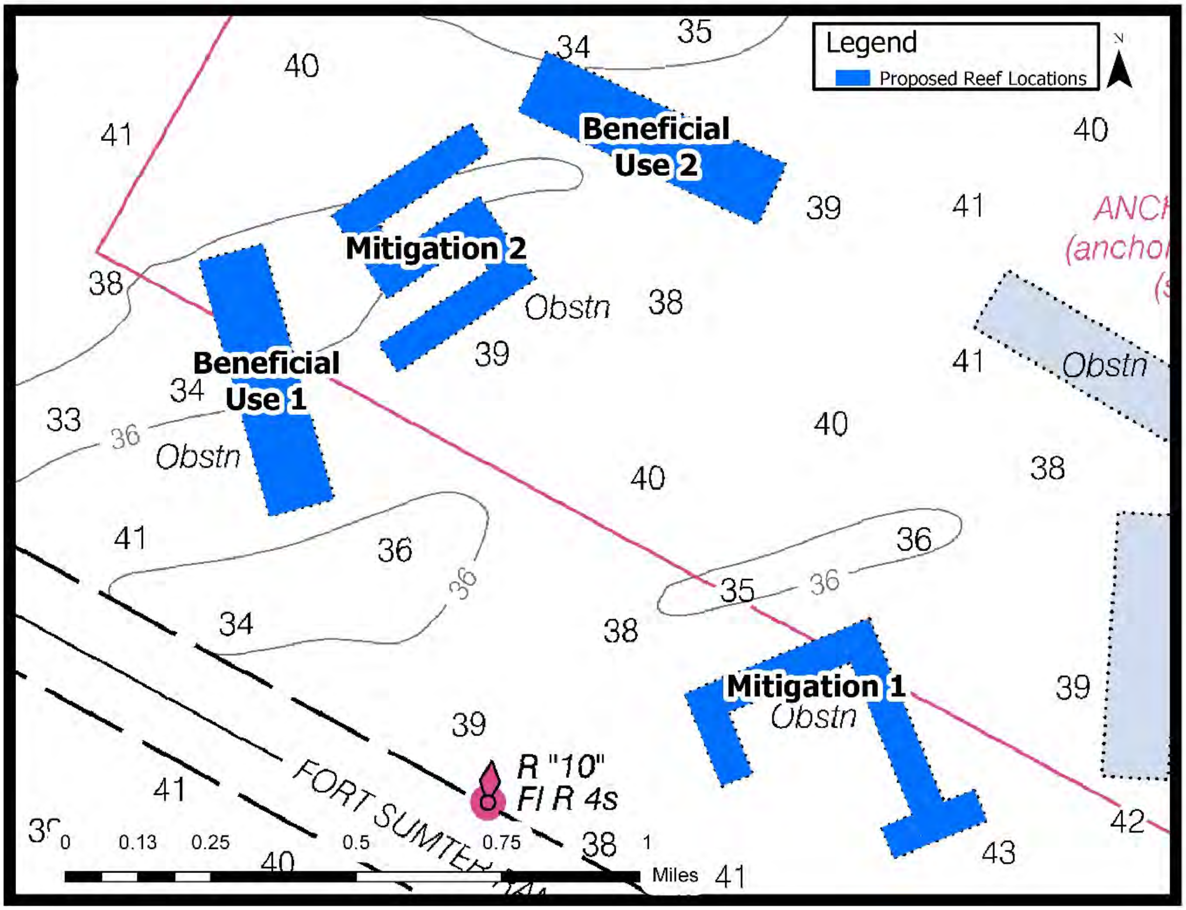


Figure 1. Proposed outlines of the beneficial use and mitigation reefs.

Table 1. Bathymetric data collection over the mitigation reef locations.

Date	Bathymetry	Backscatter	Frequency	Resolution	Type of Survey
4/26/2018	X	X	400 kHz	0.5 ft	Before Dredge
11/20/2018	X	X	400 kHz	0.2 ft	After Dredge
4/6/2020	X	X	400 kHz	0.2 ft	Condition Survey
8/25/2021	X	X	400, 300, 200 kHz	0.2 ft	Condition Survey
7/12/2023	X	X	400, 300, 200kHz	0.2 ft	Condition Survey

2. PROCEDURE and PRODUCTS

The bathymetric dataset collected on 7/12/2023 was used for analysis in this report. The USACE Charleston District survey team surveyed the mitigation reef areas using an R2sonic 2022 multibeam to collect multibeam data. Hypack was used for acquisition, processing, and quality control of the multibeam data. Gridded surfaces were created at a resolution of 0.2 feet using the average depth value for the gridding methodology. A visual of the bathymetric surfaces from 2023 is shown in Figure 2.

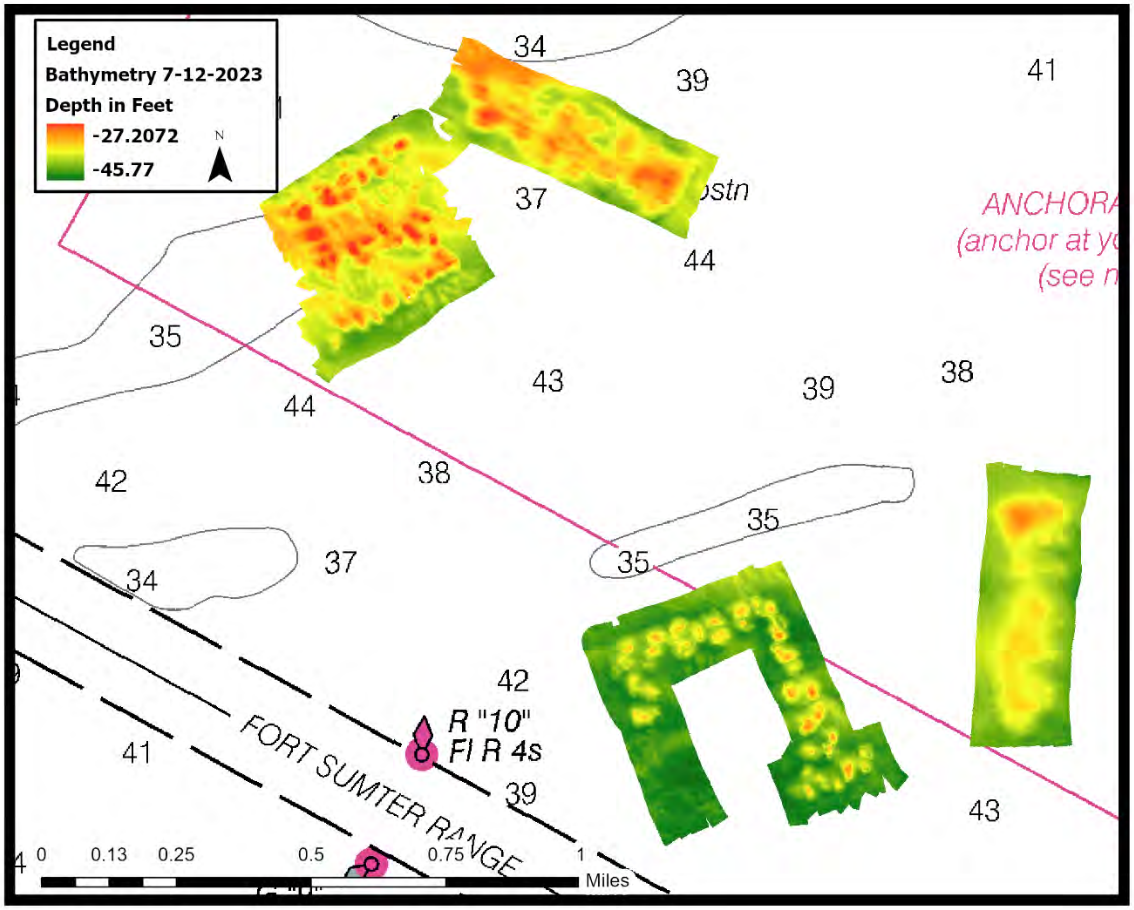


Figure 2. Bathymetric surfaces of the data collected on 7-12-2023 at a 0.2ftx0.2ft resolution (average gridded surface).

After multibeam data was processed the resulting .gsf files and reference grid were imported into Fledermaus Geocoder Toolbox, which was used to create backscatter mosaics at each of the collected frequencies - 400, 300 and 200kHz. The 0.2 x 0.2 ft. resolution bathymetric grids were used as reference surfaces for the backscatter processing. The three backscatter mosaics were then imported into ArcGIS Pro where the composite banding tool was used to develop a multispectral backscatter mosaic using the 400kHz frequency as the red band, 300 kHz as the green band, and the 200 kHz as the blue band. Figure 3 displays the multispectral backscatter surface over mitigation reef 2. Figure 4 displays the multispectral backscatter surface over mitigation reef 1.

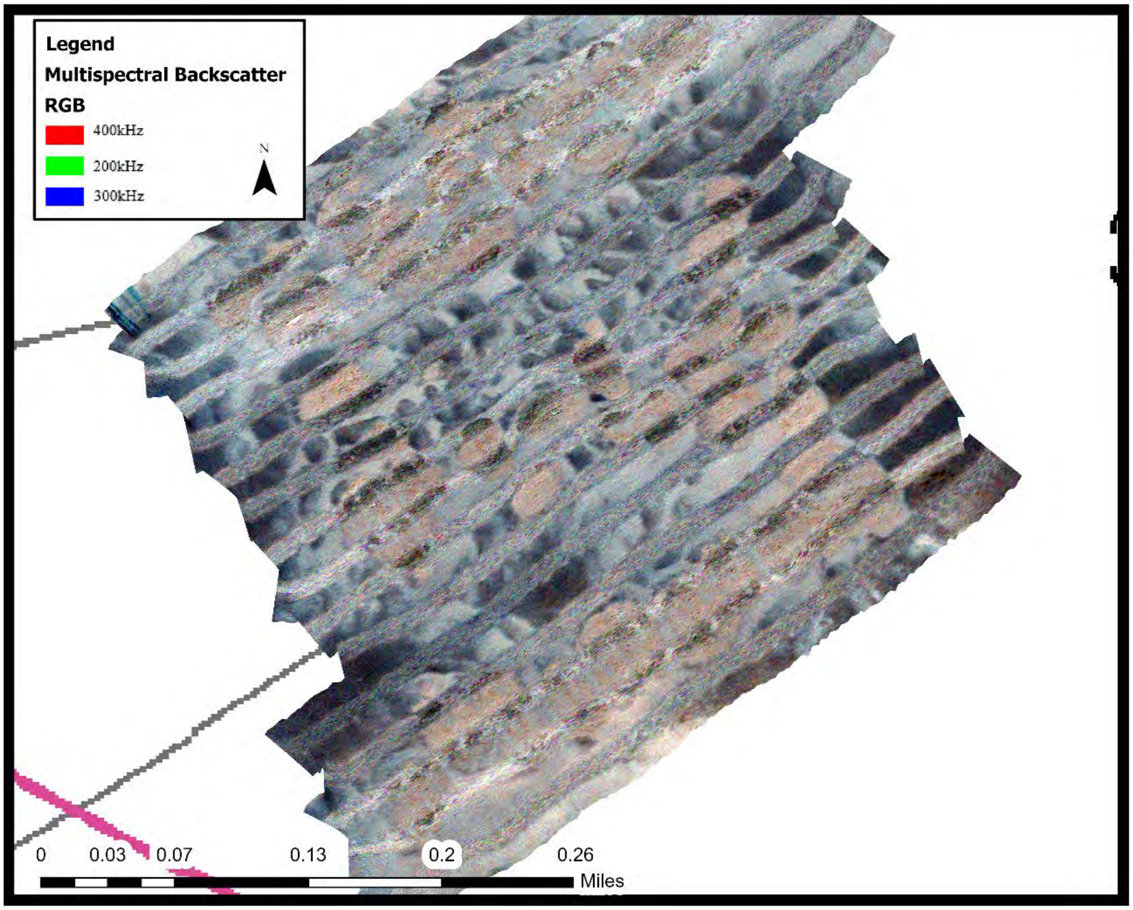


Figure 3. Multispectral Backscatter surfaces of Mitigation Reef 2 developed from the multibeam data collected on 7-12-2023.

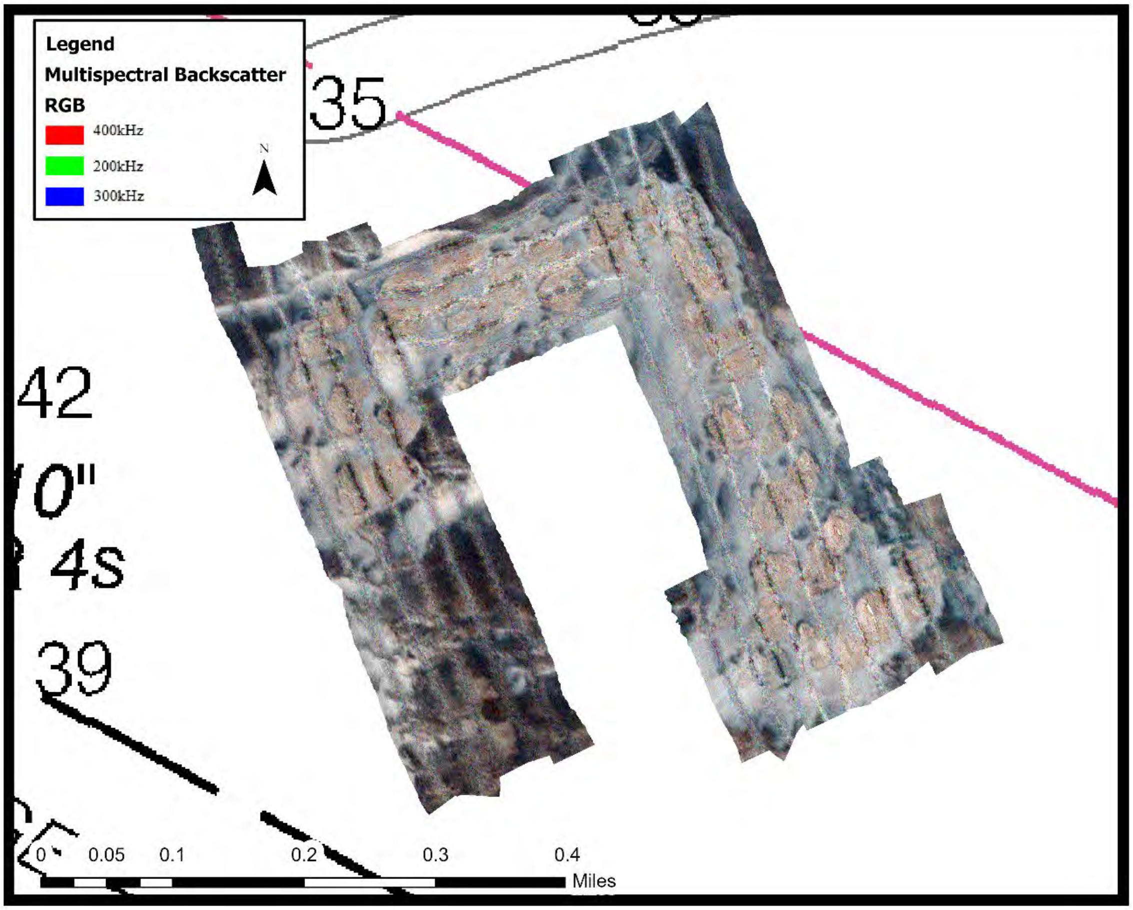


Figure 4. Multispectral Backscatter surfaces of Mitigation Reef 1 developed from the multibeam data collected on 7-12-2023.

Using a supervised classification technique called Train Random Trees Classifier in ArcGIS Pro, the multispectral backscatter mosaics displayed in Figures 3 and 4 were classified to create shapefiles encompassing areas in the mosaic most likely associated with the densest materials (i.e., hardbottom). Due to noise in the backscatter data, primarily around the nadir location, some hand editing was done to the shapefile using the 3d visualizations tool. Hand editing was completed by visual analysis of the grids in ArcGIS Scene Viewer. After assessing the multispectral backscatter mosaics draped over the bathymetric data, as shown in Figure 5 (MitReef 2) and Figure 6 (MitReef 1), it is reasonable to conclude that the areas with higher responses at the 400 kHz frequency (red) are the densest material and thus are most likely hardbottom. Figure 7 shows the outlines in red of the locations determined to be hardbottom using the multispectral backscatter. For ease of discussion, each hardbottom location was assigned a number sequentially for both mitigation reefs. To verify this information bottom samples would need to be collected in these locations and compared to the bathymetric and backscatter grids.

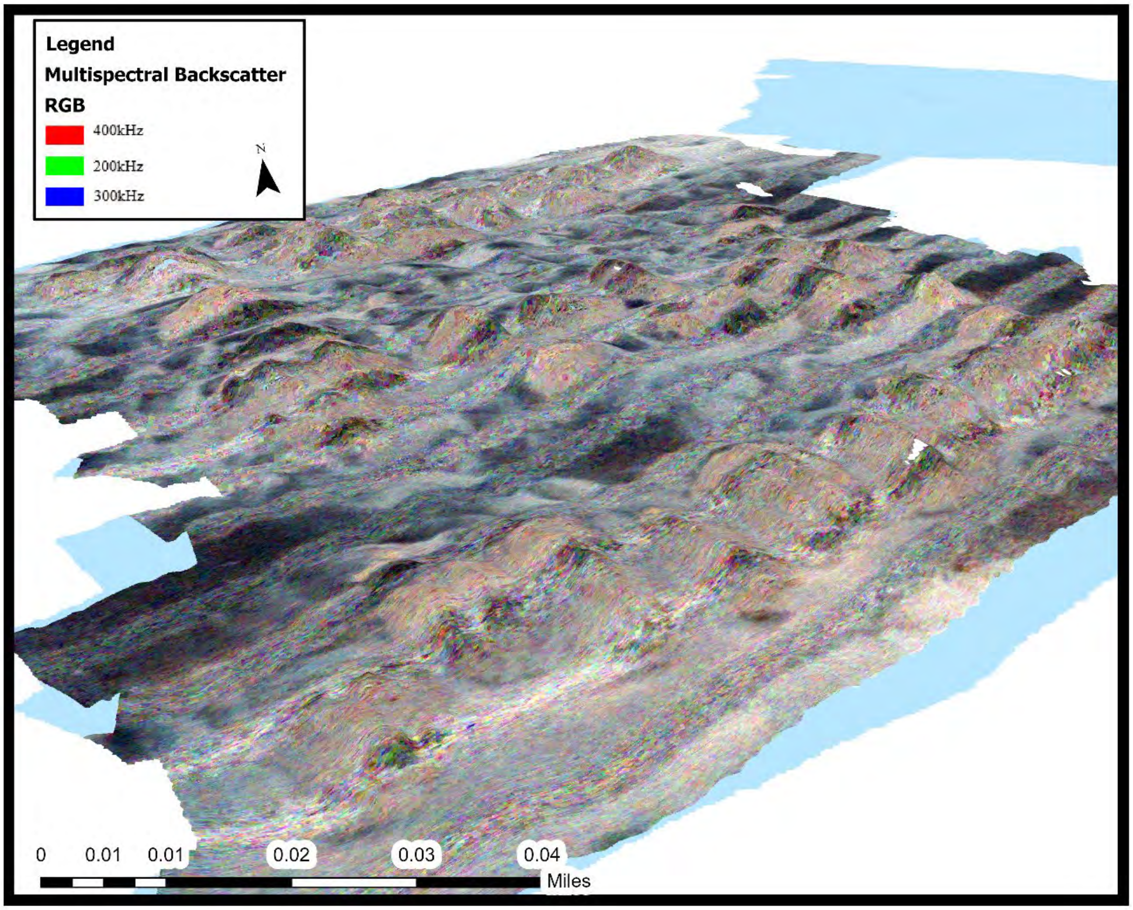


Figure 5. Multispectral Backscatter surface of Mitigation Reef 2 draped over the bathymetric surface from the same survey in 3d demonstrating the red band corresponding to increase in height and thus correlating the red banded backscatter data to the mitigation reefs.

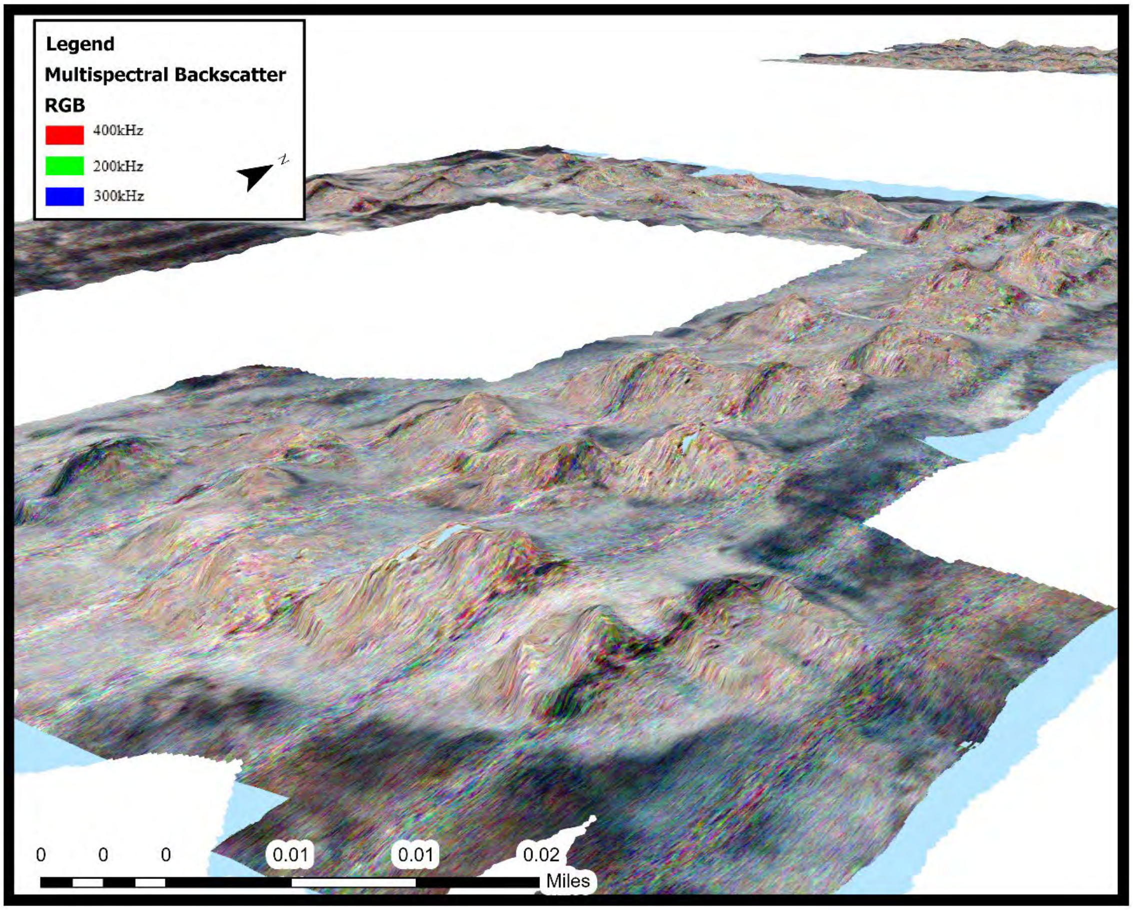


Figure 6. Multispectral Backscatter surface of Mitigation Reef 1 draped over the bathymetric surface from the same survey in 3d demonstrating the red band corresponding to increase in height and thus correlating the red banded backscatter data to the mitigation reefs.

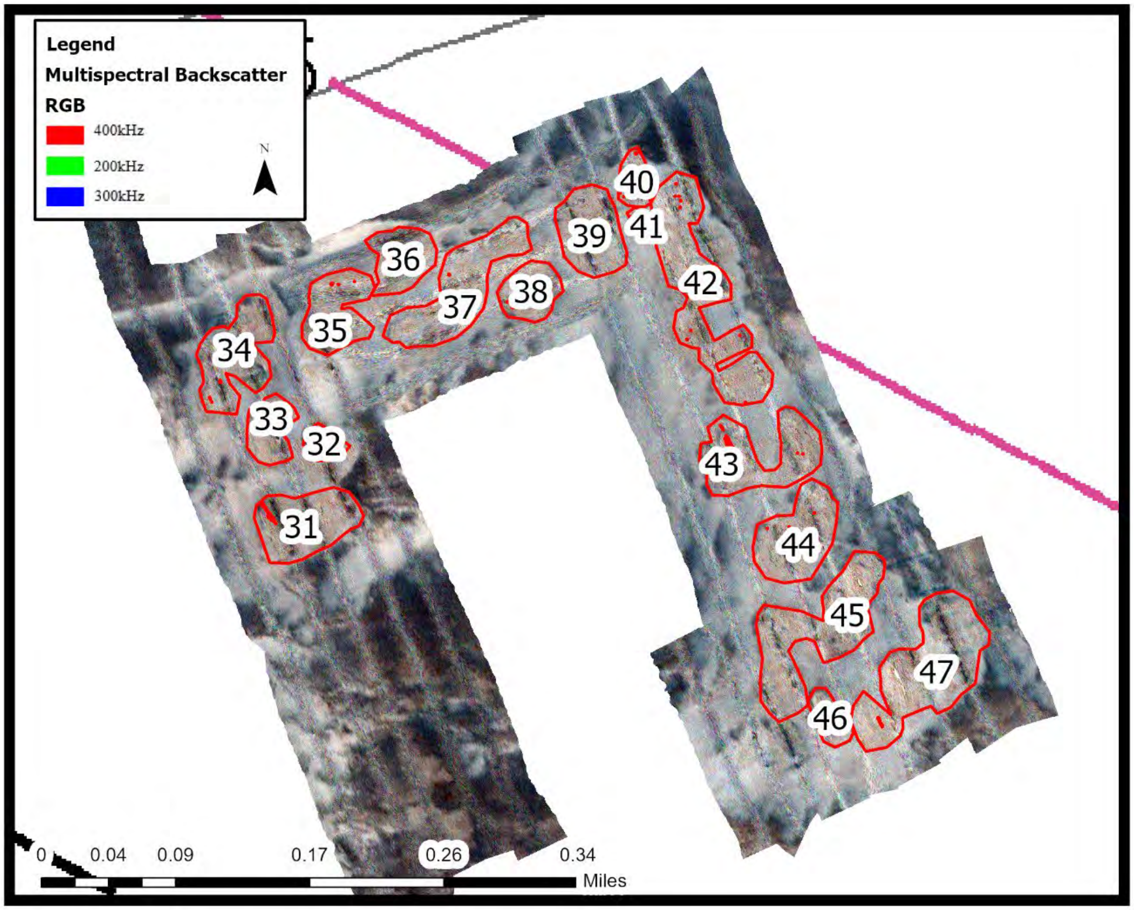


Figure 7. Outlines in red of the locations determined to be hardbottom using the multispectral backscatter over Mitigation Reef 2.

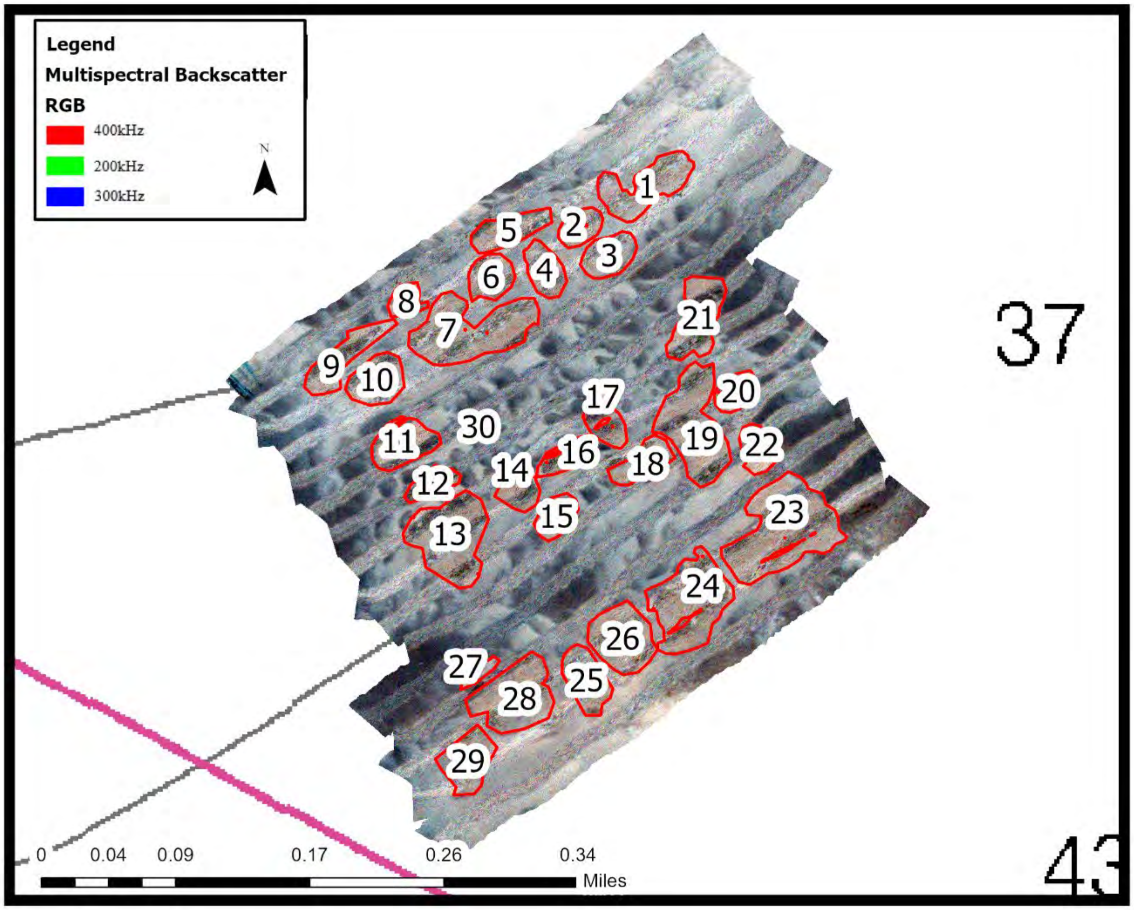


Figure 8. Outlines in red of the locations determined to be hardbottom using the multispectral backscatter over MitReef 1.

After determining and assigning hard bottom locations, the bathymetric data was imported into Fledermaus where rugosity grids were created using Fledermaus's rugosity calculator tool found in Jenness, 2004[1.] The rugosity grids produced for this analysis are shown in Figures 9 and 10. Next, the rugosity grids were then imported into ArcGIS Pro, where the geoprocessing tool 'interpolate shape' was used to assign the average rugosity value from the Fledermaus derived surface to the shapefile developed encompassing the extents of each reef or hardbottom location in mitigation reef 1 and mitigation reef 2.

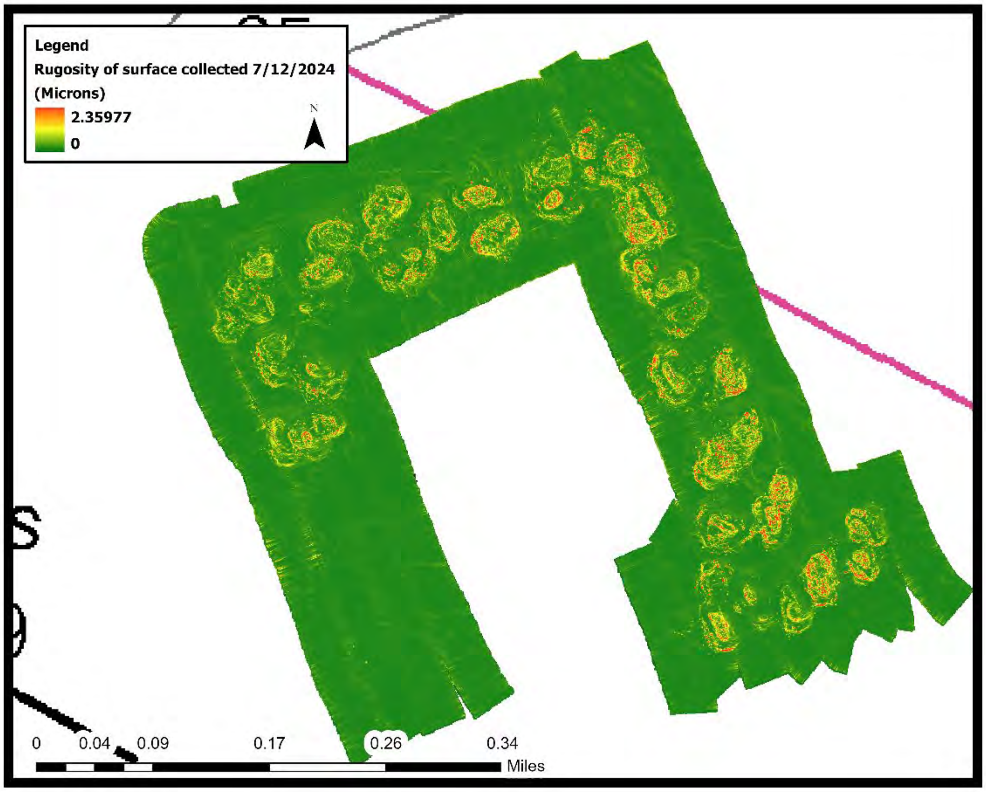


Figure 9. Rugosity for Mitigation Reef 1.

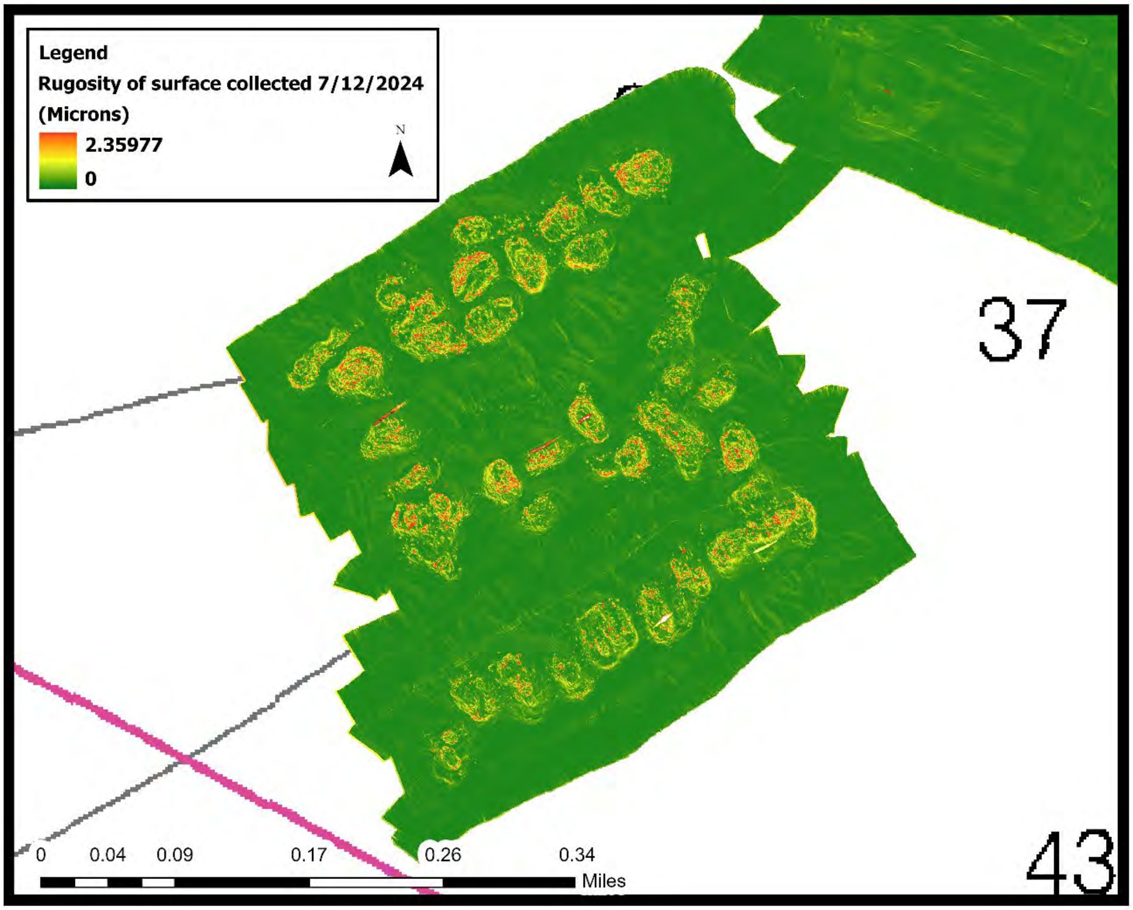


Figure 10. Rugosity for Mitigation Reef 2.

Finally, the bathymetric data was also used to develop an average relief value assigned to each reef location outlined in Figures 7 and 8. Using the interpolate shape tool a minimum z value and a maximum z value were extracted for each reef into a table. The values were then subtracted to result in the relief value.

3. RESULTS

Tables 2 and 3 display the summary of all values- area, relief and average rugosity for each reef number displayed in Figures 7 and 8 for both mitigation reefs.

The total area identified by the multispectral backscatter classification as hardbottom is 41.2 acres (21.6 acres for MitReef 1 and 19.6 acres for MitReef 2).

The average rugosity for each "reef" or mound can be visualized over the bathymetry for mitigation reef 2 in Figure 11. Overall, the reefs encompassed by mitigation reef 2 had an average rugosity of 0.9478217 microns. The average rugosity MitReef 1 is displayed in Figure 12. The "reefs" encompassed by MitReef 1 had an average rugosity of 0.926895524 microns.

The relief in feet for MitReef 2 can be visualized in Figure 11. The average relief of "reefs" contained in mitigation reef 2 is 5.6 ft. The relief in feet for MitReef 1 can be visualized in Figure 12. The average relief of "reefs" contained in MitReef 1 is 6.3 ft.

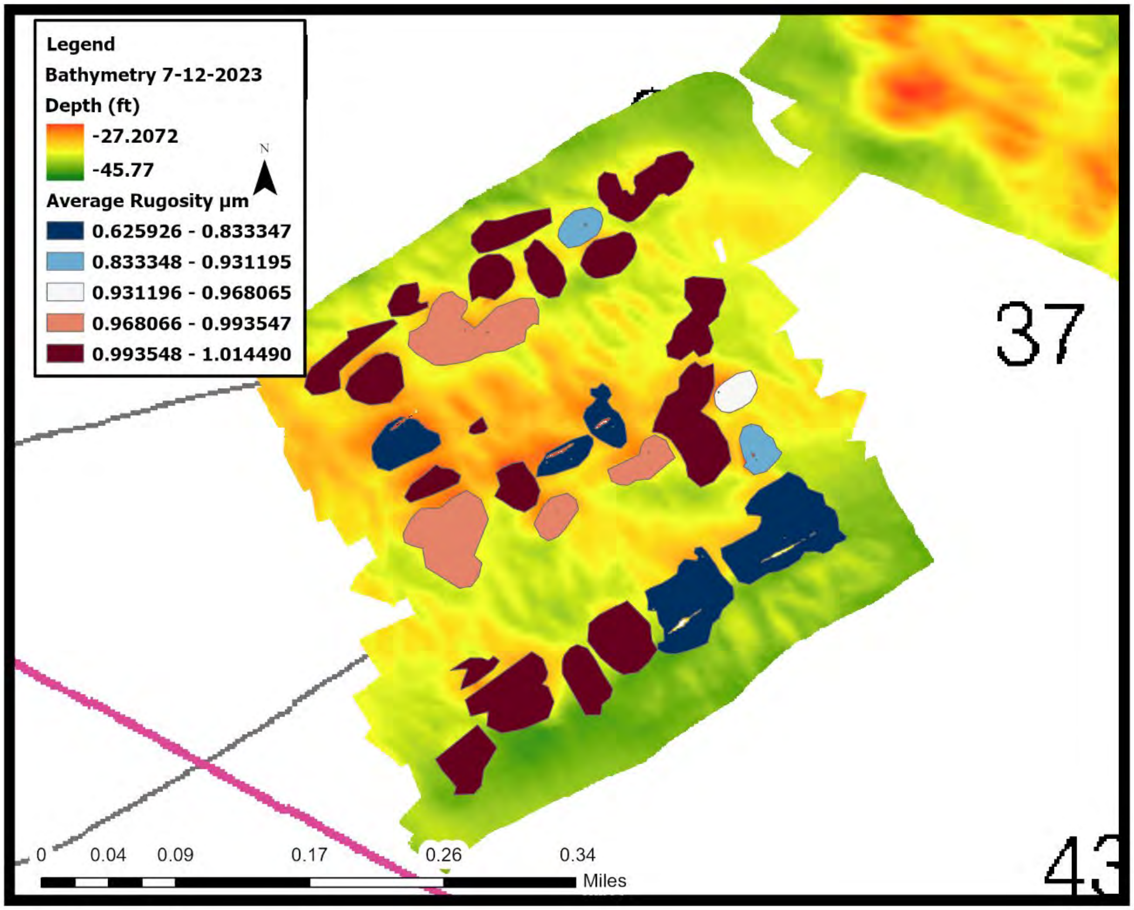


Figure 11. Average Rugosity for each “reef” over the bathymetry over MitReef 2.

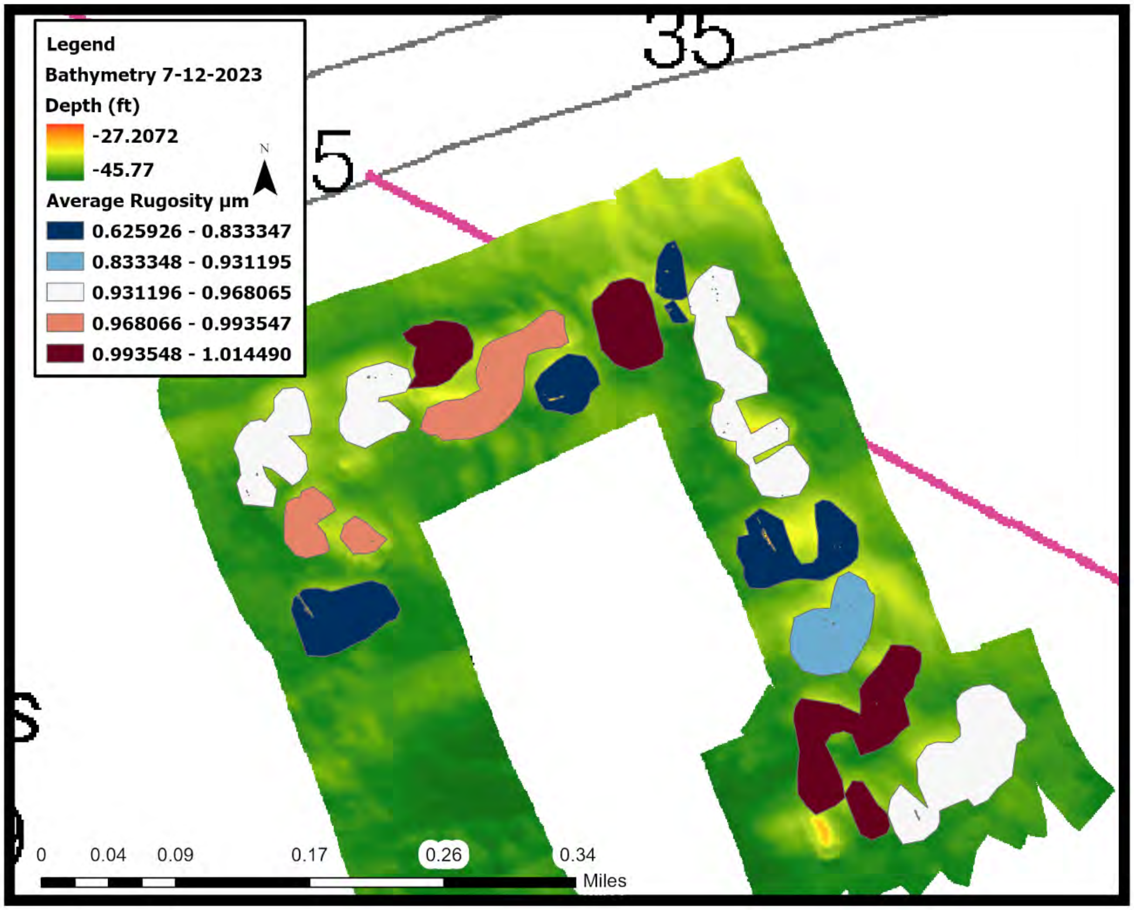


Figure 11. Average Rugosity for each “reef” over the bathymetry over MitReef 1.

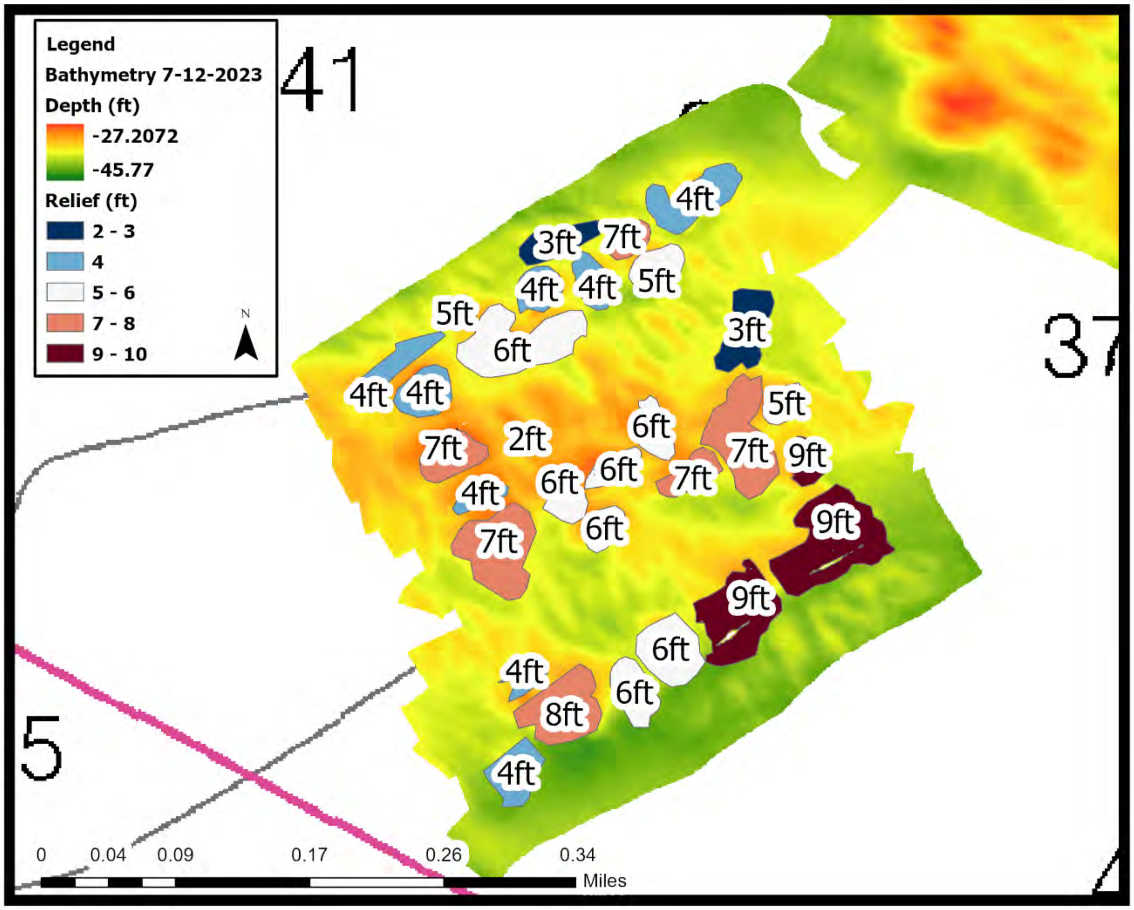


Figure 12. Relief of “reefs” in feet over MitReef 2 draped over the bathymetry.

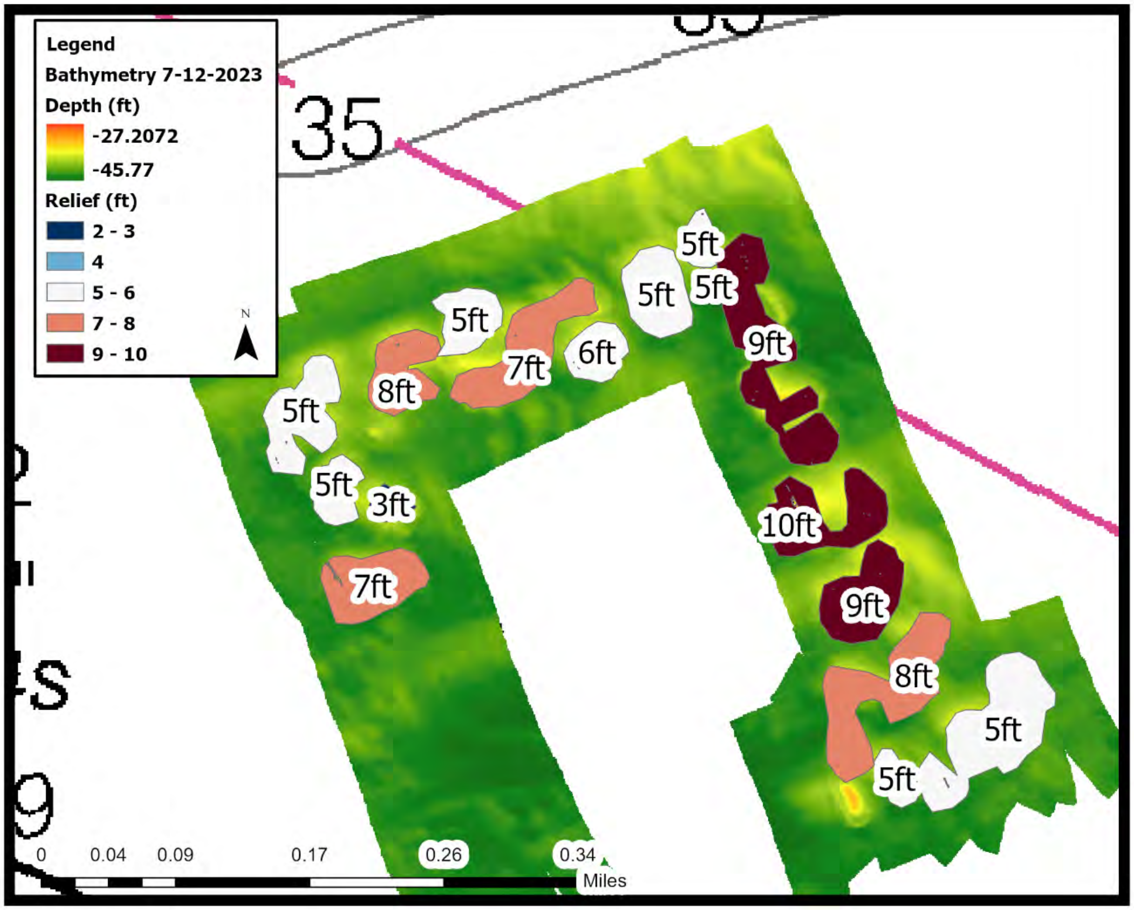


Figure 12. Relief of “reefs” in feet over MitReef 1 draped over the bathymetry.

Table 2. All “reefs” and their corresponding 2d surface area, relief and rugosity for MitReef 2.

Reef Number	Area (sq ft)	Average Rugosity	Relief (ft)
1	37365	1.012449	4
2	14018	0.92173	7
3	20477	1.003863	5
4	18079	1.007976	4
5	22089	1.007158	3
6	18661	1.01449	4
7	64330	0.983452	6
8	10095	1.007364	5
9	25789	1.002083	4
10	24655	1.009963	4
11	26984	0.755078	7
12	12316	1.00275	4
13	57916	0.975201	7
14	17819	1.003379	6

15	14563	0.985792	6
16	14554	0.625926	6
17	18321	0.772194	6
18	19031	0.984386	7
19	58760	1.003714	7
20	13852	0.968065	5
21	32671	1.002839	3
22	15735	0.909539	9
23	84366	0.735525	9
24	61890	0.725697	9
25	24898	1.001619	6
26	38485	1.004446	6
27	8175	1.001458	4
28	48606	1.003588	8
29	26945	1.002147	4
30	2275	1.00078	2
	SUM = 853720	**AVG= 0.9478217**	**AVG = 5.6**

Table 3. All reefs and their corresponding 2d surface area, relief and rugosity for mitigation reef 1.

Reef Number	**Area (sq ft)**	**Average Rugosity**	**Relief (ft)**
31	63677	0.753106	7
32	12384	0.976541	3
33	28677	0.987927	5
34	64536	0.963946	5
35	49013	0.960962	8
36	38003	1.00337	5
37	81494	0.993547	7
38	31698	0.804611	6
39	54254	1.002502	5
40	16195	0.833347	5
41	3443	0.820899	5
42	118956	0.959922	9
43	71816	0.816071	10
44	64189	0.931195	9
45	105345	0.998332	8
46	17728	1.001479	5
47	118774	0.949523	5
	SUM = 940182	**AVG= 0.926895524**	**AVG = 6.3**

4. REFERENCES

[1]Jenness, J. S. 2004. Calculating landscape surface area from digital elevation models. Wildlife Society Bulletin. 32(3):829-839

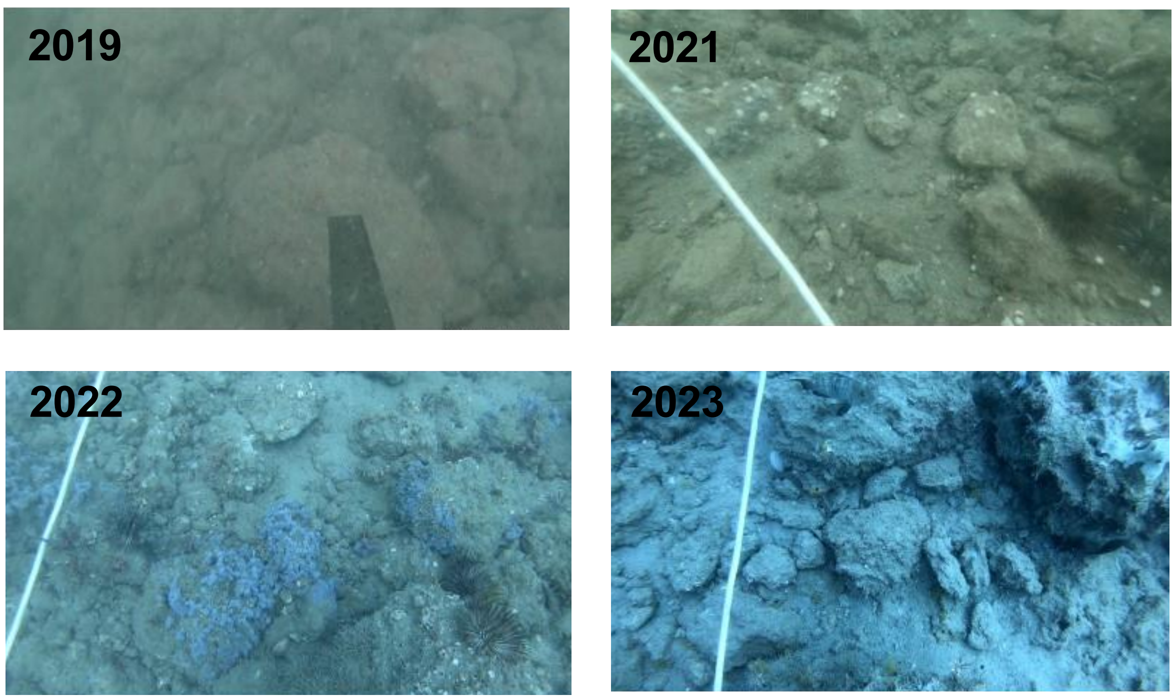
Appendix 2

Charleston Harbor Post 45: Mitigation Reef Monitoring in the Charleston Harbor Entrance Channel, Final Report (2019-2023)

Charleston Harbor Post 45:

Mitigation Reef Monitoring in the Charleston Harbor Entrance Channel

Final Report (2019-2023)
To
The U.S. Army Corps of Engineers, Charleston District



Visualization of observed temporal succession in biotic cover, MR-02-07 survey center

Prepared By:
South Carolina Department of Natural Resources
Marine Resources Division
217 Fort Johnson Road
Charleston, South Carolina

FINAL REPORT (2019-2023) TO U.S. ARMY CORPS OF ENGINEERS

For

Charleston Harbor Post 45: Mitigation Reef Monitoring
in the Charleston Harbor Entrance Channel

by

MICHAEL ARENDT, WILEY SINKUS, HOMER HIERS & RYAN YADEN

5 March 2024

Year Five Final Report for Grant Number W912HP-17-2-0002, Task 7

TABLE OF CONTENTS

Table of Tables

Table of Figures

EXECUTIVE SUMMARY

In June 2015, the U.S. Army Corps of Engineers (USACE), Charleston District completed an Environmental Impact Statement (EIS) to assess impacts associated with Charleston Harbor Post 45 Deepening Project. The EIS anticipated that up to 28.6 acres of hard bottom habitat may be directly impacted due to the project. As such, USACE proposed to construct eight new reefs using excavated hard bottom material removed from the channel. Six reefs were designated as beneficial use reefs while two reefs (MitReef) mitigated for the lost ecological function of the hardbottom habitat. At each new reef, material was deposited in 16 x 2.1-acre grid cells; thus, each reef footprint exceeded anticipated impact acreage. Mitigation Reefs (MitReef) were completed in 2018, and a year later the South Carolina Department of Natural Resources (SCDNR) initiated a five-year monitoring plan at study sites within a subset (n = 6) of material deposition grids per MitReef.

USACE, National Marine Fisheries Service (NMFS), and SCDNR established successful mitigation as fish and invertebrate species similarity between MitReefs and the impact area. Scientific divers established and surveyed 36 reference transects in 2019 that, except for 2020 due to the global Covid-19 pandemic, were monitored annually through 2022. In 2023, a subset of MitReef transects were surveyed to support novel data collection at Beneficial Use (BU) reefs which were built using smaller rubble than MitReef sites. Baited video remotely documented fishes in the absence of divers; baited video was collected in spring and summer 2019 but then only annually thereafter (n = 6 days total). Lastly, in 2022 and 2023, four days of fishing enabled the capture of 34 black sea bass and one gag grouper for acoustic tagging.

Twelve of 13 (92%) finfish species seen by divers in the impact area in March 2016 were also seen at MitReef sites during 2019-2023 across survey techniques, with success defined as ≥75%. In addition, median target finfish species abundance at MitReef sites fell within inter-quartile ranges of respective median impact area abundances. Thus, MitReef construction was a “success” regarding finfish. Furthermore, nearly 5x as many fish (including sharks and rays) were seen at MitReef sites than at the impact area; however, because impact area surveys only relied on diver observations, the occurrence of these species at the impact area is unknown.

Temporal succession in invertebrate coverage was evident at MitReef sites. At study end, target taxa at the MitReef sites comprised 37% of all invertebrates, and in order of prevalence were represented by hard corals (43%), sponges (36%), and soft corals (21%). Through 2022, sponge and hard coral density at MitReef sites significantly exceeded respective impact area densities; however, species compositions differed. Soft coral density, species ratios, and size distributions were significantly lower at MitReef sites in 2022 than seen at the impact area in 2016. Despite these differences, a more in-depth examination of the SC hard bottom literature concluded that the MitReef was like existing reefs and a success concerning invertebrate colonization.

In summary, the MitReef sites supported greater invertebrate and finfish diversity than the impact site and thus successfully mitigated hard bottom habitat loss during the Post 45 project.

Background
Following completion of the Post 45 project in December 2022, Charleston Harbor became the deepest (52 feet, formerly 45 feet) port on the U.S. East Coast.[1] Planning for this endeavor began in 2011 and was initiated to ensure safe navigation of the largest commercial vessels. Subsequent Environmental Impact Assessment estimated that 28.6 acres of hard bottom would be adversely impacted by dredging, which in turn prompted plans to redistribute impacted hard bottom material in a series of 90,000 ft^2 grids comprised of 16 (300 x 300 ft) cells.[2]

New reefs were built with material dredged from the shipping channel during the Post 45 project. Initial plans proposed placing four reefs in near parallel on the north and south sides of the shipping channel[2]; however, this configuration ultimately included six reefs on the northside and two reefs on the southside of the shipping channel (Figure 1). All reef material was placed between U.S. Coast Guard Aids to Navigation (ATON) buoy pairs 11-12 and 7-8. Four north-side reefs (and both south-side reefs) were constructed for "beneficial use", with the remaining north side reefs designated as "mitigation" for losses in hard bottom habitat due to the deepening and widening. Impact material removal and construction of mitigation reefs, referred to as "J" (MR02-xxx) and "S" (MR01-xxx), was completed in the second half of 2018; however, beneficial reef construction continued for several more years.[3]

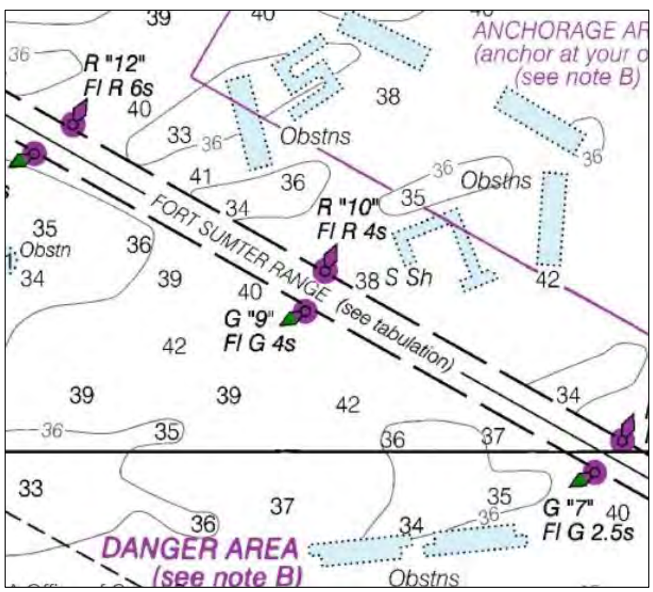


Figure 1. Two "mitigation" and four "beneficial use" reefs were created on the north side of the Charleston, SC shipping channel, with two other "beneficial use" reefs created on the south side. Source: NOAA Chart 11521; https://www.charts.noaa.gov/OnLineViewer/11521.shtml

[1] Charleston Harbor Post 45 Project; https://www.sac.usace.army.mil/Missions/Civil-Works/Charleston-Harbor-Post-45/ (accessed 30 January 2024)
[2] Post 45 Documentation, Appendix I – Hard Bottom Resources; https://www.sac.usace.army.mil/Missions/Civil-Works/Charleston-Harbor-Post-45/ (accessed 30 January 2024)
[3] "If you build it, they will come", USACOE News Story; https://www.sac.usace.army.mil/Media/News-Stories/Article/1656154/if-you-build-it-they-will-come/ (accessed 30 January 2024)

Methods

Per the Environmental Impact Assessment[2], the USACOE was required to monitor the reefs for 3.5 years post-construction for colonization by fish and invertebrate reef organisms that represent a community appropriate for offsetting the impacts to hardbottom from the channel deepening. Baseline reference data for invertebrate and fish assemblages were collected at six hardbottom impact locations in March 2016 (Dial Cordy & Associates, 2016), two years prior to dredging. Following completion of mitigation reef construction in late 2018, the South Carolina Department of Natural Resources (SCDNR) initiated a multi-year research study in spring 2019. In all years, temporal colonization by benthic invertebrates and fish assemblages was monitored using multiple data collection techniques (Job 1). Using a network of deployed acoustic receivers, transient occurrence of acoustically tagged animals was also monitored annually. In the final two years of the study, residence by black sea bass (*Centropristis striata*) captured on site was also monitored using acoustic telemetry (Job 2).

Site selection

Following mitigation reef construction, the USACOE provided geo-referenced bathymetry maps to the SCDNR to assist with site selection within the "S" (MR-01-xx) and "J" (MR-02-xx) reefs (Figure 2). Mitigation reefs were sited near 32.7°N and -79.7°W, with the "J" reef situated slightly further offshore than "S" reef along a bearing of ~135°. Bathymetry imagery suggested potential uneven distribution of rubble two grids between reefs. Visually, two of 16 "S" reef material deposit grids were classified as high density (HD), five as medium density (MD), and nine as low density (LD). Conversely, visual classification suggested five MD and 11 LD grids for the "J" reef. Both HD grids were selected for monitoring, with stratified (MD, LD) random selection of remaining grids for monitoring through 2023.

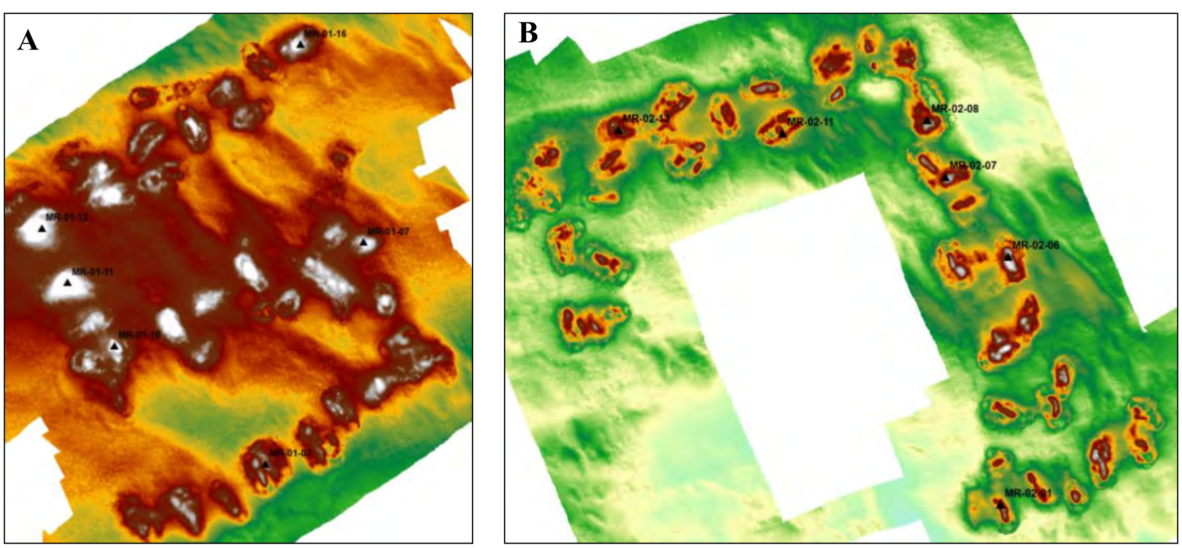


Figure 2. Spatial configuration of the "S" (panel A) and "J" (panel B) reef material.

Latitude-longitude coordinate pairs were positioned within each selected grid to optimize hard bottom continuity for laying out 66-ft (20-m) radius survey lines. Bathymetric imagery differences between reefs conveyed to the transect-level, with a nearly inverse relationship in visual material composition between reefs (Figure 3). Specifically, 81% of "S" reef transect length was associated with the strongest return bathymetry colors; however, 83% of "J" reef transect length was overlaid with the weakest return colors. Consequently, in addition to evaluating species composition at both reefs relative to baseline data collected at the impact site in March 2016 (Dial Cordy & Associates, 2016), comparison of trends between the "S" and "J" reefs was also a high analysis priority.

Diver surveys
One central and three terminal transect posts (#6 x 0.75" diameter iron re-bar (5' length) located 20-m due north (0°), southeast (120°), and southwest (240°) of center were established by scientific divers in April 2019; however, low visibility and strong current often precluded divers from relocating terminal posts. Extensive diver surveys were also not completed in 2020 due to the global Coronavirus pandemic. Beginning in 2021, when the central transect was not located within five minutes, diver surveys commenced at the point of the descent line anchor with 20-m transect lines laid out at 0° (T1), 120° (T2), and 240° (T3) bearings.

Transect surveys were conducted using a modified method of Dial Cordy and Associates (2016). Given triplicate vs. single transects at each monitoring site, two dives (one per diver team) were completed at each site per survey day. The first diver team worked as a pair to lay out all three transect lines along the prescribed bearings. After the first dive team returned safely to the surface, the second diver team entered the water and initiated data collection. During surveys, the lead diver recorded video (and noted target fish species, Table 1) while the second diver trailed behind to count and measure (height and/or width as appropriate) soft corals and sponges located within 0.5m of either side of the transect line. Underwater video predominantly involved two passes per transect line such that footage was collected ~0.5m above the seafloor and with the transect line just kept in the field of view on one side of the camera. Diver video surveys were completed by swimming at a target speed of 3m every 30 seconds; although this pace was faster than the pace specified by Dial Cordy and Associates (2016), prior filming at this pace (and using a semi-lateral vs. downward-looking perspective) in the general study area has produced quality video for species identification (M. Arendt, pers. obs.). Tidal windows for data collection and triplicate transects necessitated these methodology changes.

Underwater observations (fish, invertebrates) were recorded on a waterproof data recording slate. True counts of all fish and invertebrate species seen along the transect swath were generated later during video review in the laboratory. Videos were reviewed (and species counts recorded) in segments of variable duration as appropriate. For each segment, the proportion of seafloor associated with rock (>5 in. circumference), rubble, and sediment grades (shell hash, coarse, medium, fine) were also estimated. Segment-level estimates of geological feature proportions were then weighted (for segment duration) to compute transect-level habitat classifications.

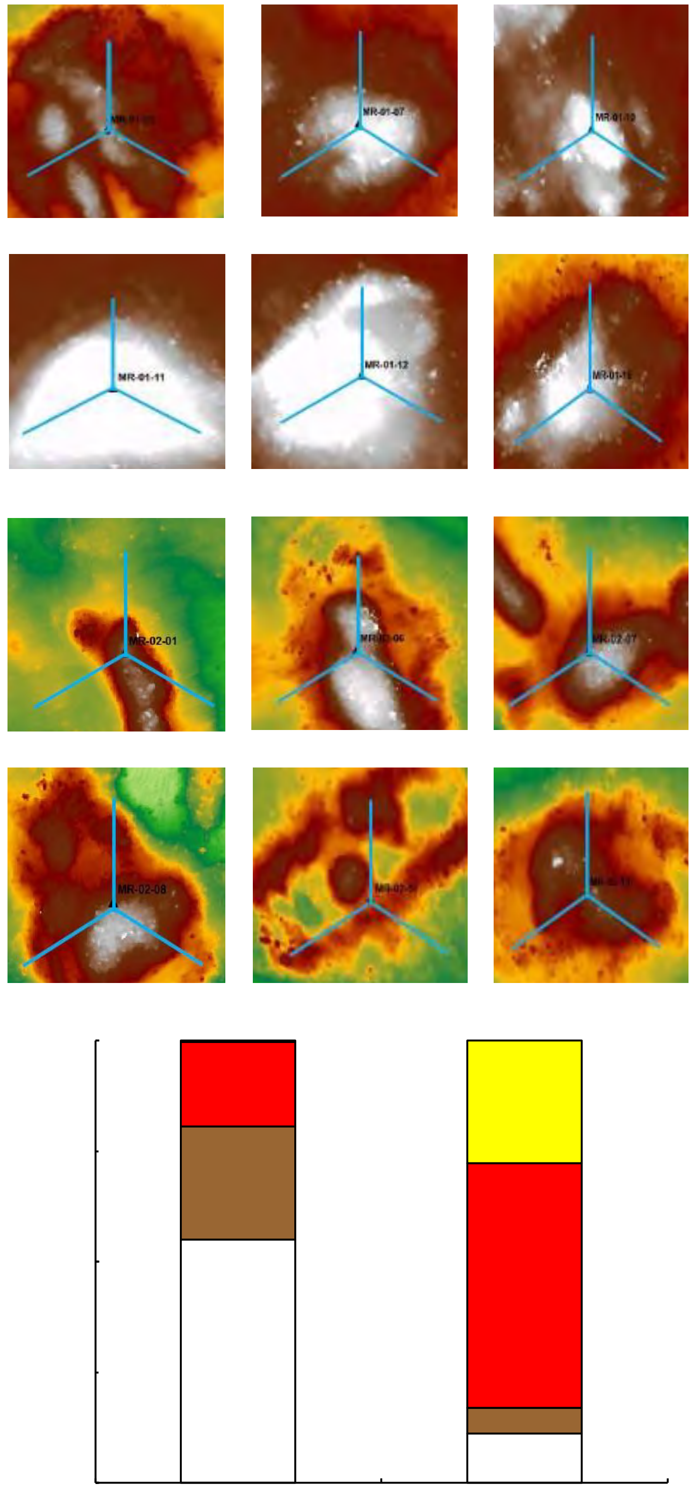


Figure 3. An inverse relationship between bathymetry color (white = strongest) distribution was reflected in transect-level coverage between the “S” and “J” reefs.

Table 1. In addition to enumeration and measurement of corals (soft and hard species) and sponges, divers estimated the relative abundance for 13 target finfish species.

Scientific Name	Common Name	Managed?	Low	Medium	High
Centropristis striata	Black Sea Bass	yes	50 or less	50 to 150	150 or more
Archosargus probatocephalus	Sheepshead	yes	25 or less	25 to 75	75 or more
Mycteroperca microlepis	Gag Grouper	yes	2 or less	3 to 7	8 or more
Paralichthys lethostigma	Southern Flounder	yes	1	2	3 or more
Lagodon rhomboides	Pinfish	no	100 or less	100 to 300	300 or more
Decapterus sp.	Scad	no	100 or less	100 to 300	300 or more
Diplodus holbrookii	Spottail Pinfish	no	5 or less	5 to 15	15 or more
Halichoeres bivittatus	Slippery Dick	no	5 or less	5 to 15	15 or more
Opsanus tau	Oyster Toadfish	no	5 or less	5 to 15	15 or more
Pareques umbrosus	Cubbyu	no	5 or less	5 to 15	15 or more
Serranus subligarius	Belted Sandfish	no	5 or less	5 to 15	15 or more
Urophycis cirrata	Southern Hake	no	1 or less	2 to 4	5 or more
Ogcocephalus radiatus	Batfish	no	1	2	3 or more

Baited video

Independent of diver surveys, but coinciding with annual data collection, baited camera frames (8 ft^3; 2-ft sides) were deployed for one hour near the center reference mark for each survey site. The purpose of this data collection was to augment data collected by divers but during periods devoid of diver presence (and potential negative influence on species activity). Standard bait for this aspect of data collection was Atlantic Menhaden (*Brevoortia tyrannus*).

Each baited frame consisted of one downward and two outward-facing GoPro cameras (see Report Cover for example camera fields of view). After May 2019, only Hero 6 cameras were used, with a target resolution of 60 frames per second x 1080 pixels (wide angle). Video data files (~16GB per hour per camera) were backed up on an external hard drive for later review and cataloguing of species. Analysis emphasized maximum instantaneous count per species per site.

Acoustic telemetry monitoring

To evaluate baseline occurrence of acoustically tagged animals captured off South Carolina and elsewhere along the eastern seaboard of North America, acoustic receivers (Innovasea) were deployed at two “S” reef grids and three “J” reef grids in August 2019. Acoustic receiver placement was selected to provide full coverage of these reefs assuming a minimum detection radius of 0.15 mi (820 feet). Acoustic receivers deployed on Aids to Navigation in the Charleston shipping located 1.2 to 1.9 km (LB09) and 2.5 to 4.1 km (LB11) also complement species detection patterns at MitReef sites.

On 10 November 2021, range transmitters were deployed 300m NW and SE of MR-01-07 but only deployed this distance SW of MR-02-01 due to dense hard bottom under sand to the NE. As noted in the 2022 Annual Report, hourly range transmitter detections through May 2022 did not reliably reflect water level (Reef Sensus Ultra; https://reefnet.ca/products/sensus/) nor surface hydrography or meteorological attributes (National Data Buoy Center Station #41029; https://www.ndbc.noaa.gov/station_page.php?station=41029).

Black sea bass acoustic tagging

Black sea bass were opportunistically captured by hook-and-line fishing using a combination of live (cut squid) and artificial (jigs). Specimens smaller than 10% of the legal-size limit for possession (12 in, 30.5cm TL) were promptly unhooked and released back into the sea. Conversely, larger specimens were held in a 100-gal seawater tank until reaching the goal of five replicates per each of four capture locations was acquired or until fishing effort ceased.

Prior to surgery, each specimen was measured (TL in cm) and externally identified using a nylon t-bar tag distributed by the SCDNR Gamefish Tagging Program. Specimens were then placed right side down on a 3" PVC pipe 'litter' that facilitated a head-down (seawater submerged) orientation with a wet towel covering the cranial region to induce calming (Figure 4). Scales were carefully removed from the target incision area which was located approximately 3cm anterior of the anus and one-third (also about 3cm) between the midline and the rib cage. While carefully gripping and lifting the descaled area with forceps or tweezers, a small incision was made using a #15 sterile surgical blade until the opening was just large enough to accommodate the diameter (1.3cm) of the acoustic transmitter, which was cold sterilized in 70% Isopropenol between removing each specimen from the holding tank and transmitter implantation. After confirming good internal transmitter placement, the incision was closed with a sterile, synthetic absorbable suture material (Coated Vicryl, 4-0) and reverse cutting needle (FS-2, 12mm).

To assist with interpreting short-term post-release detection patterns, the following procedural milestones were measured: mean pre-procedural holding time; handling prior to making incision; time between incision and suture; post-procedure recovery time; and post-recovery holding time. In lieu of using a descending device to individually return black sea bass to the seafloor[4], fish were returned to the seafloor in groups (2-4 individuals) using a weighted milk crate (Figure 5).

Statistical analysis

Data management and analysis metric generation occurred in Microsoft Access (2016 Office Suite; Redlands, CA). Data visualization and summation was performed in Microsoft Excel, with statistical testing completed in Minitab 20® (Minitab, Inc.; State College, PA).

Four prior annual reports convey data collection methodology influences on fish and invertebrate species abundance; thus, Final Report analyses emphasize overall species distribution at MitReef sites relative to six impact site surveys in 2016 (Dial Cordy & Associates). Due to transect-level bathymetry signature differences, target species data were also first compared between reefs to determine the extent to which data could be pooled for comparison with impact site observations. In addition to the hypotheses proposed for evaluating MitReef "success", this Final Report also includes additional "success" metrics that better account for variability in the 2016 baseline data. Specifically, these additional metrics better reflect baseline transects conducted over "…low to medium relief in some areas to no relief in other areas" (Dial Cordy & Associates, 2016) compared to maximizing survey coverage over hard bottom relief in the present study.

---

[4] South Atlantic Fishery Management Council, Black sea bass regulations; https://safmc.net/species/sea-bass-black/#:~:text=The%20descending%20device%20must%20be,with%20head%20and%20fins%20intact. (accessed 30 January 2024)

Figure 4. Acoustic transmitters (V13-1H, Innovasea) implanted into black sea bass measured 1.3cm (diameter) x 3.1cm (length) and weighed 5.1 g in water. Transmitters emitted coded signals at random (~3 min) intervals to minimize transmitter signal collisions (and in turn reduced specimen detection), which resulted in an estimated battery life of 3.1 years.

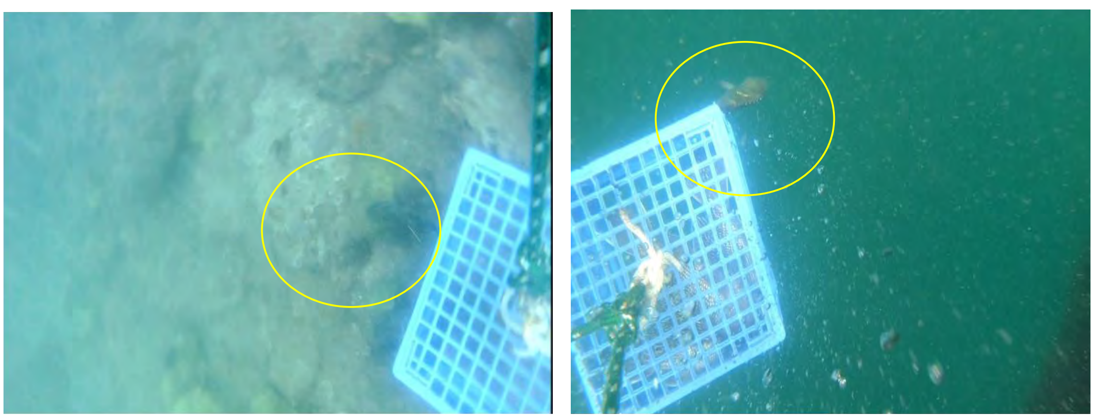


Figure 5. Telemetered and non-telemetered (control) black sea bass were returned to the seafloor using a weighted plastic crate (A). Black sea bass occasionally escaped early during descent (B) but continued to swim towards the seafloor at a similar rate as crate-descended black sea bass.

"Success" criteria, Fish

Two metrics were proposed for evaluating fish colonization at MitReef sites. First, a minimum of 10 of 13 (>75%) species seen at the impact area in shipping channel prior to the Post 45 project must also be documented within four years of MitReef construction using this material. Second, relative abundance of species at MitReef would be statistically compared with impact area baseline data using correlation analysis and/or Chi-square contingency tests as appropriate.

Closer inspection of baseline transects revealed that counts across transects were not normally distributed (Anderson-Darling, $p<0.05$) for nine target species, which consequently produced a median abundance of “0” for seven species only observed at two or fewer transects (Table 2). Variable abundance across transects also produced inter-quartile ranges and/or 95% confidence intervals that equaled or exceeded median and mean abundance estimates, respectively, for five other finfish species (Table 2). Confidence intervals overlapped with inter-quartile ranges for the four finfish species with normally distributed abundance across baseline transects (Table 2). Consequently, target finfish species abundance at MitReef was considered statistically similar when median abundance fell within baseline inter-quartile ranges for the respective species.

Table 2. Among 13 target fish species reported during impact area diver surveys in March 2016, more than half were seen at two or less transects. Species ordered by frequency, then normality.

Transect	*Black sea bass*	*Gag grouper*	*Sheepshead*	*Oyster toadfish*	*Pinfish*	*Slippery dick*	*Spottail pinfish*	*Belted sandfish*	*Cubbyu*	*Carolina hake*	*Batfish (sp.)*	*Southern flounder*	*Scad (sp.)*
T1	200	3	25	7	30	0	0	0	0	0	2	0	0
T2	200	0	0	10	500	10	0	0	0	0	0	0	500
T3	100	2	30	10	300	0	0	0	0	0	0	0	0
T4	30	0	0	0	0	25	0	15	0	0	0	0	0
T5	200	8	150	0	0	0	20	0	30	5	0	0	0
T6	50	6	50	3	0	1	17	5	0	0	0	1	0
Frequency	*6*	*4*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	*1*	*1*	*1*	*1*
Sum	*780*	*19*	*255*	*30*	*830*	*36*	*37*	*20*	*30*	*5*	*2*	*1*	*500*
Median	*150*	*3*	*28*	*5*	*15*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
IQR	*137*	*4*	*38*	*8*	*232*	*7*	*12*	*3*	*0*	*0*	*0*	*0*	*0*
Mean	*130*	*3*	*43*	*5*									
95% CI	*84*	*3*	*59*	*5*									
Normality	*0.076*	*0.463*	*0.053*	*0.237*	*0.017*	*0.010*	*<0.005*	*<0.005*	*<0.005*	*<0.005*	*<0.005*	*<0.005*	*<0.005*

“Success” criteria, Invertebrates

Baseline invertebrate analysis was reported as proportional cover among taxonomic groups using Coral Point Count with Excel extensions (CPCe; Kohler and Gill, 2006). Further examination of this technique relative to transect-level abundance (Appendix A; Dial Cordy & Associates, 2016) revealed poor fit for sponges and hard corals but significant correlation for Gorgonians (Table 3). Gorgonian abundance was also inversely correlated with CPCe points on bare surfaces (Table 3). Sponge counts were also inversely correlated with CPCe points on Gorgonians but positively correlated with CPCe points on bare surfaces (Table 3). These observations reinforce dropping CPCe analysis in lieu of full video data review after a preliminary method comparison in 2019.

In contrast to finfish, invertebrate abundances across transects were normally distributed for *Titanidium* sp. ($p = 0.567$) and stony corals ($p = 0.391$); however, *Leptogorgia* sp. ($p = 0.007$) and sponge ($p = 0.005$) counts were not normally distributed across transects.

Table 3. Correlation matrix analysis of inter-relatedness of transect-level counts of Gorgonians, sponges, and hard coral at the impact area in March 2016 and subsequent percent cover analysis using the CPCe technique. Significant ($p<0.05$) correlation scores (r values) highlighted in gray.

	CPCe_Bryozoan	*CPCe_Coral*	*CPCe_Gorgonian*	*CPCe_Other*	*CPCe_Sponge*	*CPCe_SSHR*	*CPCe_TB*	*CPCe_Fish*	count_Gorgonian	count_Sponge	count_Coral
CPCe_Coral	-0.18										
CPCe_Gorgonian	-0.79	0.22									
CPCe_Other	-0.01	0.61	0.18								
CPCe_Sponge	-0.24	0.98	0.35	0.61							
CPCe_SSHR	-0.99	0.06	0.76	-0.08	0.12						
CPCe_TB	0.68	-0.50	-0.94	-0.38	-0.61	-0.61					
CPCe_Fish	0.20	-0.37	0.05	-0.53	-0.22	-0.20	0.07				
count_Gorgonian	-0.74	0.45	0.91	0.54	0.54	0.68	-0.94	-0.30			
count_Sponge	0.66	-0.23	-0.88	-0.26	-0.41	-0.60	0.82	-0.31	-0.78		
count_Coral	-0.49	0.60	0.01	0.26	0.53	0.44	-0.11	-0.52	0.21	-0.05	

Following greater appreciation of taxonomic associations revealed by transect level review of invertebrate counts, additional hypotheses were added (and denoted by ‘) to complement the initial success criteria hypotheses proposed by SCDNR in 2018. As appropriate, transect counts were standardized to percentile distributions prior to comparison using correlation analysis.

a. No departure from octocorals comprising three-quarters of benthic invertebrates.
a’. No departure from an inverse correlation between octocoral and sponge abundance.

b. No departure from *Titanidium* sp. being 2.9 times more abundant than *Leptogorgia* sp.
b’. No departure from *Titanidium:Leptogorgia* transect ratios spanning 0.6 (T2) to 40.3 (T5)

c. No departure from a mean of 5.3 (±3.0 95% CI) octocoral colonies per square meter.

d. No departure from sponges being the third most prevalent “functional group” and represented by the following genera: *Ircinia; Spirastrella; Chondrilla; Desmapsamma*.

e. No departure from a mean of 1.7 (±2.0 95% CI) stony coral colonies per square meter

f. No difference in size distributions for octocorals, sponges, and stony corals relative to size distributions for these taxa reported in March 2016 (Dial Cordy and Associates).

Results

Effort expenditure and video data quality

Between the first (28 January 2019) and final (30 October 2023) project field days, a total of 163 scientific dives representing 65.4 hours underwater were completed during 26 unique field days. Transect layouts followed by faunal surveys comprised the principal scientific diving activity, but also included transect mooring establishment (April 2019) and acoustic telemetry support. Baited frame data were collected on six additional days across all project years, whereas capture plus acoustic tagging of black sea bass occurred over four days in the final two project years. Conversely, orders of magnitude more effort were expended on land to process, manage and analyze extensive video and telemetry data sets reported herein.

Survey swimming speed and underwater visibility both improved across project years (Figure 6). The poorest quality video data occurred in summer 2019 (80-83°F) when underwater visibility only exceeded five feet for a single transect. Summer 2019 was also the only period of overlap between diver surveys and material dumping to construct Beneficial Use reefs on the north side of the shipping channel (Figure 7). Underwater visibility modestly improved in 2021 due to completing half of diver surveys in May (71°F) vs. July (79-83°F). Greatest visibility plus slowest swimming speeds produced the best video data quality in May-June 2022 (71-80°F). Across survey periods, tidal amplitudes ranged from 4.3’ (2022) to 6.1’ (2023), and with few exceptions, diver surveys were completed between mid-flood and mid-ebb tide stages.

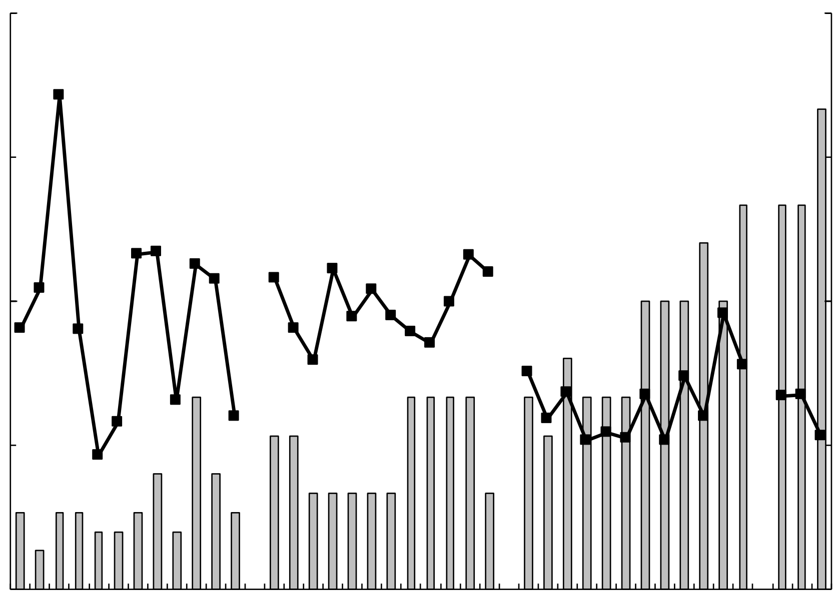


Figure 6. Systematic improvements in dive day selection criteria as well as reinforcing diver protocols contributed to higher quality video data collection for review in later project years.

Figure 7. Active construction of Beneficial Use reefs in summer 2019 contributed to reduced underwater visibility during initial diver surveys, but fortunately was not problematic thereafter.

Habitat classification comparison between "J" and "S" reefs

Only one significant ($p<0.05$) correlation was detected between reef grouping ("S" = 1, "J" = 2) and a habitat feature (coarse sand, $r = 0.19$; Table 4); thus, bathymetric profile differences noted at study start did not produce perceivable differences in habitat composition across reefs. Concurrent with improved transect layouts (and improved visibility to assess habitat type), the proportion of transects over rocky substrate significantly increased through time (Table 4). All transects included ≤6% non-rock substrate; however, median rock substrate coverage increased systematically between 2019 (53%), 2021 (69%), and 2022 (75%). In 2019 (and again in 2021) a transect was laid out over ≥98% sand; however, in 2022, transects featured ≤46% sand. These observations reinforced greatest analysis emphasis on 2022 surveys from 2022 (~4 years after MitReef construction), when optimal visibility also enhanced taxonomic review (Figure 6).

Table 4. Correlation matrix analysis of reef ("S" = 1, "J" = 2) survey cycle (2019, 2021, 2022), transect direction (1,2,3), and gross transect proportion associated with rock, coarse sand, and fine sand habitats. Significant ($p<0.05$) correlation scores (r values) highlighted in gray.

	Reef	Cycle	Transect	Rock	Coarse
Cycle	0.00				
Transect	0.00	0.00			
Rock	-0.09	0.37	0.06		
Coarse	0.19	-0.24	-0.02	-0.81	
Fine	-0.16	-0.24	-0.06	-0.36	-0.25

Taxonomic overview and comparison between "J" and "S" reefs

Video review of 36 transects per scientific diver survey cycle in 2019, 2021, and 2022 catalogued 167,361 organism counts across 17 broad taxonomic groupings. Overall, barnacles (47%), hard coral (37%), and echinoderms (9%) comprised 90% of diver video counts. Sponges and finfish each comprised 3% of diver video counts, followed by tunicates (2%) and soft corals and hydroids (1% each). Collectively, the following nine taxonomic classifications accounted for <1% of diver video counts and are presented in order of relative abundance: algae; mollusks; worms; bryozoans; anemones; crustaceans; arks; elasmobranchs; and jellyfish.

Among taxonomic groups comprising >1% of diver counts, single-linkage (Euclidean distance) cluster analysis revealed strongest associations (73-76% similarity) between finfish, hydroids, and sponge, followed (69-73% similarity) by rock, hard coral, and echinoderms (which were >99% long-spined urchins, *Arbacia punctulata*). Cluster analysis only distinguished soft corals with respect to survey reef (69% similarity), 81% of which were from the "J" reef. Barnacles joined tunicates with 65% similarity; however, all remaining clusters were <50% similar.

Across reefs and transects, temporal succession in taxonomic coverage was evident (Figure 8). Hard encrusting organisms dominated coverage in summer 2019 (reef age <1 year) through spring 2022 (reef age <4 years); however, systematic increase was also observed in the relative abundance of soft encrusting organisms as well as echinoderms/urchins (Figure 8). Sponges were most responsible for the temporal increase in soft encrusting cover (Figure 8).

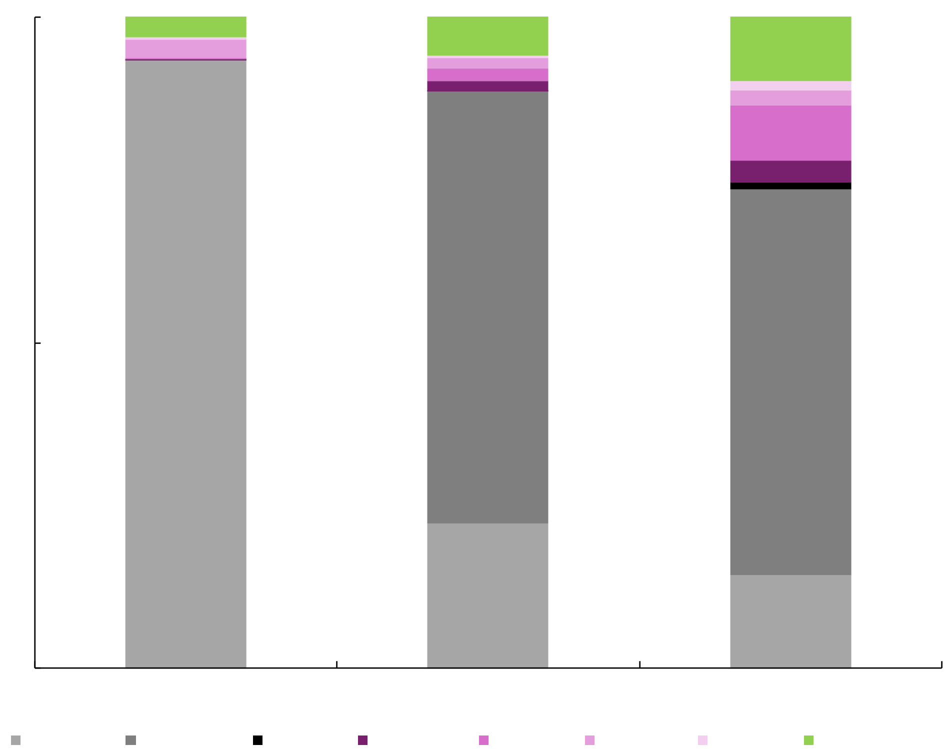


Figure 8. Temporal succession in hard- vs. soft-encrusting habitat coverage at MitReef sites.

Mitigation Reef "success", Fishes

Apart from pinfish, diver slate (99 data sets) abundance estimates exceeded values computed from video review of 108 diver videos and 60 baited frame deployments, and where the latter reflected maximum count across camera angle per deployment (Table 5). Consequently, prior study reporting of finfish success using quantitative video data provided a more conservative metric than qualitative counts estimated by divers (i.e., the nature of baseline survey data). Consequently, here we report abundance using diver slate data. For low and medium count categories, the upper abundance level for each species was multiplied by the number of transect surveys characterized with that relative abundance level (Table 1). Where minimum high abundance was identical to maximum medium abundance, medium abundance was increased by 33% (i.e., the difference between 3 and 2 for gag grouper, Table 1) for the high multiplier value. Mean diver slate abundance was computed as the sum of categorical abundances divided by the number of diver slate surveys recorded. All mean diver slate abundances overlapped with 95% confidence intervals (CI) for baseline surveys (Figure 9), where CI was computed as the standard error multiplied by the two-tailed t-statistic (2.571) for five degrees of freedom (Zar, 1996).

Temporally, six finfish species seen at ≥50% of impact area surveys were routinely observed at MitReef sites between 2019 and 2022 (Table 6). Among these six species, only gag grouper were not seen until later survey years. Three of seven finfish species infrequently seen during baseline surveys were also routinely observed at MitReef sites (Table 6). Conversely, southern flounder were not observed after 2020, perhaps in part reflecting increased effort to survey over rocky substrate (Table 4). Scad and Southern hake were rarely documented at MitReef sites, and batfish were never seen.

In addition to target finfish, nine elasmobranch (89% identified to species level) and 60 finfish (73% identified to species level) classifications were also documented at MitReef sites across survey cycles and observation techniques, notably baited video frames (Appendix A).

Table 5. Mean count (per deployment replicate) of target finfish species by survey technique.

Species	Diver Slate	Diver video	Baited frames
Batfish	0	0	0
Belted sandfish	7	3	<1
Black sea bass	99	30	22
Cubbyu	1	<1	<1
Gag grouper	<1	<1	<1
Oyster toadfish	<1	<1	<1
Pinfish	27	<1	20
Scad	4	0	0
Sheepshead	26	1	4
Slippery dick	8	3	1
Southern flounder	<1	<1	<1
Southern hake	<1	0	<1
Spottail pinfish	5	<1	1

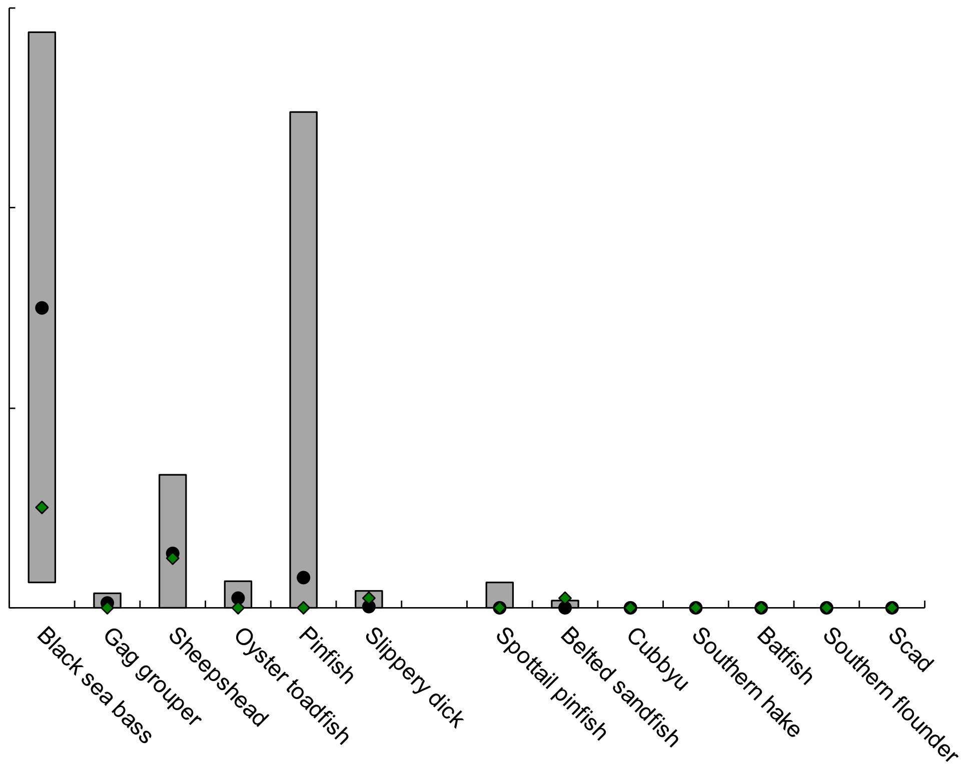


Figure 9. Median abundance for target finfish species at MitReef (2019-2022, green diamonds) fell within inter-quartile ranges (gray bars) for median abundance (black circles) of these species across baseline transect surveys in the impact area in March 2016.

Table 6. Temporal presence of target finfish species at MitReef sites, including *seven species* seen at <50% of baseline surveys in the impact area in March 2016. Cell letters indicate three survey techniques (B = baited frames, V = diver video counts, S = diver slate estimations). Dashed lines (---) denote species not seen by any technique across survey periods (rows).

	Black sea bass	Gag grouper	Sheepshead	Oyster toadfish	Pinfish	Slippery dick	*Spottail pinfish*	*Belted sandfish*	*Cubbyu*	*Southern hake*	*Batfish*	*Southern flounder*	*Scad*
May-19	B	---	B	B	B	B	B	B	B	B	---	B	---
Jul, Aug -19	V, S, B	---	V, S, B	---	S, B	V, S, B	V, S, B	S	S	---	---	S	S
Jun-20	B	---	B	B	B	B	B	B	---	---	---	B	---
Apr-21	B	---	B	B	B	---	B	---	---	---	---	---	---
May, Jul -21	V, S	S	V, S	V	---	V, S	V, S	V, S	V, S	---	---	---	---
Mar-22	B	B	B	B	B	B	B	B	---	---	---	---	---
May, Jun -22	V, S	V, S	V, S	V, S	V, S	V, S	V, S	V, S	V, S	---	---	---	---

Mitigation Reef "success", Invertebrates

Contrary to fishes, diver video review provided greatest counts for target invertebrate taxa which comprised *Leptogorgia* sp. and *Titanidium* sp. soft corals, sponges, and hard corals (Table 7). Including nine MitReef transects surveyed in 2023, target taxa comprised 28% of invertebrate classifications and 42% of invertebrate abundance recorded during video review (Appendix B).

Across survey periods and reefs, soft coral counts from diver slates and video survey review aligned with perfect regression prediction ($y = x$, $r^2 = 1.0$). Conversely, across reviewers of diver survey video consistently noted greater sponge abundance than was reported on the diver slates (i.e., Review count = (2.0569 * Diver count) + 223.15; $r^2 = 0.95$). Discrepancy explanations include poor visibility in early years and greater diver emphasis on measuring maximum sponge sizes than counts in later years as sponges became prolific. Due to extensive hard coral abundance, divers did not count these taxa; thus, methodological impacts were not assessed.

Within each data collection methodology, the ratio of soft coral counts to sponge counts across reefs and years was consistently greater for diver slate data than obtained during review of diver survey video (Table 7): Review ratio = (0.6959 * slate ratio) – 0.1254; $r^2 = 0.99$. Given this observation, as well as very limited (<1k) invertebrate counts obtained from baited video review, diver video review received the greatest emphasis during target invertebrate taxa analysis.

In 2019, soft corals and sponges comprised similar proportions of target invertebrate taxa and did not statistically differ ($p = 0.185$) between reefs. In 2021, when star coral (*Astrangia* sp.) comprised ≥90% of target invertebrates, a significant difference ($\chi 2 = 389.6$, df = 1, $p<0.001$) was detected in the proportionality of soft corals and sponges due to relatively few soft corals observed at the "S" reef (Table 7). Statistical difference ($\chi 2 = 438.8$, df = 1, $p<0.001$) in the ratio of soft corals to sponges persisted in 2022, also due to reduced observation of soft corals at the "S" reef (Table 7). In 2022, sponges comprised 12% of target invertebrate taxa at both reefs (12%), which reduced the hard coral proportion to 81-87% across data source types (Table 7).

Table 7. Target invertebrate counts and transect density at MitReef sites across survey methods.

Year	Reef	Source	*Titanidium* sp.	*Leptogorgia* sp.	ratio	density	Hard coral	density	Sponge	density
2019	"S"	Slate	0	0		0.0	---		0	0.0
2019	"S"	Review	0	109	0.0	0.2	0	0.0	115	0.2
2019	"J"	Slate	0	0		0.0	---		0	0.0
2019	"J"	Review	1	38	0.0	0.1	0	0.0	57	0.1
2021	"S"	Slate	9	20	0.5	0.0	---		77	0.1
2021	"S"	Review	51	36	1.4	0.1	26,762	37.2	619	0.9
2021	"J"	Slate	65	221	0.3	0.3	---		139	0.2
2021	"J"	Review	259	536	0.5	0.7	12,471	17.3	590	0.8
2022	"S"	Slate	96	63	1.5	0.1	---		717	1.0
2022	"S"	Review	94	43	2.2	0.1	12,873	17.9	1793	2.5
2022	"J"	Slate	558	174	3.2	0.2	---		702	1.0
2022	"J"	Review	593	183	3.2	0.3	10,039	13.9	1528	2.1

During MitReef diver surveys in 2019, 2021, and 2022, octocorals comprised ≤12% of target invertebrate taxa vs. 75% of CPCe point distributions at the impact area. Contrary to a negative correlation between octocorals and sponges in CPCe analysis, significant correlations ($p>0.05$) were not detected among target invertebrate taxa (nor among taxa and reef complex). Combined target species octocoral density was not normally distributed ($p<0.005$) due to a density of “0” for 18 transect surveys between 2019 (33%) and 2021 (17%). Octocoral density only exceeded the lower 95% CI density of baseline surveys at 14 transects, all located at the “J” reef in 2021 (17%) or 2022 (22%). In 2021, transect #3 at MR-02-06 exceeded (8.9 colonies m^{-2}) the upper 95% CI density of baseline surveys; however, overall median density for target octocoral species was 0.3 with an IQR of 0.8 colonies m^{-2}.

An overall ratio of 1.1 *Titanidium* sp. to *Leptogorgia* sp. was obtained from video review across MitReef surveys in 2019, 2021, and 2022. Only one target octocoral genera was present in 48 transect surveys (44%), with *Titanidium* sp. slightly more absent (28) than *Leptorgorgia* sp. (20). Among 42 transect surveys with both target octocoral species present, the ratio of *Titanidium* sp. to *Leptogorgia* sp. ranged from 0.02 to 44, with 13 (31%) below 0.6 but only one above 43, the lowest and highest baseline survey transect ratios, respectively.

The mean density of 0.2 sponges m^{-2} in the impact area in 2016 was exceeded during video review of MitReef diver surveys in all years except 2019 and was more than 10x greater than base levels by 2022 (Table 7). Consequently, among target invertebrate taxa, sponges were either the first or second most prevalent in all years and were the only target invertebrate taxa associated with a significant increase across years ($r = 0.92$, $p<0.001$). During baseline surveys sponges were predominantly in the genera *Ircinia* and *Spirastrella*; however, only two of 4,749 video survey review sponge counts were identified as *Ircinia* and *Spirastrella* was never noted. Alternatively, two genera (*Haliclona* and *Cliona*) not seen in baseline surveys accounted for 71% ($n = 3{,}347$) and 15% ($n = 709$) of sponge counts from review of MitReef diver video. Remaining sponge classifications included *Microciona prolifera* ($n = 36$) and sponges not identified to genera ($n = 635$), with most of the latter likely assigned to prevalent genera had suitable visibility and/or survey video quality supported more definitive identifications.

Despite normal distribution ($p = 0.391$), a low mean (i.e., 1.7 stony corals per m^{-2}) and variability across six baseline transects rendered “0” within the 95% CI for this target taxa. Consequently, there was limited possibility of significant difference between baseline surveys and those completed at MitReef since 2019. Beginning in 2021, stony coral density at MitReef sites was typically 10x greater (Table 7) than reported for the impact area in 2016; however, MitReef stony corals were almost exclusively star coral as opposed to *Oculina arbuscula*.

Invertebrate size distributions in the impact area were not normally distributed ($p\leq0.006$); thus, size bin distribution correlations were used for statistical analysis. By 2021, boring sponge widths ($n = 92$) at MitReef sites were statistically similar ($r = 0.82$, $p = 0.001$) to mixed-species sponge size distribution from the impact area. Maximum sponge sizes at MitReef sites in 2022 ($n = 43$) were also statistically similar ($r = 0.74$, $p = 0.006$) to sponges measured in 2021. Through 2022, all MitReef soft corals measured ≤25cm tall; thus, neither *Titanidium* sp. ($n = 90$) nor *Leptogorgia* sp. ($n = 386$) achieved statistical similarity ($p>0.05$) with the impact area.

Modified monitoring efforts, 2023

Prior to commencement of the spring field season, a summary of key findings from the 2022 Annual Report was presented to the Charleston Harbor Post 45 Interagency Coordination Team (ICT) on 23 March 2023. At this meeting, initial concern of failure to satisfy success criteria for fishes and octocorals was expressed by the National Marine Fisheries Service (NMFS), which was discussed in more detail at a follow-up meeting on 29 June 2023. Given those concerns and that logistics and/or weather had limited new data collection to just capture and tagging of black sea bass for the 2023 season, highest priority was placed on characterizing fish and invertebrate fauna at the two Beneficial Reefs (BU's) on the north side of shipping channel. This consensus was made to support a potential need for "out-of-kind" vs. "in-kind" mitigation.

In the month following verbal approval to proceed with modified sampling, weather and tide only supported two field days (24-25 July 2023) of scientific diving. Furthermore, because median visibility was only four feet, these field efforts were used to locate and upload/swap out acoustic receivers which were nearing the end of their deployment battery life.

Weather, tide, and visibility (median = 7 feet) allowed scientific diving operations at BU sites on 25 August 2023. In contrast to MitReef sites, rubble and associated biological organisms were widely scattered and rarely located within 0.5m of either side of transect lines. As such, qualitative rather than quantitative data were collected for BU surveys (Table 8, Appendix C). Completion of remaining BU site surveys were attempted on 6 September 2023, but were called off on-site due to borderline sea state for safe diving operations and ~1 foot of visibility. On the next tide window, RV *Silver Crescent* availability prioritized baited frame video data collection. Due to ~4 feet of visibility, limited baited video new data were obtained across sites (Table 8).

Only two days of field work were completed in October 2023, the final month of scientific diver and vessel availability in CY2023. Scientific divers encountered excellent visibility (≥20 feet) for MitReef surveys on 19 October, which also enabled locating one of two receivers not found following extensive searching in low visibility on consecutive days in July 2023 (Table 8). Reduced visibility on 30 October 2023 hindered a fourth unsuccessful diving day to locate the acoustic receiver at MR-02-01, the data ramifications of which are addressed elsewhere.

At one "S" reef (MR-01-10) and two "J" reef (MR-02-01, MR-02-07) sites surveyed by scientific divers in 2023, target finfish accounted for 91% of 550 fish counts recorded during review of diver video (Table 8). Similarly, divers reported seeing 10 of 13 target finfish along at least one of nine transects surveyed, with median observation along ≥6 transects (Table 8). Red snapper (*Lutjanus campechanus*) dominated non-target species noted by divers along MitReef transects surveyed in 2023, whereas UnID Damselfish comprised most non-target finfish species reported during review of the same transect videos (Table 8). In contrast to MitReef sites, more non-target than target finfish species were seen across four Beneficial Use reef surveys (Table 8).

Target taxa comprised 37% of all invertebrates, and in order of prevalence were represented by hard corals (43%), sponges (36%), and soft corals (21%), and inclusion *Telesto* sp. increased the collective soft coral representation to 29% (Table 8). Overall, soft-encrusting taxa comprised 72% of invertebrates across a subset of nine MitReef transects surveyed in 2023 (Table 8).

Table 8. Taxonomic observations across survey techniques at MitReef (3 sites, 9 transects) and Beneficial Use reefs (4 sites, presence off transects) between 25 August and 30 October 2023.

	Video Review		**Diver Slate**			**Diver Qualitative**				**Baited Video**			
	MitReef		*MitReef*			*Beneficial Use*				*MitReef*		*Beneficial Use*	
Name	Sites	Sum	Low	Med	High	04-01	04-04	02-01	02-04	Sites	Sum	Sites	Sum
Black sea bass	3	285	7	2				x	x	3	11	5	18
Gag grouper			6		1					1	1		
Sheepshead	3	16	8	1						1	1		
Oyster toadfish			1										
Pinfish			1									1	1
Slippery dick	3	112	1	4	1		x	x	x	2	3	2	3
Spottail pinfish	1	11	1	7	1					2	4		
Belted sandfish	3	74	6	3			x			3	4		
Cubbyu	3	5	4										
Southern hake													
Batfish													
Southern flounder				1									
Scad													
Blue angelfish			1										
Northern puffer			1										
Red snapper			6										
Reef butterflyfish			1										
Blenny						x							
Sand perch						x							
Sea horse							x						
Beaugregory								x	x				
Bank sea bass								x	x				
Orange filefish								x					
Tomtate	1	1											
Longspine porgy	1	1											
Northern puffer	1	1											
Bandtail puffer	2	2											
Cocoa damselfish	1	1											
UnID Damselfish	3	41											
Titanidium sp.	3	175					x	x	x				
Leptogorgia sp.	3	125				x	x	x	x				
Hard coral	3	609						x	x				
Sponges	3	513					x	x	x				
Tunicates (9 listings)	1 to 3	172					x	x	x				
Barnacles	1	22											
Hydroids	3	66											
Telesto sp.	3	165											
Long-spined urchin	3	375					x	x	x				
Other Echinoderm	1	1											
Eastern oyster	1	70											
Macroalgae	3	1530											
Anemone						x							
Portunid crab						x	x						
Encrusting Bryozoan							x	x	x				

MitReef fish capture rates and acoustic tagging

Four fishing expeditions occurred in 2022 (15 February, 21 March) and 2023 (15 April, 15 May).

In 2022, 198 black sea bass were captured in 5.6 hours of hook-and-line fishing at four sites. Based on total length, 35 (18%) black sea bass captured in 2022 were good candidates for tagging; thus, all 20 acoustic transmitters were able to be deployed. In 2022, only two non-black sea bass were captured: a bluefish (*Pomatomus saltatrix*) and a whiting (*Menticirrus saxatalis*).

In 2023, 212 black sea bass were captured in 6.0 hours of hook-and-line fishing at four sites plus 2.7 hours of blackfish trap fishing at one site. Based on total length, 25 (12%) black sea bass captured in 2023 were good candidates for tagging; however, only 14 transmitters were deployed due to (a) no tagging occurring on 15 April and (b) emphasis on deploying acoustic transmitters evenly across sites with acoustic receivers. Collectively in 2023, 10 additional fish species were encountered: six bluefish (6), five pigfish (*Orthopristis chrysoptera*), three red snapper, two gag grouper (including one acoustically tagged), two oyster toadfish, and one specimen each of pinfish, whiting, bank sea bass, lizardfish, and weakfish (*Cynoscion regalis*).

Thirty-four telemetered black sea bass measured 27.9 to 38.5 cm TL (median = 30.9 cm TL), with the sole telemetered gag grouper measuring 50.0 cm TL. Only half of black sea bass were confidently sexed (7 female, 3 male) in 2022; thus, sexing was not attempted in 2023. Across years, 10 black sea bass were acoustically tagged at two sites (MR-01-10, MR-02-07), five released at two sites (MR-02-13 in 2022, MR-02-01 in 2023), and four released at the fifth site (MR-01-07 in 2022). The acoustically tagged gag grouper was also captured at MR-01-10.

The median time for surgically implanting acoustic transmitters in 34 black sea bass was six minutes (range = three to 13 minutes), the same as transmitter implantation in the gag grouper. Due to short surgery times and the absence of anesthesia[5], post-surgery recovery time was also rapid but was not specifically recorded. Prior to surgery, black sea bass were held in an aerated surface live well (3' deep) between five and 111 minutes (median = 65 minutes) compared to just three minutes for the gag grouper. Post-surgery holding time in the live well for black sea bass ranged from three to 84 minutes (median = 25 minutes), also longer than the gag group post-op holding time of five minutes. Total surface pressure exposure time for black sea bass ranged from 29 to 157 minutes (median = 107 minutes), but just 14 minutes for the gag grouper.

Following release, and through final acoustic receiver uploads for this report in October 2023, only two black sea bass were never detected, both of which were captured and tagged at the only site (MR-02-01) with a receiver loss during this five-year study. All other black sea bass were detected between one- and 567-days post-release (median = 166 days). No significant ($p>0.05$) correlations were detected between days detected post-release and any of four surgery metrics.

[5] Anesthesia was not used given the possibility of fish capture and fish consumption within a month of anesthesia. In 2022, two black sea bass telemetered on 15 February was recaptured after 35 and 67 days, respectively, with one of these fish recaptured a second time four days later. In 2023, two black sea bass telemetered on 12 May were later reported as recaptured after 76 to 208 days at large.

Acoustic telemetry monitoring
Acoustic receivers were established at five MitReef sites on 6 August 2019. Sites were selected to monitor as much of each reef complex with as few receivers as possible. Assuming a modal detection range of 250m, receivers were placed at two "S" reef sites (MR-01-07, MR-01-10) and three "J" reef sites (MR-02-01, MR-02-07, MR-02-13). Final data uploading for this report occurred on 19 October (MR-01-07, MR-01-10, MR-02-07) and 30 October (MR-02-13); however, no data were available for MR-02-01 after 18 November 2022 given that the new receiver deployed on that day was never relocated in 2023 following multiple search attempts.

Acoustic receivers were deployed 88 to 446 days (median = 302 days) across five upload cycles. Between 5 May 2022 and 19 October 2023, temperature logging acoustic receivers (i.e., VR2Tx) were also deployed at MR-01-10. During the final 18 months of acoustic telemetry monitoring, mean daily bottom water temperature reached a minimum of 11.6°C (29 December 2022) but achieved similar warm temperature distributions in summers 2022 and 2023 (Figure 10). Mean hourly noise was also recorded by VR2Tx acoustic receivers, and mean daily noise was significantly correlated ($r = 0.82$, $p<0.001$) with mean daily water temperature (Figure 10).

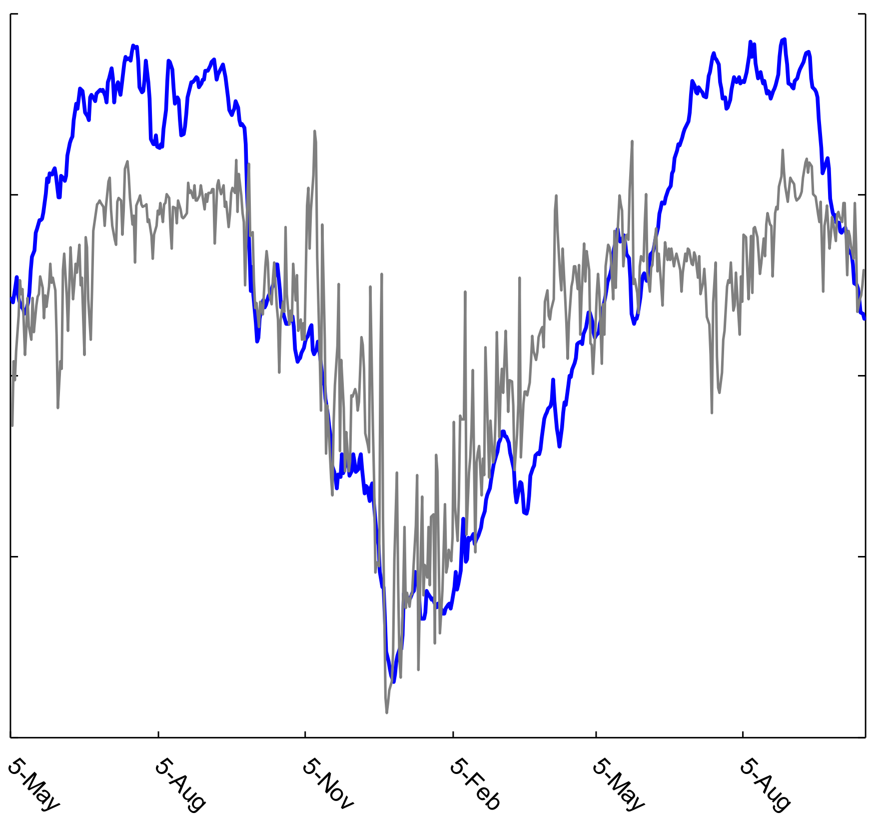


Figure 10. Mean daily bottom water temperature (blue line, first y-axis) at MR-01-10 was significantly correlated with acoustic receiver noise (gray line, second y-axis) between 5 May 2022 and 19 October 2023.

Acoustic detections were recorded within a day of deploying acoustic receivers at MitReef sites and continued being recorded through the final report upload day. In total, 683,713 acoustic detections were recorded across five sites, 82% of which stemmed from 34 black sea bass and one gag grouper acoustically tagged at these sites (Table 9). Three range tags deployed prior to acoustic tagging fishes at MitReef sites accounted for an additional 17% of detections. Less than 7k detections were associated with 341 transmitter codes spanning 22 species tagged by other research groups, and only 44 transmitter codes (127 detections) remain unmatched (Table 9). Despite low overall detection, 30% of transient species transmitters were detected in multiple years (Table 10), including 21 transmitters detected in more than two years.

Total detections for individual black sea bass ranged from four to 62,682 (median = 15,921). All 14 black sea bass tagged at the "S" reef were detected by both receivers at that reef, but 77-100% (mean = 93%) of detections for these fish were by the respective capture site receiver. Two black sea bass captured and tagged at the "S" reef were also detected by "J" reef receivers, but both fish were detected 95-99% by their capture site receivers. Fifteen black sea bass captured at "J" reef sites with no data loss were detected 31-100% (mean = 82%) by the respective capture site receiver. Across receiver sites, black sea bass detections were not significantly correlated ($p>0.05$) with the number of fish tagged at the respective site nor total site monitoring days.

Black sea bass were only tagged at MR-02-01 in 2023, which was devoid of receiver coverage. Among the five black sea bass tagged at this site in May 2023, three were episodically detected by other "J" reef receivers, including one that was recaptured during fieldwork in July; this recaptured fish was also briefly detected by "S" reef receivers. No acoustic detections were recorded for two black sea bass tagged at MR-02-01 in 2023; however, one was recaptured by a public angler in the Charleston, SC shipping channel on 5 December 2023. In 2022, four black sea bass were detected briefly (2 to 38 detections) and a fifth extensively (>23k detections) by acoustic receivers in the shipping channel, notably at station CHS Green 09.

Only three of 20 black sea bass tagged in 2022 were detected in 2023. Two of these fish, both tagged on 15 February 2022, were detected routinely until abrupt departure on 22 February 2023 and 16 March 2023, respectively. A third black sea bass, tagged on 21 March 2022, was also routinely detected until abrupt departure on 27 February 2023; however, on 30 September this fish returned to the capture (and 99% detection site) and was detected routinely through receiver uploading a few weeks later. A fourth black sea bass was detected routinely at its capture site from 21 March 2022 until abrupt departure on 22 December 2022, followed by three sequential detections off Stono Inlet (CHS S6) eleven hours later.

Across five sites, black sea bass detections were greatest between 0000 and 1200 UTC, which roughly corresponds nocturnal activity (Figure 11). Black sea bass diel activity was significantly correlated across "J" and "S" reefs (Table 10), which supports a behavioral vs. locational basis. Diel activity for gag grouper was also significantly inversely correlated with black sea bass diel activity across reefs (Table 10); however, because only one gag grouper was acoustically tagged, inverse correlation could also reflect improved detection opportunity for this gag grouper.

Fish transmitters in this study expire in mid-2026; thus, receiver monitoring will continue.

Table 2. Ninety-nine percent of detections recorded by acoustic receivers at five MitReef sites between August 2019 and October 2023 were affiliated with transmitters deployed for this study; however, >400 transient transmitters deployed by other research groups were also detected, nearly a quarter of which were also detected at MitReef sites in multiple years.

Group	Identification	Transmitters	Repeat yrs	Detections
This study	Range tag; MR-01-07NW	1		18665
This study	Range tag; MR-01-07SE	1		37844
This study	Range tag; MR-02-13SW	1		59662
This study	Black sea bass	32		542419
This study	Gag grouper	1		18083
Gamefish	Cobia	18	4	527
Gamefish	Red drum	7	3	295
Gamefish	Tarpon	2		9
Gamefish	Little tunny	1		31
ESA/SARBO	Atlantic sturgeon	183	71	3527
ESA/SARBO	Leatherback sea turtle	1		15
ESA/SARBO	Mobula birostris	1		3
Elasmobranch	White shark	65	10	636
Elasmobranch	Blacktip shark	12	2	71
Elasmobranch	Cownose ray	11	3	109
Elasmobranch	Tiger shark	10	1	231
Elasmobranch	Sand tiger shark	8	2	967
Elasmobranch	Sandbar shark	6	1	160
Elasmobranch	Bull shark	5	1	24
Elasmobranch	Blacknose shark	2	1	94
Elasmobranch	Finetooth shark	2		7
Elasmobranch	Lemon shark	2	1	92
Elasmobranch	Bonnethead shark	1		4
Elasmobranch	Common thresher	1	1	92
Elasmobranch	Roughtail stingray	1		11
Elasmobranch	Thresher shark	1		4
Elasmobranch	Atlantic sharpnose shark	1		4
	To-be-assigned	44		127

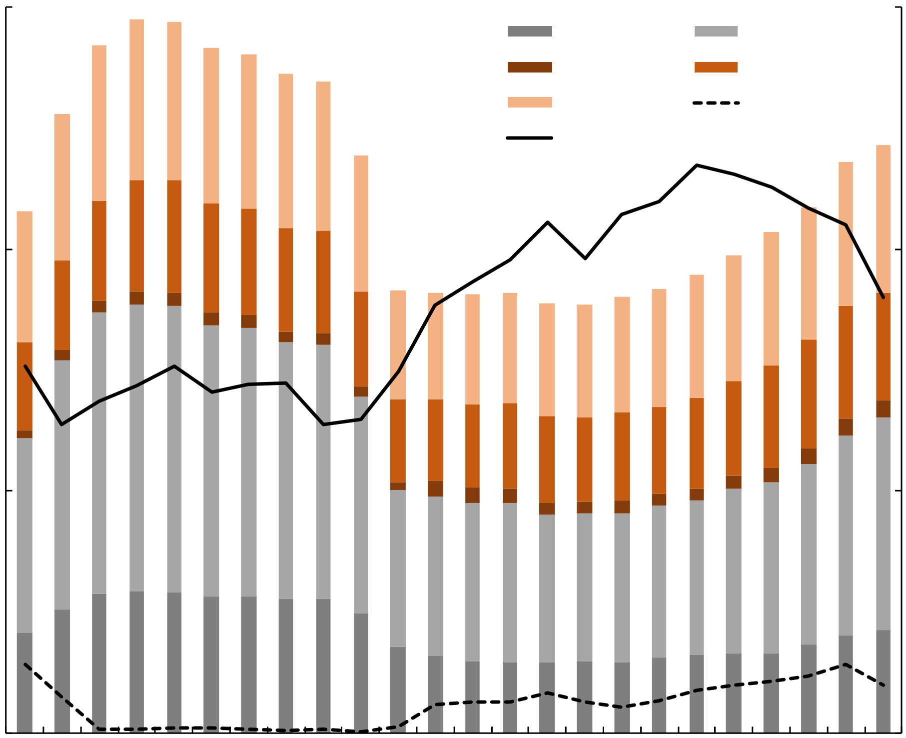


Figure 11. Diel acoustic receiver detection of 32 black sea bass (bars, first y-axis) and one gag grouper (lines, second y-axis) across MitReef sites between February 2022 and October 2023.

Table 3. Correlation (r-value, cells) matrix of diel detection trends between species and receiver sites; significant (p<0.05) correlations are highlighted in gray font.

	BSB, 01-07	BSB, 01-10	BSB, 02-01	BSB, 02-07	BSB, 02-13	Gag, 01-07
BSB, 01-10	0.99					
BSB, 02-01	-0.23	-0.13				
BSB, 02-07	0.69	0.72	0.35			
BSB, 02-13	0.93	0.94	-0.01	0.86		
Gag, 01-07	-0.60	-0.57	0.33	-0.13	-0.36	
Gag, 01-10	-0.82	-0.77	0.47	-0.22	-0.57	0.68

Discussion

For as long as new reefs have been constructed in the ocean, distinction between biological production vs. attraction has been paramount to evaluating their success (Grossman et al., 1997). Fishes with recreational and/or commercial 'value' have received considerable emphasis, but fish communities vary with time and habitat (Sedberry and VanDolah, 1984). As such, a multi-taxa analytical approach is best for characterizing new reef success. Data collection duration appropriate for capturing temporal succession is also a crucial consideration, particularly when reefs are constructed to mitigate habitat loss (Hueckel et al., 1989). Dredging to maintain, deepen, and/or widen shipping channels for safe navigation poses a risk of habitat degradation. In areas with suitable visibility, relocating sensitive species before dredging can minimize loss.[6] However, in low visibility, relocating substrate with biota attached may present the only option. Following the creation of two new reefs using material dredged from the Charleston Harbor shipping entrance channel, we characterized temporal succession of finfish and invertebrate taxa at these new reefs for five years, which extended through the minimum colonization time for this material suggested by a Habitat Equivalency Analysis completed as part of the EIS.[2].

Two years prior to material removal, scientific divers documented fish and invertebrate taxa at the impact area along six, 20-m transects (Dial Cordy and Associates, 2016). "Overall, the habitat monitored over these six transects was characterized by relatively low species diversity", with just eight sessile invertebrate and 13 finfish species emphasized (Dial Cordy and Associates, 2016). Extensive variability in relative abundance of seven finfish species across these transects also produced a median abundance of "0" (Table 2). Consequently, despite never (batfish) or rarely (scad, hake) observing some of these species at MitReef transects during 2019-2023, statistical differences were not detected relative to the 2016 reference data. Large inter-quartile ranges were also associated with six species seen in 2016 with median abundance >0. Median abundance for these species at MitReef during 2019-2023 fell within the large reference abundance ranges; thus, statistical differences were also not detected. As conveyed in Figure 3, median abundance at MitReef was only noticeably different than median abundance in 2016 for two species. The first species, black sea bass, is comprised of two stocks along the U.S. Eastern Seaboard with the stock north of Cape Hatteras, NC exhibiting increased commercial but generally declining recreational landings since 2016.[7] Conversely, south of Cape Hatteras, black sea bass landings since 2016 have declined across fisheries and capture gear types.[8] Regarding pinfish, standardized indices of abundance from multiple long-term data fishery-independent data sets suggest relatively low pinfish abundance in coastal waters off South Carolina relative to other areas in the Southeast U.S. (Burke, 2023). A high degree of inter-annual variability in pinfish abundance was also noted, but unfortunately 2019 was the terminal year of temporal data analysis (Burke, 2023) so is of limited value for interpreting MitReef pinfish abundance trends.

---

[6] Kenney et al. (2012) "Coral relocation: A mitigation tool for dredging works in Jamaica." Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9-13 July 2012, 20A Restoration of coral reefs. https://www.icrs2012.com/proceedings/manuscripts/ICRS2012_20A_4.pdf (accessed 12 February 2024).

[7] Atlantic States Marine Fisheries Commission, Black Sea Bass. https://www.asmfc.org/species/black-sea-bass (Accessed 12 February 2024)

[8] Southeast Data Assessment and Review (SEDAR) 76, South Atlantic Black Sea Bass Assessment Report. https://safmc.net/documents/a04a_sedar-76-stock-assessment-report-south-atlantic-black-sea-bass-pdf/ (Accessed 12 February 2024.

In addition to differences in invertebrate community succession, nuances in survey designs could have also influenced invertebrate discrepancies between the impact area and MitReef sites. During surveys in March 2016, “hardbottom habitat throughout all transects ranged from low to medium relief in some areas to no relief in other areas (Dial Cordy and Associates, 2016).” Furthermore, during surveys in March 2016, “bare areas of hardbottom were not widely observed and were usually colonized by either bryozoans, turf algae, octocorals, stony corals, or invertebrates (Dial Cordy and Associates, 2016).” These qualitative statements were consistent with CPCe analysis in which sandy substrate accounted for 70-91% of randomly assigned points superimposed on still images created from video (Dial Cordy and Associates, 2016). Provided that random point assignment was representative of habitat feature distribution, impact area transects may have only contained 9-30% rocky substrate, vastly different than the 53-75% (median) rocky substrate coverage along MitReef transects. Concern for this distinction was visually conveyed by Figures 10 and 11, respectively, of Dial Cordy and Associates (2016) which contrasts 91% sandy substrate with extensive octocoral (and maximum *Oculina* count) relative to just 70% sandy substrate with predominantly Bryozoan and turf/bare substrate. Fortunately, among invertebrate functional groups analyzed for CPCe analysis in 2016, only Bryozoan distribution significantly declined with decreasing rocky substrate coverage (Table 3).

At the impact area, turf algae/bare substrate accounted for just 1-6% of random point distributions in CPCe analysis (Dial Cordy and Associates, 2016). Excluding sandy substrate and fish points, turf algae/bare substrate represented 1% (T3) to 34% (T4) of rocky substrates, or invertebrate colonization of 66-99% of rocky surfaces (Dial Cordy and Associates, 2016). Target invertebrate counts (>27k) across 36 MitReef sites in 2022 (Appendix B) were 5.3x greater than target invertebrate counts (851) from 6 impact area surveys in 2016 (Appendix A, Dial Cordy and Associates, 2016). Furthermore, non-target invertebrates accounted for 30% of all invertebrate counts recorded at MitReef transects in 2022 (Appendix B). Thus, although percent cover of rocky substrate was not specifically computed for either the impact area or MitReef surveys, numerical differences in taxonomic counts support comparable colonization coverage between studies despite differences in invertebrate colonization.

Temporal invertebrate coverage succession was evident at MitReef sites (Figure 8, Appendix B). Hard-encrusting colonizers dominated coverage in all years but transitioned from barnacle dominance in 2019 to stony coral dominance thereafter (Appendix B). At rocky reefs in higher latitudes dominated by star coral (*Astrangia poculata*), this species succeeds macroalgae and encrusting bryozoan recruitment after two years and is thus considered an indicator species for “end successional state (DiPreta, 2019).” As such, star coral absence from the impact area in 2016 (Dial Cordy and Associates, 2016) was surprising but may reflect conducting 2016 surveys in water temperatures approximate to a physiological threshold (<15°C) for star coral calcification (Jacques et al., 1983). Conversely, the impact area supported *Oculina* colonies (Dial Cordy and Associates, 2016) but this species was rarely seen across MitReef sites. In a 1981 taxonomic survey of benthic community structure off South Carolina and Georgia, star corals were rare, but *Oculina* corals were common, particularly at the shallowest (17m) sites (Wenner et al., 1984). Across >400 taxa, water depth best predicted invertebrate composition (Wenner et al., 1984), and may have influenced differences between impact area and MitReef sites given that both stony corals species locally occur close to shore (Devictor et al., 2010).

In the Southeast U.S., where vertical relief is sufficiently moderate to support trawl and dredge sampling, hard bottom invertebrate communities are dominated by a diversity (≥70 taxa each) of sponges, bryozoans, and Cnidarians (Wenner et al., 1984). At the impact area, CPCe analysis suggested that Bryozoans, identified as *Bugula turrita*, were proportionately more prolific than sponges and Cnidarians; however, bryozoans were not quantified during impact area surveys (Dial Cordy and Associates, 2016). Bryozoans also dominated colonization of experimental reefs located near natural structure at Gray's Reef National Marine Sanctuary, particularly when cages excluded predators (Fioravanti-Score, 1988). Contrary to impact area abundance, *B. turrita* was rarely encountered during hard bottom taxonomic surveys off South Carolina and Georgia but at least five other species of *Bugula* were routinely collected, notably from sites the middle shelf (Wenner et al., 1984). Only the tubular bryozoan (*Schizoprella floridana*) was reported from MitReef sites, with 60% (n = 15) of observations across transects at a single site (MR-02-07) in 2021. Instead, sponges were 9% of invertebrate abundance across MitReef sites in 2022, nearly double the collective contribution of tunicates and soft corals combined (Appendix B). Curiously, impact area sponge genera in 2016 were absent or rare at MitReef sites through 2023, despite two of these genera (*Ircinia*, *Spirastrella*) also being common sponges on the inner shelf (Wenner et al., 1984). Alternatively, the most common sponge genus (*Haliclona*) at MitReef sites was also frequently encountered during hard bottom taxonomic surveys on the inner and middle shelf (Wenner et al., 1984). However, the second most common sponge genus (*Cliona*) at MitReef sites was rarely encountered during taxonomic surveys in 1981, and never identified as *C. celata* (Wenner et al., 1984). Given that *C. celata* has been identified at natural reefs with high relief complexity off South Carolina (Burgess, 2008) and Georgia (Freeman et al., 2007), we attribute this discrepancy to inability to sample high topographic relief in 1981 surveys vs. misidentification during MitReef surveys. We likewise emphasize prevalence of *C. celeta* at MitReef as further support for reef success.

Soft coral recruitment to MitReef sites posed the least favorable comparison to the impact area which featured significantly greater densities and for significantly larger-sized specimens of *Titanidium* and *Leptogorgia* species (Dial Cordy and Associates, 2016). At first glance this observation is also quite unexpected given both genera were ubiquitous during hard bottom taxonomic surveys in 1981 (Wenner et al., 1984). However, Burgess (2008) also reported absence of *Titanidium* and both *Leptogorgia* species from substrate scrapings at both artificial and natural reefs off South Carolina. Furthermore, Burgess (2008) only reported *Leptogorgia cardinalis* from the natural reef site, and this species was also far less common during 1981 surveys than other *Leptogorgia* species (Wenner et al., 1984). Octocorals (and stony corals) infrequently colonized ship reefs off South Carolina (22-31 m), with attachment to horizontal surfaces 7x greater than vertical surfaces up to 10 years later (Wendt et al., 1989). Alternatively, aqueous extracts from sea whips inhibit barnacle settlement (Ritschof et al., 1985), which may reflect a natural defense mechanism developed over an evolutionary history of resource competition. Indeed, soft coral coverage at MitReef sites increased systematically across survey years, concurrent with a decline in the abundance of live barnacles (Appendix B). Lastly, *Telesto* sp. soft corals not reported from impact area surveys were also observed extensively at MitReef sites beginning in 2022, with regal sea fans (*Muricea pendula*) also occasionally seen (Appendix B). Therefore, MitReef rubble provides appropriate substrate for soft coral colonization, but for which density appears to be governed by other ecological processes.

Excluding bryozoans, MitReef soft-encrusting community structure mirrored structure reported for natural reefs at similar water depth but latitudinally more distant sites in the Grand Strand region of South Carolina (Burgess et al., 2011). Alternatively, despite geographic proximity, MitReef community structure across and within taxa was less aligned with the impact area in the Charleston, SC shipping channel (Dial Cordy and Associates, 2016). Our findings collectively reinforce the conclusion of Wenner et al. (1984) that water depth, far more than latitude or season, shape invertebrate species structure at hard bottom reefs in the South Atlantic Bight. Seasonality influences initial community structure, but after a year, community structure appears to be mostly influenced by spat settlement distance from natural reefs (Van Dolah et al., 1988). When comparing among similar water depths, the orientation of reef surfaces available for invertebrate recruitment should also factor into setting new reef colonization success metrics. Largely based on Wendt et al. (1989), USACE expected MitReef community structure to resemble the impact area after 3.5 years.[2]. Without fully appreciating habitat configuration nuances that shape community structure, MitReef functional ratios through 2022 may seem 'off'. Alternatively, viewing the same data through a more refined ecological lens suggests incredible success, particularly achieving sponge dominance (on both horizontal and vertical surfaces) as opposed to octocoral dominance in as little as 3.5 years (Wendt et al., 1989). In summary, MitReef sites supported greater invertebrate and finfish diversity than impact sites.

In addition to temporal increases in species diversity at MitReef sites, scientific divers routinely observed juvenile black sea bass beginning in 2021 (but not always coded as such, Appendix A). Juvenile high hat (*Pareques acuminatus*) were also observed in 2021. Particularly if juvenile fishes were spawned at MitReef sites their occurrence is especially noteworthy. Alternatively, even if juvenile fishes merely recruited to MitReef sites, their occurrence suggests that habitat complexity provided by a range of rubble deposited and/or weathered across years supports diverse age/size structure. Acoustic detection of seasonally transient elasmobranchs also conveys a high degree of MitReef ecological functionality; although acoustic transmitter ranges could indicate detection of tagged animals 'off site', several large elasmobranchs were also occasionally documented 'on site' by baited video frames. In both tagging years, most black sea bass captured in spring remained resident through peak warm water periods in the summer, with several individuals detected year-round. Seasonal residence and site fidelity data for black sea bass remains preliminary but has already demonstrated greater intra-seasonal movement than suggested by tag-recapture at a nearby artificial reef (Low and Waltz, 1991). Likewise, three-year transmitter battery life should enable these fish to be detected at MitReef and other monitored locations for several more years. To date, black sea bass have only been monitored within a single period of extended residence (Fabrizio et al., 2014); thus, continued telemetry monitoring at MitReef sites should be of great interest to regional fisheries managers.

Acknowledgements
In chronological order, we thank key USACOE personnel for funding and contract assistance: M. Messersmith, H. Carpenter, B. Ward, E. Fritz, and A. Shirey. We likewise thank C. Cooksey and P. Wilbur (NMFS) plus D. Sanger, A. Tweel, and S. Crowe (SCDNR) for study design and analysis support. We also thank S. Dial and M. Rice (Dial Cordy and Associates) for providing data and insights regarding impact area surveys during Final Report preparation. We are also grateful to K. Joyner (SCDNR) for superb grants management.

Four report authors collectively completed 35% of scientific diving effort, with remaining support provided by eight active and nine in-active divers (listed in order of contribution): K. Spanik, M. Davin, E. Waldrop, K. Kolmos, J. Evans, C. Evans, G. Sorg, J. Vecchio, L. Vinyard, M. Taliercio, H. Hillman, W. Gould, C. Doll, S. Burns, B. Austin, C. Pickens, and C. Parker.

C. Evans and C. McQuaid completed video review in 2019 and 2021, with this task completed by two co-authors (W. Sinkus, H. Hiers) in final project years. We also thank J. Cowan, C. Parker, and D. Knott for invertebrate identification assistance.

Black sea bass fishing and acoustic tagging was possible thanks to contributions by J. Yost, J. Evans, H. Hiers, B. Von Harten, K. Spanik, H. Hiers, M. Reichert (ret.). We also thank M. Perkinson and J. Coz for managing conventional tagging and recapture data.

Lastly, we thank several SCDNR researchers (B. Post, B. Frazier, J. Yost/M. Perkinson) and a plethora of researchers operating from the Northeast U.S. through the Bahamas (Table 11) for capturing and tagging transient species detected at MitReef since August 2019.

Table 4. Telemetry researchers (* denotes SCDNR) and affiliated species tagged that were detected by MitReef receivers between August 2019 and October 2023.

Primary Researcher	*Atlantic sharpnose shark*	*Atlantic sturgeon*	*Blacknose shark*	*Blacktip shark*	*Bonnethead shark*	*Bull shark*	*Cobia*	*Common thresher*	*Cownose ray*	*Finetooth shark*	*Leatherback sea turtle*	*Lemon shark*	*Little tunny*	*Mobula birostris*	*Red drum*	*Roughtail stingray*	*Sand tiger shark*	*Sandbar shark*	*Tarpon*	*Thresher shark*	*Tiger shark*	*White shark*
Alistair DM Dove														x								
Andy J. Danylchuk																			x			
Anne Markwith; Steve Poland							x															
Austin Gallagher; Ollie Shipley																					x	
Beth Bowers; Stephen Kajiura				x																		
Bill Post*		x																				
Bob Fisher									x													
Bryan Franks																						x
Bryan Frazier*				x	x																x	
Caroline Collatos																		x				
Carter Watterson		x																				
Charles Bangley									x													
Charles P. Stence		x																				
Chris Hager		x																				
Chris Kalinowsky															x							
Christina LoBuglio; Bryan Franks																						x
Christina LoBuglio; Bryan Franks; Bryan Frazier*																					x	
Christina LoBuglio; Bryan Franks; Tobey Curtis																						x
Connor McManus																			x	1		
Danielle Haulsee																	x					
Derek Aoki; Anne Page-Karjian										x	1											
Dewayne Fox		x																				
Doug Peterson		x																				
Edd Brooks						x																
Eric Hilton		x																				
Eric Reyier	x		x							x		x										
Evan Ingram		x																				
Fredrick Scharf		x																				
GA Aquarium; Bryan Frazier*																	x					
Greg Skomal																						x
Ian Park		1																				
Jason Kahn		1																				
Jeff Kneebone													x									
Jeffrey A. Buckel							x															
Jeremy Arnt						x																
Jessica Wingar																		x				
Jon Dodd																						x
Joy Young							x															
Justin Yost*; Matt Perkinson*							x															
Keith Dunton				x												x		x				
Kevin Weng							x															
Madeline Marens; Carol Price																	x					
Matt Balazik		x																				
Matt Ogburn						x			x													
Matt Smukall; Maurits VZB; Vital Heim						x																
Michael Fogg								x														
Michael Frisk				x																		
Nancy Pham Ho																	x					
Neil Hammerschlag																					x	
Riley Gallagher							x															
Steven Kessel												x										

References

Burgess, D.E. 2008. Development of invertebrate assemblages on artificial reef cones off South Carolina: Comparison to an adjacent hard-bottom habitat. Thesis, College of Charleston.

Burgess, D. E., George H.M. Riekerk, and Derk C. Bergquist. 2011. The 2007-2009 Grand Strand nourishment project: Impact of sand migration on invertebrate communities associated with nearshore and hardbottom habitats. Submitted to US Army Corps of Engineers, Charleston District, Prepared by SC Department of Natural Resources, Marine Resources Division.

Burke, S.R. 2023. Long term population trends for pinfish (*Lagodon rhomboides*) off the Southeastern U.S. Thesis, College of Charleston.

DeVictor, S.T., D.M. Knott, and S.E.Crowe. 2010. South Carolina Beachcomber's Guide: A Guide to the common invertebrates, plants, and natural artifacts of the South Carolina seashore. Printed by the South Carolina Department of Natural Resources, Columbia, SC., 94 p;

DiPreta, G.M. 2019. Successional state of benthic communities in temperate coral dominated habitats in Rhode Island. Thesis, Southern Connecticut State University.

Dial Cordy and Associates, Inc. 2016. Entrance Channel Hardbottom Surveys and Biological Characterization, Charleston Harbor Post 45 Deepening Project. Final Report, 34 p. + Appendices.

Fabrizio, M.C., J.P. Manderson, and J.P. Pessutti. 2014. Home range and seasonal movements of black sea bass (*Centropristis striata*) during their inshore residency at a reef in the mid-Atlantic Bight. *Fishery Bulletin* 112(1):82-97.

Fioravanti-Score, A.M. 1998. Sessile invertebrate colonization and community development in the South Atlantic Bight. Thesis, Georgia Southern University. Statesboro, Georgia

Freeman, C.J., D.F. Gleason, R. Ruzicka, R.W.M. van Soest, A.W. Harvey, and G. McFall. 2007. A biogeographic comparison of sponge fauna from Gray's Reef National Marine Sanctuary and other hard-bottom reefs of coastal Georgia, U.S.A. Porifera Research: Biodiversity, Innovation and Sustainability. *Série Livros* 28:319-325.

Grossman, G.D., G.P. Jones, and W.J. Seaman, Jr. 1997. Do artificial reefs increase regional fish production? A review of existing data. *Fisheries* 22(4):17-23.

Hueckel, G.J., R.M. Buckley, and B.L. Benson. 1989. Mitigating rocky habitat loss using artificial reefs. *Bulletin of Marine Science* 44(2): 913-922.

Jacques, T.G., N. Marshall, and M.E.Q. Pilson. 183. Experimental ecology of the temperate scleractinian coral *Astrangia danae* II. Effect of temperature, light intensity and symbiosis with zooxanthellae on the metabolic rate and calcification. *Marine Biology* 76:135-148.

Kohler, K.E. and S. M. Gill. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* 32(9): 1259–1269.

Low, R.A., and C.W. Waltz. 1991. Seasonal utilization and movement of black sea bass on a South Carolina artificial reef. *North American Journal of Fisheries Management* 11(2):131-138.

Rittschof, D., I.R. Hooper, E.S. Brnascomb, and J.D. Costlow. 1985. Inhibition of barnacle settlement and behavior by natural products from whip corals, Leptogorgia virgulate (Lamarck, 1815). *Journal of Chemical Ecology* 11:551-563.

Sedberry, G.R., and R.F. VanDolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the U.S.A. *Environmental Biology of Fishes* 11:241-258.

Van Dolah, R. F., P.H. Wendt, D. M. Knott, and E. L. Wenner. 1988. Recruitment and community development of sessile fouling assemblages on the Continental Shelf off South Carolina, U.S.A. *Estuarine, Coastal and Shelf Science* 26:697-699.

Wenner, E.L., P. Hinde, D.M. Knott, and R.F. Van Dolah. 1984. A temporal and spatial study of invertebrate communities with hard-bottom habitats in the South Atlantic Bight. *NOAA Technical Report NMFS 18*, 104 p.

Zar, J.H. 1996. Biostatistical analysis, 3rd edition. Prentice Hall, Upper Saddle River, NJ.

Appendix A: Non-target fishes observed across survey techniques and monitoring sites, 2019-2023. Symbols denote species not seen until non-standardized surveys in 2023, either at Beneficial Use reef sites (*) or at a subset of MitReef sites (^).

				Baited frames				**Diver video**				**Diver slate**			
				2019 - 2022		*2023*		*2019 - 2022*		*2023*		*2019 - 2022*		*2023*	
Code	Group	ScientificName	Common Name	Freq	Sum	BU	MR	Freq	Sum	BU	MR	Freq	Sum	BU	MR
AA06	Elasmo	*Carcharodon carcharias*	White shark	1	1			0	0						
A048	Elasmo	*Dasyatis americana*	Southern stingray	2	2			0	0						
A049	Elasmo	*Dasyatis centroura*	Roughtail stingray	6	6			0	0						
A023	Elasmo	*Galeocerdo cuvier*	Tiger shark	1	1	*		0	0						
A054	Elasmo	*Gymnura micrura*	Smooth butterfly ray	1	1			0	0						
A057	Elasmo	*Myliobatis freminvillii*	Bullnose ray	5	5			0	0						
A039	Elasmo	*Rhinobatos lentiginosus*	Atlantic guitarfish	3	3			1	1						
A028	Elasmo	*Rhizoprionodon terranovae*	Atlantic sharpnose shark	12	13			0	0						
B345	Elasmo	*Sphyrna* sp.	Hammerhead shark	1	1			0	0						
A439	Finfish	*Acanthostracion quadricornis*	Scrawled cowfish	5	5			0	0						
A681	Finfish	*Acanthurus bahianus*	Ocean surgeonfish	0	0			1	1						
A426	Finfish	*Aleuterus schoepfi*	Orange filefish	0	0			1	1	*					
A428	Finfish	*Balistes capriscus*	Gray triggerfish	11	13			3	5			10			
A084	Finfish	*Brevoortia tyrannus*	Atlantic menhaden	2	250			0	0						
A986	Finfish	*Calamus* sp.		1	1		^	2	5						
A215	Finfish	*Caranx bartholomaei*	Yellow Jack	6	17			0	0						
A216	Finfish	*Caranx chyrsos*	Blue runner	14	1259			3	11						
A481	Finfish	*Caranx* sp.		1	1		^	0	0						
A175	Finfish	*Centropristis ocyurus*	Bank Sea Bass	0	0			1	1						
A601	Finfish	*Centropristis* sp.	juvenile black sea bass	12	25			2	9						
A297	Finfish	*Chaetodipterus faber*	Atlantic spadefish	29	163			5	28			12			
A301	Finfish	*Chaetodon sedentarius*	Reef butterflyfish	0	0			0	0			1			^
A448	Finfish	*Chilomycterus schoepfi*	Striped burrfish	5	6			2	2						
A220	Finfish	*Chloroscombrus chrysurus*	Atlantic bumper	10	707			0	0						
A482	Finfish	Clupeidae	UnID Herring	4	320	*		0	0						
A278	Finfish	*Cynoscion regalis*	Weakfish	7	14			0	0						
A878	Finfish	*Diplectrum bivittatum*	Dwarf sand perch	1	1			0	0						
A178	Finfish	*Diplectum formusom*	Sand perch	17	30			18	45						

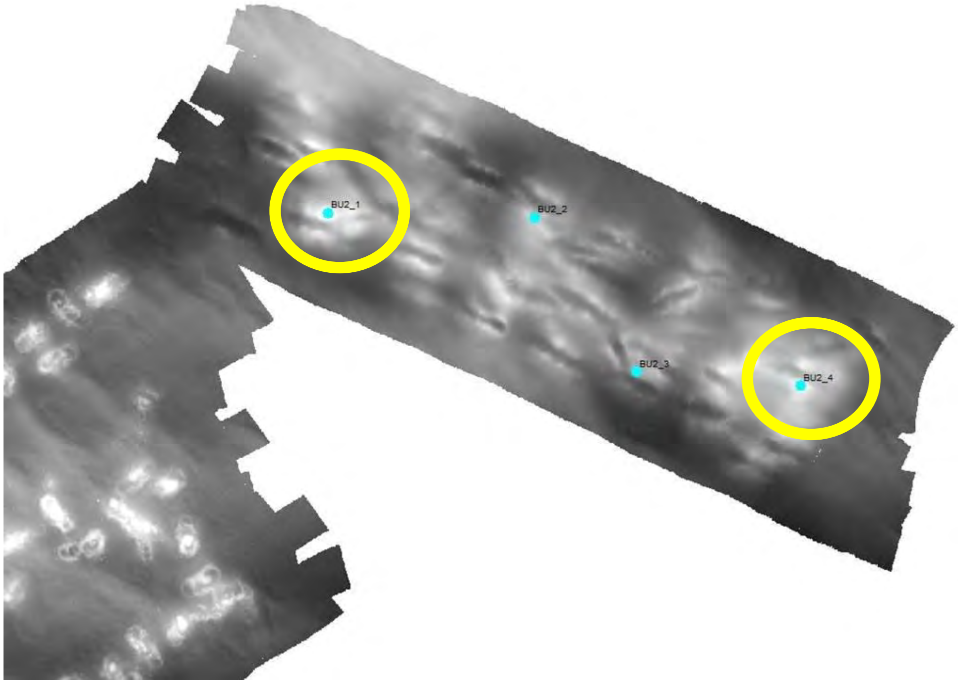
Appendix A (continued)

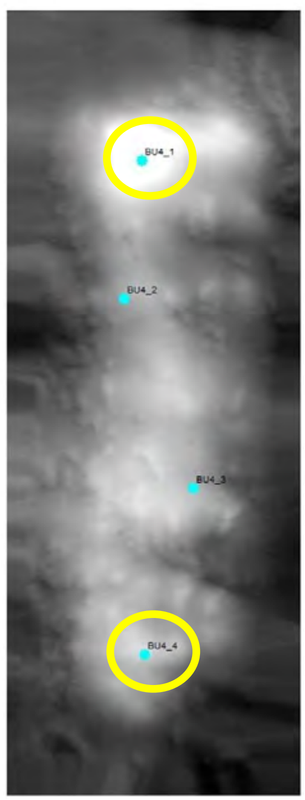
Code	Group	ScientificName	Common Name	Baited frames 2019 - 2022 Freq	Sum	2023 BU	MR	Diver video 2019 - 2022 Freq	Sum	2023 BU	MR	Diver slate 2019 - 2022 Freq	Sum	2023 BU	MR
A488	Finfish	Echeneidae	Remora	1	1			0	0						
A208	Finfish	*Echeneis naucrates*	Sharksucker	1	1	*		0	0						
A063	Finfish	*Elops saurus*	Ladyfish	2	2			0	0						
B020	Finfish	*Eupomacentrus* sp.	Damsel Fish	2	2		^	10	42						
A548	Finfish	*Gymnothorax saxicola*	Ocellated Moray	6	7			0	0						
A968	Finfish	Haemulidae	UnID Grunt	2	131			0	0						
A258	Finfish	*Haemulon aurolineatum*	Tomtate	23	63			3	9			13			
A303	Finfish	*Holacanthus isabelita*	Blue Angelfish	1	1			0	0			1			^
A442	Finfish	*Lagocephalus laevigatus*	Smooth Puffer	5	7	*		0	0						
A284	Finfish	*Leiostomus xanthurus*	Spot	16	136			0	0						
A506	Finfish	Lutjanidae	UnID Snapper	4	6			0	0						
A244	Finfish	*Lutjanus campechanus*	Red snapper	33	62			7	12			25			
A245	Finfish	*Lutjanus griseus*	Gray snapper	4	5			0	0						
B535	Finfish	*Lutjanus synagris*	Lane snapper	0	0			0	0			2			
A288	Finfish	*Micropogonias undulatus*	Atlantic Croaker	0	0			2	3						
B428	Finfish	Monacanthidae	UnID Filefish	1	1		^	0	0						
A262	Finfish	*Orthopristis chrysoptera*	Pigfish	16	121			2	2						
B277	Finfish	*Paralichthys* sp.	UnID Flounder	0	0			1	1						
A279	Finfish	*Pareques acuminatus*	Hi-Hat	0	0			2	21						
A376	Finfish	*Peprilus triacanthus*	Butterfish	1	4			0	0						
A289	Finfish	*Pogonias cromis*	Black drum	5	6			0	0						
A516	Finfish	Pomacentridae	Damselfish	1	1			0	0						
A206	Finfish	*Pomatomus saltatrix*	Bluefish	6	16			0	0						
A207	Finfish	*Rachycentron canadum*	Cobia	6	49			0	0						
A252	Finfish	*Rhomboplites aurorubens*	Vermilion snapper	0	0			0	0			5			
A915	Finfish	*Rypticus maculatus*	White soapfish	3	3			1	1						
A362	Finfish	*Scomberomors maculatus*	Spanish Mackerel	15	120			0	0						
A521	Finfish	Scombridae	UnID Mackerel	2	4		^	0	0						
B019	Finfish	*Segastes variabilis*	Cocoa damselfish	0	0			1	1		^				
A229	Finfish	*Selene vomer*	Lookdown	1	2			0	0						
A525	Finfish	Serranidae	UnID Grouper	2	2			0	0						
A444	Finfish	*Sphoeroides maculatus*	Northern puffer	16	19			3	3			2			
A552	Finfish	*Sphoeroides spengleri*	Bandtail Puffer	1	1		^	2	2		^				
A322	Finfish	*Sphyraena barracuda*	Great barracuda	4	4			0	0						
A308	Finfish	Stegastes leucostictus	Beaugregory	0	0			2	4	*					
A273	Finfish	*Stenotomus aculeatus*	Longspine porgy	25	77			21	64			26			
A865	Finfish	*Sygnathus* sp.	UnID Seahorse	0	0			1	1	*					
A097	Finfish	*Synoedus foetens*	Inshore lizardfIsh	0	0			1	1						
B037	Finfish	*Xyrichtys* sp.	Pearly razorfish	1	1			0	0			11			
A474	Finfish		Cometooth blennies	0	0			26	59						
B560	Finfish		UnID Finfish	5	24			13	23						

Appendix B. Frequency of occurrence (number of transects) and annual survey abundance of target and non-target invertebrate classifications recorded during MitReef video review. For both statuses, taxa appear in alphabetical order by taxonomic group then scientific name.

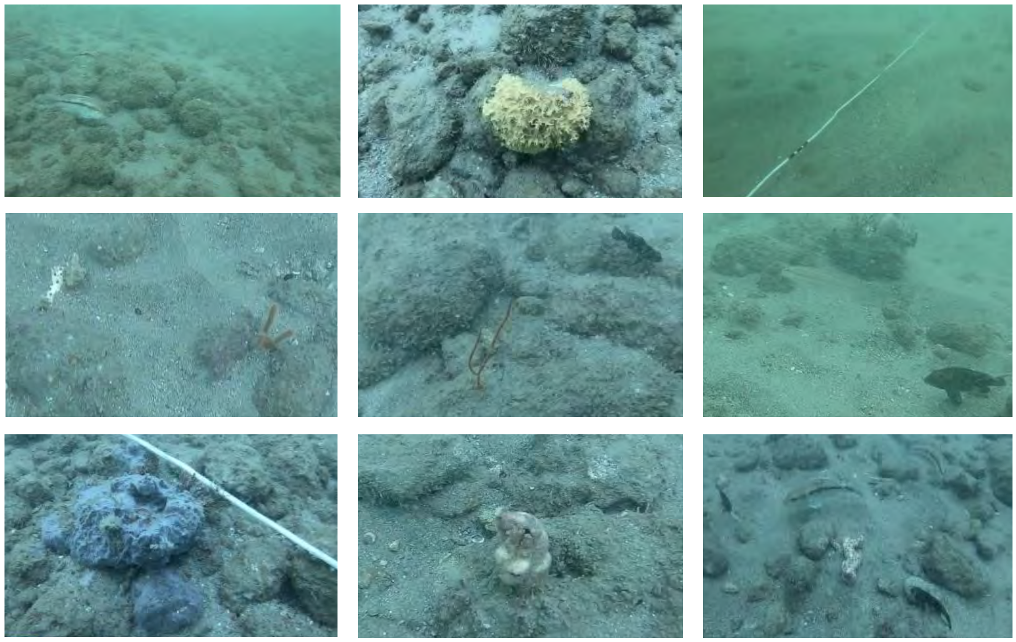
				Total transects				*Combined abundance*			
Status	Group	Code	ScientificName	2019	2021	2022	2023	2019	2021	2022	2023
Target	Hard coral	H039	*Astrangia danae*		17	36	9		17707	22912	586
Target	Hard coral	H305	Scleractinia		20	1	7		21526	1	23
Target	Soft coral	H002	*Leptogorgia virgulata*	23	23	7	8	146	552	33	113
Target	Soft coral	H275	*Leptogorgia hebes*	1	10	17	5	1	20	193	12
Target	Soft coral	H351	*Titanideum* sp.	1	26	35	8	1	310	687	175
Target	Sponge	C324	*Microciona prolifera*	4	9			4	32		
Target	Sponge	C357	*Cliona celata*	17	26	30	9	50	117	208	135
Target	Sponge	C374	Porifera	21	26	1		118	282	1	
Target	Sponge	C375	*Cliona* sp		19				329		
Target	Sponge	C400	Poecilosclerida			31	8			117	34
Target	Sponge	C402	Demospongea			24	8			95	65
Target	Sponge	C414	*Haliclona sp.*		19	36	9		447	2900	279
Target	Sponge	C428	*Ircinia sp.*		1				2		
Non-target	Algae	Q004	Algae		2		9		370		1530
Non-target	Algae	T265	*Polysiphonia* sp.		5				144		
Non-target	Anemone	H288	Actiniaria		2				2		
Non-target	Ark	X002	Arcoida	1				1			
Non-target	Barnacle	E316	Cirripedia	35	32	18	2	60005	13188	5527	22
Non-target	Bryozoan	M545	*Schizoprella floridana*	1	9			2	23		
Non-target	Crustacean	D112	*Calappa flammea*	1				1			
Non-target	Crustacean	D195	*Stenorhynchus seticornis*		1				1		
Non-target	Echinoderm	J001	*Asterias forbesi*		2				2		
Non-target	Echinoderm	J072	*Lyttechinus variegatus*	1				1			
Non-target	Echinoderm	J085	*Arbacia punctulata*	29	35	36	9	2003	3512	3826	375
Non-target	Echinoderm	J090	*Echinaster* sp.	2	1	5	1	2	1	8	1
Non-target	Hydroid	H300	Hydroidolina	25	26	34	8	192	197	549	66
Non-target	Jellyfish	H246	*Aurelia aurita*		1				1		
Non-target	Mollusc	N001	Nudibranchia			1				1	
Non-target	Mollusc	N112	*Pleuroploca gigantea*	1				1			
Non-target	Mollusc	N227	*Crassostrea virginica*		3	16	3		14	444	70
Non-target	Mollusc	N396	Gastropoda		1	1			1	1	
Non-target	Mollusc	N481	Muricidae	1				1			
Non-target	Soft coral	H010	*Muricea pendula*		1				2		
Non-target	Soft coral	H309	*Telesto* sp.		1	30	9		1	338	165
Non-target	Tunicate	B601	Tunicata	16	23	12		80	189	20	
Non-target	Tunicate	B617	*Clavelina oblonga*			29	1			291	1
Non-target	Tunicate	B627	*Aplidium* sp.	2	7	7	6	4	14	19	31
Non-target	Tunicate	B629	*Didemnum* sp.			11	4			21	8
Non-target	Tunicate	B634	*Stylea* sp.	36	31	30	1	1713	245	198	1
Non-target	Tunicate	B639	*Aplidium stellatum*	2	9	11	4	2	32	21	8
Non-target	Tunicate	B644	*Eudistoma* sp.		8	27	7		30	143	54
Non-target	Tunicate	B653	*Symplegma viride*		5	13	6		66	26	16
Non-target	Tunicate	B654	*Trididemnum* sp.		17	27	7		66	118	40
Non-target	Tunicate	B670	*Eudistoma hepaticum*		10		3		55		13
Non-target	Tunicate	B673	Botryllidae		4				6		
Non-target	Tunicate	B675	*Botryllus* sp.		18				217		
Non-target	Worm	P915	Sabellidae		2				32		

Appendix C: Site layout, qualitative fish and invertebrate observations, and representative imagery from non-standardized diver surveys at Beneficial Use reefs, 25 August 2023.





Appendic C (continued)



Appendic C (continued)