

USING SEDIMENTOLOGY, FORAMINIFERA, AND SEABED MORPHOLOGY TO
ASSESS THE ENVIRONMENT OF SUGARLOAF ISLAND, BOGUE SOUND, NC BEFORE
AND AFTER A COASTAL SHORELINE STABILIZATION PROJECT

By: Kristen Nicolina Malosky

July 2025

Directors of Thesis: Dr. D.J. Mallinson and Dr. S.J. Culver

Department: Earth, Environment and Planning

Abstract

Sugarloaf Island is a spoil island within Bogue Sound, off the coast of Morehead City, NC. It acts as a fetch-limited barrier island, protecting the mainland from erosion resulting from wind and wave energy. Currently, the shoreline of Sugarloaf Island is eroding, making it the focus of a shoreline stabilization project. Morehead City's project plan calls for the installation of wave attenuation devices (WADs), subaquatic vegetation (SAV, i.e., coastal seagrass), oyster reefs, and a rock revetment to try to boost the island's resilience and reduce erosion. To evaluate the effects of the stabilization structures, this study has utilized sedimentology, foraminifera and side-scan sonar imagery to understand the characteristics of sediment transport and erosion. This study has determined a general sediment transport direction of west to east and a fining of sediment in that direction as well. Following emplacement of stabilization structures, there was a coarsening of sediments around the island. Sorting of beach and nearshore samples was maintained or worsened, whereas offshore sites showed maintained or improved sorting. This study also analyzed living, modern dead, and fossilized foraminifera. Across both sampling times, *Elphidium excavatum* and *Ammonia parkinsoniana* were the most abundant species in

both the modern dead and the live foraminiferal assemblages. Following emplacement of stabilization structures, there was an increase in living foraminifera, specifically in the onshore samples. Lower numbers of live foraminifera in round 1 samples was likely due to the time of sampling (mid-winter) when reproduction is reduced or paused. There was also a decrease of fossilized foraminifera specimens. These findings are the result of the implementation of stabilization structures, which has reduced wave energy and onshore sediment transport.

USING SEDIMENTOLOGY, FORAMINIFERA, AND SEABED MORPHOLOGY TO
ASSESS THE ENVIRONMENT OF SUGARLOAF ISLAND, BOGUE SOUND, NC BEFORE
AND AFTER A COASTAL SHORELINE STABILIZATION PROJECT

A Thesis

Presented to

The Faculty of the Department of Earth, Environment and Planning

East Carolina University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Geology

by Kristen Malosky

July, 2025

Direction of Thesis: David Mallinson, PhD

Thesis Committee Members:

Stephen Culver, PhD

David Lagomasino, PhD

Hannah Sirianni, PhD

© Kristen N. Malosky, 2025

Acknowledgements

First, I want to thank my friends and family, without whom this venture would not have been possible. Your endless love and support are the reason I was able to accomplish all that I have. I also would like to thank my advisors Dr. David Mallinson and Dr. Stephen Culver for their guidance during my time here at East Carolina University, as well as my committee members Dr. Hannah Sirianni and Dr. David Lagomasino for their help and support on this project.

Table of Contents

List of Tables	vi
List of Figures	vii
1.0 Introduction	1
1.1 Background Information.....	1
1.2 Previous Work.....	4
1.3 Study Area.....	8
1.4 Goals and Objectives	11
2.0 Methods	13
2.1 Sample Collection.....	13
2.2 Sample Processing and Analysis.....	17
2.2.1 <i>Sediments</i>	17
2.2.2 <i>Grain Size Analysis</i>	17
2.2.3 <i>Foraminifera</i>	17
2.2.4 <i>Foraminifera Analysis</i>	18
2.3 Side Scan Sonar	19
3.0 Results	21
3.1 Sediments.....	21
3.1.1 <i>2021</i>	21
3.1.2 <i>December 2023 – March 2024</i>	23
3.1.3 <i>October 2024</i>	28
3.1.4 <i>Side Scan Sonar</i>	35
3.2 Foraminifera.....	38
3.2.1 <i>First Round: December 2023 – March 2024; pre-WAD emplacement</i>	38
3.2.2 <i>Second Round: October 2024; post-WAD emplacement</i>	40
3.2.3 <i>Cluster Analysis</i>	41
4.0 Discussion	55
4.1 Sediments.....	55
4.2 Foraminifera.....	65
4.3 Storm impacts	69
5.0 Conclusion	71

6.0 References	74
Appendix A: Sediment Data.....	81
Appendix B: Foraminiferal Census Data	94

List of Tables

Table 1: Illustrates the latitude and longitude location of each sample.	15
Table 2: Mean percent abundance and range for taxa in Biofacies A – C defined by cluster analysis of modern dead benthic foraminifera.....	45
Table 3: Mean percent abundance and range for taxa in Biofacies 1 – 3 defined by cluster analysis of live benthic foraminifera.....	49
Table 4: Mean percent abundance and range for taxa in Biofacies a – b defined by cluster analysis of all benthic foraminifera.....	54
Table 5: Table illustrating the mean statistics for each region of the study area by year.	58
Table A1: Table of grain size analysis data	92
Table B1: Number of modern dead and live foraminifera in Sugarloaf Island samples.....	94
Table B2: Number of fossilized phosphatic and sugary foraminifera in Sugarloaf Island samples.	101
Table B3: Percentage data for the modern dead foraminifera specimens in Sugarloaf Island ..	104
Table B4: Percentage data for the live foraminifera specimens in Sugarloaf Island	104
Table B5: Percentage data for the modern dead and live foraminifera specimens in Sugarloaf Island.....	104

List of Figures

Figure 1. Site map of Sugarloaf Island	3
Figure 2. Map illustrating the addition of bulk sand between 1933 and 1936.....	9
Figure 3. Map showing shoreline loss of Sugarloaf Island from 2014 to 2020	10
Figure 4. The most recent map of the restoration plan from Morehead City, NC, 2024	11
Figure 5. Basemap of Sugarloaf Island.....	13
Figure 6. Basemap of Sugarloaf Island with 2021 sample locations	14
Figure 7. Basemap of Sugarloaf Island with Side Scan Sonar sample locations.....	20
Figure 8. Aerial image of the study area with the sediment sample sites and respective histograms illustrating the distribution of sediment sizes by weight percent of sediment samples collected in 2021	22
Figure 9. Aerial image of the study area with the sediment sample sites and respective histograms illustrating the distribution of sediment sizes by weight percent of the first round of sediment samples.	24
Figure 10. Close up aerial images of the transects labeled in figure 9.....	27
Figure 11. Aerial image of the study area, imagery sourced from MyErsi imagery basemap as of 2025, with the sediment sample sites and respective histograms illustrating the distribution of sediment sizes by weight percent of the second round of sediment samples	29
Figure 12. Close up aerial images of the transects labeled in figure 11	32
Figure 13. Map of the sediment sample sites, imagery sourced from MyErsi imagery basemap as of 2025, with respective histograms illustrating the distribution of sediment sizes by weight percent of the resampled 2021 sediment sites.....	34
Figure 14. Side-scan sonar mosaic.....	35
Figure 15. Side-scan sonar mosaic with the bathymetry (m) extracted and overlaid.....	36
Figure 16. Close-up imagery of bedforms in side-scan sonar mosaic	37
Figure 17. Map of the sediment sample sites with respective histograms illustrating the distribution of sediment sizes by weight percent of Side Scan Sonar sediment samples	38
Figure 18. Bar graph illustrating the percentages of foraminiferal preservation types, between modern dead living, fossil phosphatic, and fossil sugary in the first round of samples	40
Figure 19. Bar graph illustrating the percentages of foraminiferal preservation types, between modern dead, living, fossilized phosphatic, and fossilized sugary of the second round of samples.	41
Figure 20. Dendrogram resulting from cluster analysis of modern dead foraminifera specimens	44
Figure 21. Dendrogram resulting from cluster analysis of live foraminifera specimens.....	48
Figure 22. Dendrogram resulting from cluster analysis of all (live and dead) foraminifera	53
Figure 23. Map grouping samples by region	55
Figure 24. Map illustrating the environments included under the term “marsh.”	56
Figure 25. A) Map of the average mean grain size, average sorting, and average skewness for the Sugarloaf Island samples for the round one samples (R1) and the round two samples (R2)	61

Figure 26. Scatter plots showing the correlation between the mean grain size and the sorting values of the beach and nearshore samples in round 1 and 2 of sampling	63
Figure 27. Scatter plots showing the correlation between the mean grain size and the skewness and between the sorting values and skewness of the beach and nearshore samples in round 1 and round 2 of sampling	64
Figure 28. Bar graphs illustrating the percentages of fossilized phosphatic and fossilized sugary of the first and second round of samples	68
Figure A1. Histograms illustrating the distribution of sediment sizes by weight percent of the samples taken in 2021	82
Figure A2. Histograms illustrating the distribution of sediment sizes by weight percent of the first round of sediment samples	86
Figure A3. Histograms illustrating the distribution of sediment sizes by weight percent of the second round of sediment samples	89
Figure A4. Histograms illustrating the distribution of sediment sizes by weight percent of the side scan sonar truth samples	90
Figure A6. Histograms illustrating the distribution of sediment sizes by weight percent of the resampled 2021 sample sites	91

1.0 Introduction

1.1 Background Information

Barrier islands serve a crucial purpose in coastal environments. They are a natural defense for mainland coastal communities against storm impacts worldwide. They provide coastal ecosystems like marshes, inlets, tidal flats, subaquatic vegetation habitat, maritime forests, dune fields, etc., that are essential for sustaining coastal biological resources (Feagin et al., 2010, Anderson et al., 2016, Sirianni et al., 2022). Additionally, they provide back-barrier lagoons which are important for navigation and shelter. Fetch-limited barrier islands occur in areas where ocean driven wave height is limited or eliminated and the wave energy is generated by localized wind power, rather than the open ocean (Jackson, 1995). They are different than open-ocean barrier islands primarily because of the important role of vegetation in helping to control the shape and location of the island (Jackson, 1995).

Pilkey et al. (2009) define three distinct categories of fetch-limited barrier islands: active, inactive, and anthropic islands. Active barrier islands are defined as barrier islands that form within a fetch-limited environment and are then subject to the wave and current energy of the area. Inactive barrier islands are islands that are not currently undergoing modification because of wave and current energies and are more likely to experience change as a result of subaerial processes. Lastly, anthropic islands are islands formed entirely by human activity, such as spoil islands built for dredge maintenance.

Fetch-limited barrier islands have been the focus of limited research, even going unrecognized as coastal landforms until recently (Pilkey et al., 2009). They are about six times more common than open-ocean-facing barrier islands in the U.S. (Sirianni et al., 2022).

Sugarloaf Island is a small anthropic fetch-limited barrier island, built on a marsh island, within the Bogue Sound of North Carolina (Fig. 1). Over the years it has suffered increasing rates of erosion due to rising sea level, increased hurricane activity, and tidal conditions. While the island is small (0.8 km long, 0.25 km wide), it does reside in between the coast of Morehead City, NC and the water of Bogue Sound, providing some level of protection to that portion of the coast. Furthermore, the island is culturally significant to Morehead City, in that it provides an undeveloped space completely open to the public.

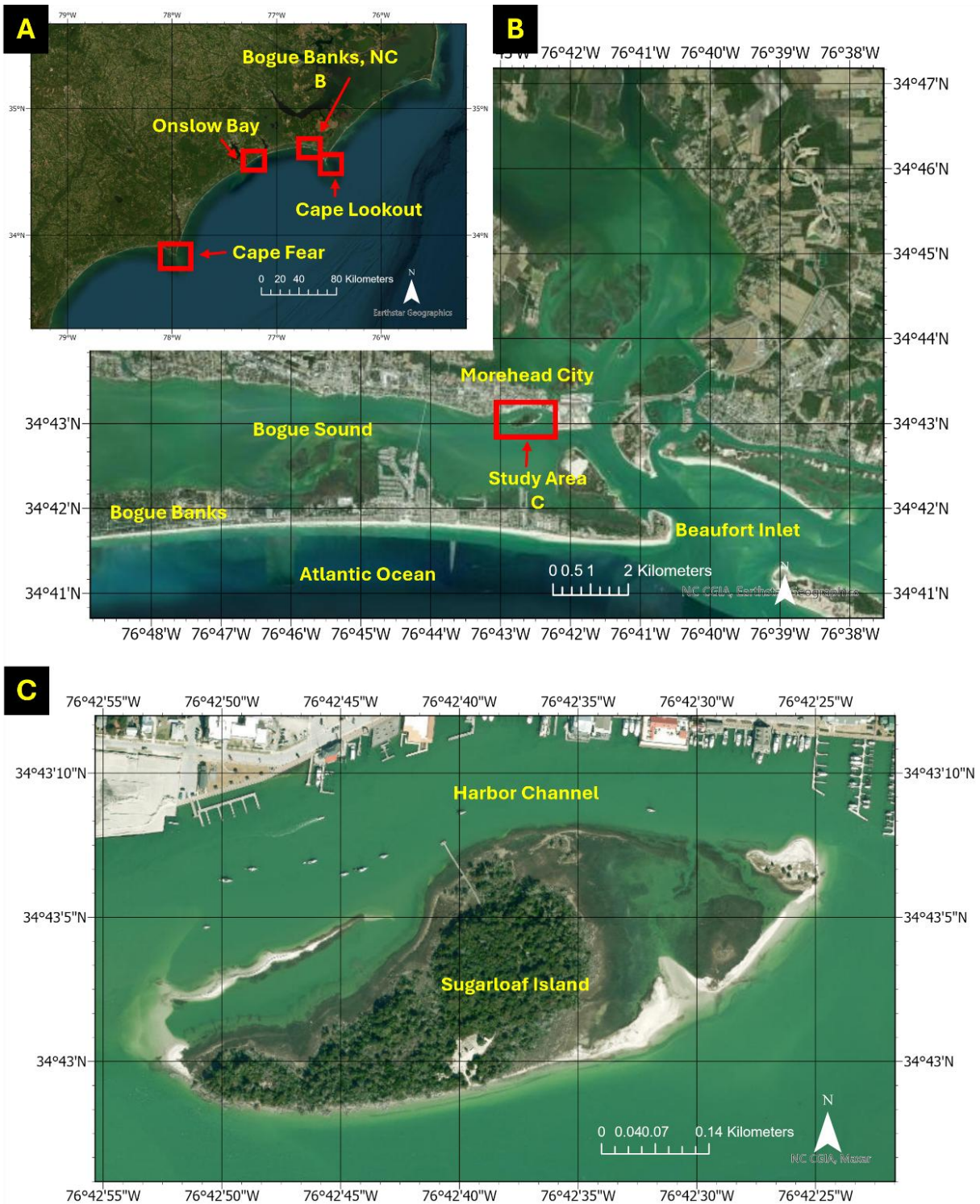


Figure 1. Site map of Sugarloaf Island A) Location map B) Close up of Bogue Banks area C) Satellite imagery of Sugarloaf Island obtained using Google Earth. Imagery date 5/13/23.

1.2 Previous Work

Living shorelines are defined as a shoreline stabilization strategy that can include vegetative and structural material to help to prevent erosion of coasts (Polk, 2016). Since coastal zones are so dynamic, they often suffer from variable amounts of erosion. Typically, hard structures are used to create armored shorelines, but these structures can often impact the coastal ecosystem (Davis et al., 2006, Currin et al., 2010) and can affect the sediment transport and deposition. This can cause further erosion of the shoreline adjacent to the structure (Polk, 2016). The introduction of natural solutions like vegetation planting can be helpful in stabilizing an eroding coastal area (Polk, 2016). Hard structures help to mitigate wave energy, while the added plants provide the sediment something to grip onto (Polk, 2016). They are also utilized for restoring habitats and boosting coastal resilience to climate change (Polk, 2016). Typically, living shoreline efforts along the North Carolina coast employ planting smooth cordgrass (*Spartina alterniflora*) in intertidal areas (Currin et al., 2010). Creating oyster habitat also allows the environment to stabilize, while still preventing further erosion (Meyer et al., 1997, Piazza et al., 2005, Scyphers et al., 2011, Polk, 2016). All these methods are being implemented on and around Sugarloaf Island.

Sediment erosion, transport and deposition in coastal environments is driven by currents related to wind, waves and tides, especially in an environment such as a fetch-limited barrier island. Sediment characteristics and foraminifera can be used as indicators of sediment source and transport direction, as well as providing data to interpret the depositional environment (Woo et al., 1997, Thomas et al., 2000, Burone et al., 2006, Culver et al., 2025). Sediment characteristics provide indications of the direction of sediment transport and energy conditions. The mean grain size, sorting, and skewness of a sediment sample are dependent on the grain size

distribution of the sediment's source as well as the sedimentary processes that influence the site (McLaren, 1981). Research demonstrates that sediments in transport tend to become finer and more negatively skewed than their source, while remaining sediment becomes coarser and more positively skewed (McLaren and Bowles, 1985). Thus, different environments tend to exhibit unique sediment characteristics depending on sediment sources and energy conditions during erosion, transport and deposition (Edwards, 2001, Grabowski et al., 2011, Koiter et al., 2013, Culver et al., 2025). For example, Grabowski et al. (2011) suggested that erosion in any given area is dependent on the sediment characteristics. In particular, sediment grain size is the most often used indicator of sediment erodibility. For example, mud is more difficult to erode than larger sized sediment like silt and sand. Because of this, adding mud (30-50%) to sandy sediments can raise the critical shear stress threshold of the sediments, thus making it more resistant to erosion (Grabowski et al., 2011). Sediment temperature can also influence erosion, Zreik et al. (1998) stated that sediment beds eroded more quickly at warmer temperatures.

Coastal erosion also depends on the surrounding environment, like that existing within a sound or lagoon. For example, a study by Zaggia et al. (2017) identified increased shoreline erosion within a coastal lagoon in Venice, Italy. They identified the cause of this erosion to be mainly ship wakes, as this study location was next to a major waterway, very similar to Sugarloaf island's proximity to the Intracoastal Waterway. In the Lagoon of Venice, wakes generated by vessels within the Malamocco Marghera Channel (MMC) impact the morphology of nearby wetlands and mudflats (Zaggia et al., 2017). The Lagoon of Venice is about 200 meters wide and 17 meters deep from east to west, and narrows in the north to south reach, measuring 120 meters wide and 12 meters deep. The lagoon was created by dredging the channel, similar to the Intracoastal Waterway near Sugarloaf Island, which is smaller in comparison to the channel in

Venice, with a depth of approximately 4 meters and a width of approximately 28 meters. Additionally, the Zaggia et al. study concluded that vessel traffic significantly affected the morphology of the environments adjacent to the MMC. However, their study determined that the Lagoon of Venice experienced minimal fetch, and that the wind speed and direction did not support the erosional events in the area. This contrasts with Sugarloaf Island, which is oriented parallel to the direction of maximum fetch (westward within the Bogue Sound. The reason for the Sugarloaf Island's orientation is because the island is anthropic, with the sand being placed there originally during the creation of the island (Sirianni et al., 2022). The long-term erosion in the area is likely a result of sea-level rise; however, there could be a contribution from boat wakes to the south in the Intracoastal Waterway, similar to the Lagoon of Venice. Evaluating the causes of the long-term erosion is beyond the scope of this investigation.

Aside from sediment characteristics, foraminifera are also key in studying environmental conditions and sediment transport. Foraminiferal species have differing tolerances to environmental variables such as temperature, salinity, dissolved oxygen, sediment characteristics, and available nutrients (Boltovskoy and Wright, 1976; Culver, 1988; Sen Gupta, 2003). Benthic foraminifera can be used as biological proxies to observe environmental changes, such as morphology of the sediment and bedforms. (Murray, 2001, Culver et al., 2006, Pruitt et al., 2010). The species assemblages and their distribution can indicate how a depositional environment has changed through time and space. For example, Abbene et al. (2006) showed that significant paleoenvironmental changes had occurred within the Pamlico Sound of North Carolina, from studying the assemblages of foraminifera in the area. Their study states that the patterns in the foraminiferal assemblages indicated an increase in salinity over the last 100 years. For example, the assemblages with higher salinity contained mostly calcareous foraminifera

where the brackish environments contained more agglutinated foraminifera (Abbene et al., 2006).

In addition to indicating natural environmental change, foraminifera have also been used to investigate whether anthropogenic environmental modifications are reflected in foraminiferal assemblages, sediment grain-size and salinity levels. For example, Culver et al. (2019) compared the salinity levels and the relative abundance of foraminifera within a barrier island estuary and lagoon on the east coast of peninsular Malaysia between 2009 to 2016, following the opening of an artificial inlet in a barrier island. The foraminiferal assemblages in the back-barrier water body exhibited a notable increase in species diversity, immediately following the opening of the inlet. When the inlet was opened, the environment experienced a rapid increase in salinity which in turn resulted in a rapid change in the foraminiferal assemblages. These changes included the distribution of foraminifera, as well as the introduction of many new species (Culver et al., 2019).

This project utilizes grain size analysis and foraminiferal analysis to assess the changes caused by the shoreline stabilization structures on the eroding Sugarloaf Island. These analyses will be utilized to better understand the evolution of the environment and provide clarity on how it has changed over time. Grain size data were used to analyze the change in sediment sources and energy patterns, such as waves and currents. Side-scan sonar data were used to analyze the bedforms surrounding the island, to further understand the energies influencing the island and the surrounding environment. Foraminiferal data were used to identify changes in sediment transport and erosion, and morphology.

1.3 Study Area

Sugarloaf Island (Fig. 1) is a small (0.8 km long by 0.27 km wide) spoil island within Bogue Sound, off the coast of Morehead City, North Carolina. Bogue Sound is constrained to the south by Bogue Banks, an east-west trending barrier island fronting Onslow Bay, an arcuate embayment between Cape Lookout to the north and Cape Fear to the south. The mean tidal range within Onslow Bay is approximately one meter (Lazar et al. 2005, Timmons et al., 2010). Shoreline erosion in this area is estimated to average around 0.6 meters per year (Kana et al., 2002). With the increased occurrence of storms, Bogue Banks has experienced accelerated rates of erosion, which has caused increasing damage to the dune system and many coastal structures (Kana et al., 2002).

Sugarloaf Island's northern and eastern sides are surrounded by the Harbor Channel, while the western and southern sides are surrounded by the open water of Bogue Sound (Fig. 1). The western end of the island contains a sandy spit which wraps around the north side of the island creating a bar that encloses the shallow back-marsh environment. The west body of the island consists of trees and other upland vegetation with a sandy sediment bank on the southern shore. The eastern half of the island is characterized by a back-barrier marsh environment, with another sandy spit defining the eastern shore of the island. Sugarloaf Island acts as a fetch-limited barrier island, protecting the mainland (i.e., the Morehead City waterfront) from erosion resulting from wind and wave energy.

Since 1888, current day Sugarloaf Island had been identified as a marsh island (Sirianni et al. 2022). Sugarloaf Island was then modified between 1933 and 1936 (Fig 2) when sand was dredged to build the Intracoastal Waterway (ICW) and placed on the marsh island with no additional spoil deposition for at least the past 35 years (Sirianni et al., 2022). Sugarloaf Island

consists of a variety of coastal environments, including sand flats, dunes, maritime forest, and salt marsh.

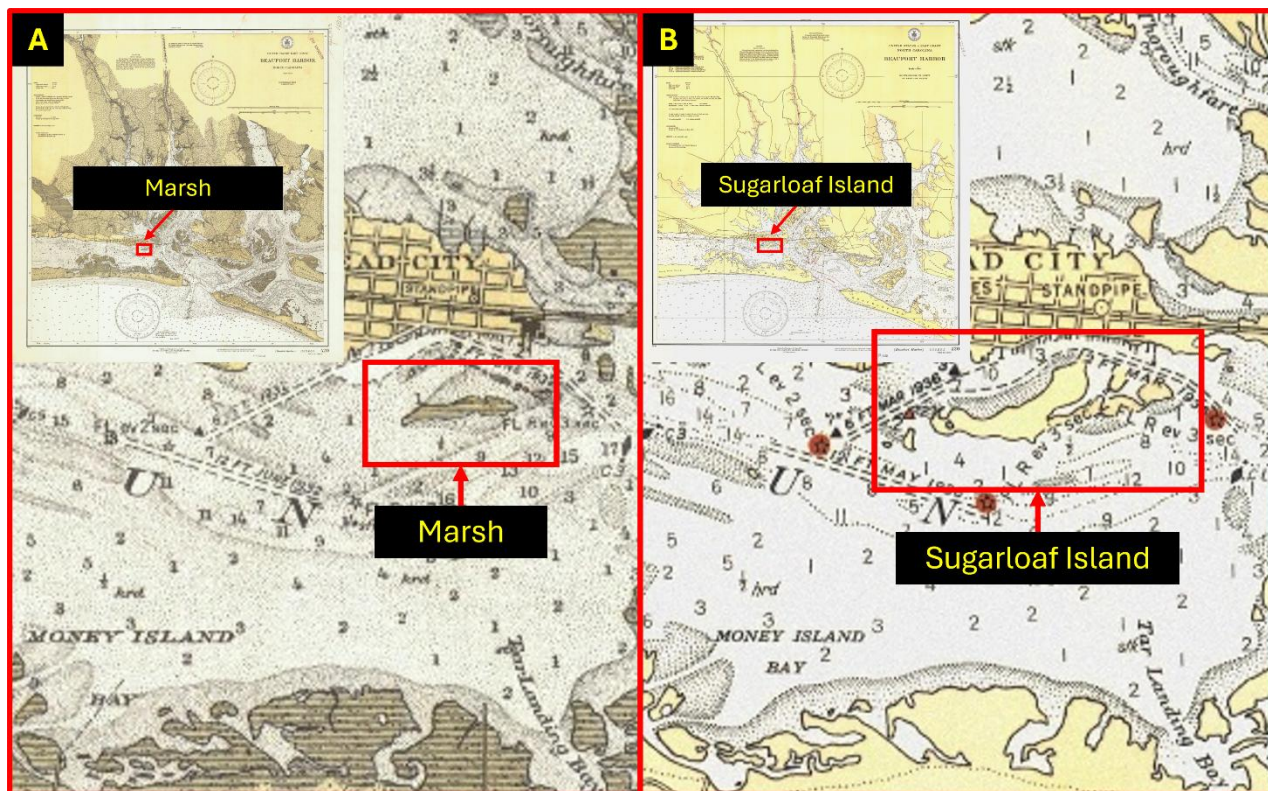


Figure 2. A) Map of the North Carolina coast in 1933 B) Map of the North Carolina coast in 1936. Illustrates the addition of bulk sand between 1933 and 1936. Both A and B encapsulate the same latitude/ longitude locations. Maps sourced from the Office of Coast Survey, National Oceanic and Atmospheric Administration U.S. Department of Commerce, 2025.

Over the past 10 years, the shoreline of Sugarloaf Island has been eroding (Fig. 3), making it the focus of a shoreline stabilization project supported by North Carolina's state legislature with \$6.6 million in funding. The project plan (Fig. 4) called for installing wave attenuation devices (WADs), subaquatic vegetation (i.e., coastal seagrass), marsh vegetation (i.e., smooth cordgrass), oyster reefs, and a rock revetment to try to boost the island's resilience and reduce erosion. The primary component of this plan was the installation of 1200 WADs. These WADs are designed to mitigate island erosion by dissipating wave energy before it reaches the shore. In turn, this should help with the restoration of the shoreline through improved seagrass growth and sand

accretion. As of summer of 2025, the installation of the WADs and oyster reefs have been completed.

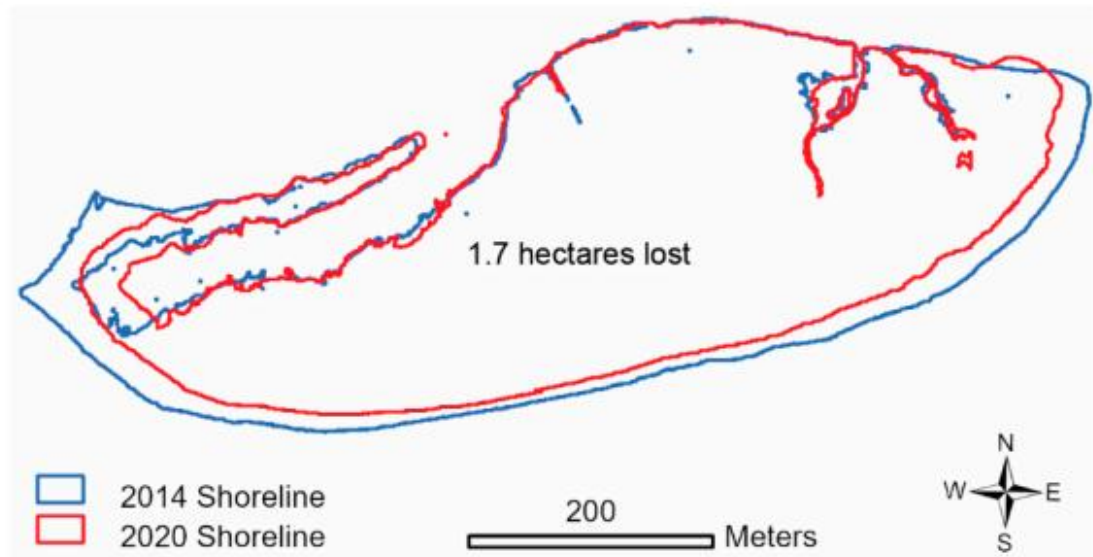


Figure 3. Shorelines derived from object-based image analysis techniques, where blue indicates 2014 and red indicates 2020. Adapted from Sirianni et al., 2022.

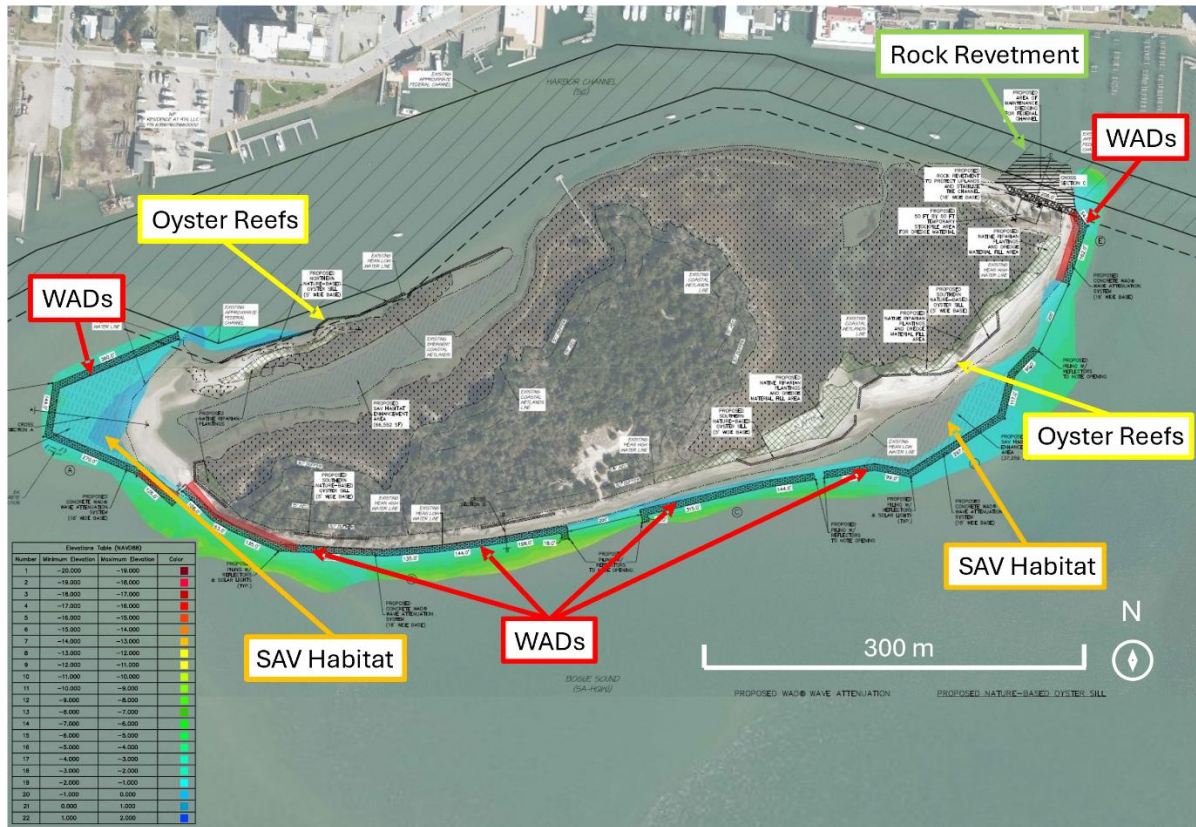


Figure 4. The most recent map of the restoration plan from Morehead City, NC, 2024.

1.4 Goals and Objectives

The overarching goal of this study is to identify the sediment transport and erosional patterns of the intertidal and subtidal portions of the island and evaluate the impact of installing WADs and other shoreline stabilization methods by characterizing changes to the distribution of foraminifera species, grain size characteristics, and seafloor morphology. This goal will be achieved by addressing the following objectives.

1. Determine the changes in the sediment transport and erosional patterns of the island, such as changes in the grain sizes at different locations and the increased or decreased rates of erosion on the island.

2. Evaluate the impact of the WADs and other shoreline stabilization methods by characterizing changes to the distribution of foraminifera species and grain size data over time.
3. Map the seafloor to assess changes to sediment characteristics, erosion, and deposition

2.0 Methods

2.1 Sample Collection

Samples were collected starting in December 2023 on Sugarloaf Island and in the surrounding waters within Bogue Sound (Fig. 5). Seven samples were collected offshore (herein defined as the subtidal areas) using a small research vessel and a Ponar Grab Sampler. Fourteen additional samples were collected on Sugarloaf Island within the intertidal zone. These samples were collected in transects with one sample collected on the beach, one collected at the shoreline, and one collected out into the water. Each sample was composed of the top 1 cm of sediment.

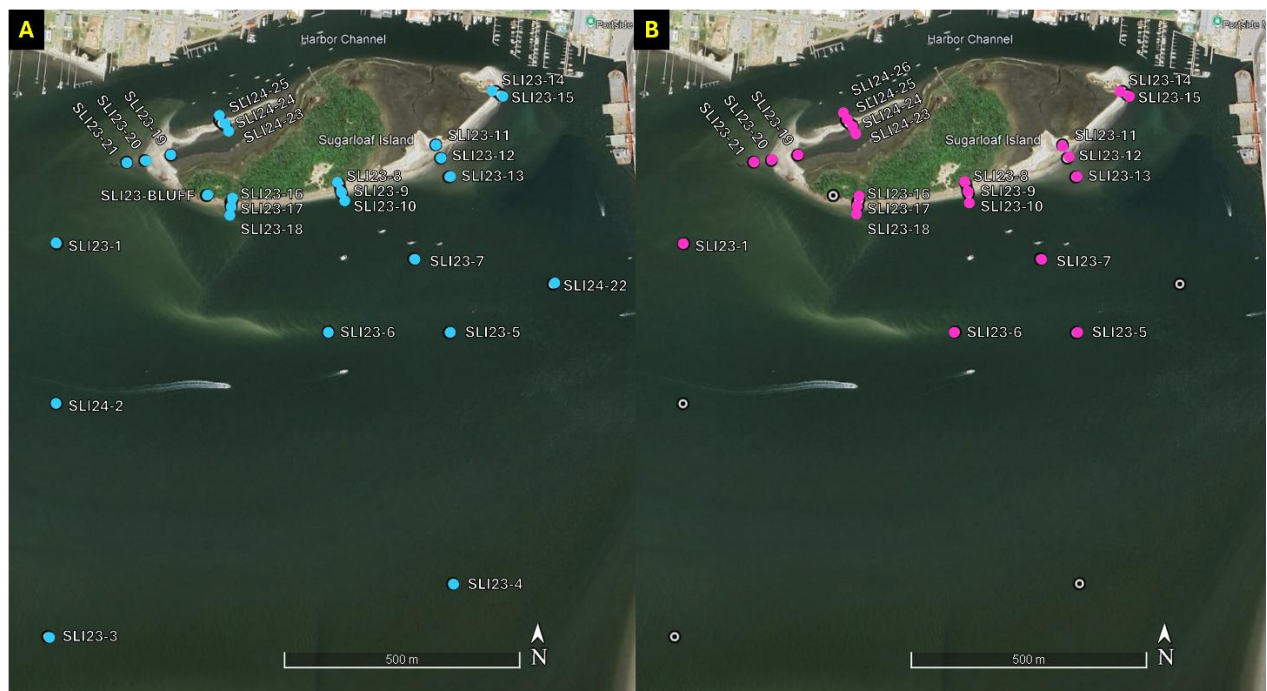


Figure 5. A) Basemap of Sugarloaf Island with Round 1 sample locations. B) Basemap of Sugarloaf Island with Round 2 sample locations. Made using Google Earth Pro. Imagery date 5/13/23.

A sample of the peat layer that runs through the island and a surface water sample from site SLI23-14 were also collected. Five additional sediment/foraminifera samples were collected using the same method in March of 2024. A preliminary set of 12 sediment samples was also collected in 2021, but only along the south-facing beach (Fig.6). Thus, a total of 38

sediment/foraminifera samples were collected before the emplacement of erosion-control structures (wave attenuation devices or WADs, oyster reefs, and subaquatic vegetation).



Figure 6. Basemap of Sugarloaf Island with 2021 sample locations. Made using Google Earth Pro. Imagery date 5/13/23.

Final sampling took place in October 2024, after the WADs and oyster reefs had been installed. These 22 samples included resampled beach and nearshore sites, as well as some offshore sites. All relevant sampling information for all samples can be found in Table 1 below.

Table 1: Illustrates the latitude and longitude location of each sample. The sixth column indicates the environment where each sample was collected. The seventh and eighth columns indicate when each sample was collected with reference to the installation of stabilization structures. SSS indicates that a sample was collected during the Side Scan Sonar.

Date	Sample ID	Latitude	Longitude	Depth (m)	Environment	Before	After
27-May-21	SLI21-1	34.716224	-76.710902	-	beach	✓	
27-May-21	SLI21-2	34.716432	-76.710639	-	beach	✓	
27-May-21	SLI21-3	34.716496	-76.710067	-	beach	✓	
27-May-21	SLI21-4	34.716627	-76.710004	-	beach	✓	
27-May-21	SLI21-5	34.716428	-76.709533	0.6 – 0.9	subtidal	✓	
27-May-21	SLI21-6	34.717731	-76.707198	-	beach	✓	✓
27-May-21	SLI21-7	34.717495	-76.707013	0.6 – 0.9	subtidal	✓	✓
27-May-21	SLI21-8	34.71832	-76.706711	-	beach	✓	
27-May-21	SLI21-9	34.716453	-76.714655	0.6 – 0.9	subtidal	✓	✓
27-May-21	SLI21-10	34.716509	-76.714572	-	beach	✓	✓
27-May-21	SLI21-11	34.716377	-76.714687	0.6 – 0.9	subtidal	✓	
27-May-21	SLI21-12	34.716138	-76.713793	-	beach	✓	
13-Dec-23	SLI23-1	34.715337	-76.717105	2.44	subtidal	✓	✓
13-Dec-23	SLI23-3	34.707859	-76.717156	1.22	subtidal	✓	
13-Dec-23	SLI23-4	34.70893	-76.707814	1.07	subtidal	✓	
13-Dec-23	SLI2305	34.7137	-76.707933	4.57	subtidal	✓	✓
13-Dec-23	SLI23-6	34.713692	-76.710749	1.52	subtidal	✓	✓
13-Dec-23	SLI23-7	34.715108	-76.708776	3.04	subtidal	✓	✓
13-Dec-23	SLI23-8	34.716533	-76.710532	-	beach	✓	✓
13-Dec-23	SLI23-9	34.716412	-76.710495	-	beach	✓	✓
13-Dec-23	SLI23-10	34.716351	-76.710469	0.6 – 0.9	subtidal	✓	✓
13-Dec-23	SLI23-11	34.717313	-76.708281	-	beach	✓	✓
13-Dec-23	SLI23-12	34.717055	-76.708167	-	beach	✓	✓

13-Dec-23	SLI23-13	34.716694	-76.707968	0.6 – 0.9	subtidal	✓	✓
13-Dec-23	SLI23-14	34.718359	-76.706878	-	beach	✓	✓
13-Dec-23	SLI23-15	34.718288	-76.706763	0.6 – 0.9	subtidal	✓	✓
13-Dec-23	SLI23-16	34.716205	-76.713032	-	beach	✓	✓
13-Dec-23	SLI23-17	34.716166	-76.713062	-	beach	✓	✓
13-Dec-23	SLI23-18	34.716095	-76.713051	0.6 – 0.9	subtidal	✓	✓
13-Dec-23	SLI23-19	34.717068	-76.714482	-	beach	✓	✓
13-Dec-23	SLI23-20	34.716957	-76.715093	-	beach	✓	✓
13-Dec-23	SLI23-21	34.716921	-76.715512	0.6 – 0.9	subtidal	✓	✓
13-Dec-23	SLI23-BLUFF	34.716291	-76.713632	-	bluff	✓	
14-Mar-24	SLI24-2	34.712702	-76.717948	8.49	subtidal (channel)	✓	
14-Mar-24	SLI24-22	34.714651	-76.705520	12.19	subtidal (turning basin)	✓	
14-Mar-24	SLI24-23	34.71765	-76.713211	0.46	transect (marsh)	✓	✓
14-Mar-24	SLI24-24	34.717692	-76.713288	-	transect (beach)	✓	✓
14-Mar-24	SLI24-25	34.717729	-76.713339	-	transect (beach)	✓	✓
14-Mar-24	SLI24-26	34.717762	-76.713351	0.61	transect (oyster reef)	✓	✓
13-May-24	SLI24-SSS1.1	34.716676	-76.717402	-	collected during SS survey	✓	
13-May-24	SLI24-SSS1.2	34.715627	-76.71543	-	collected during SS survey	✓	
13-May-24	SLI24-SSS1.3	34.716059	-76.71193	-	collected during SS survey	✓	
13-May-24	SLI24-SSS1.4	34.715195	-76.709057	-	collected during SS survey	✓	
13-May-24	SLI24-SSS1.7	34.715195	-76.713789	-	collected during SS survey	✓	

2.2 Sample Processing and Analysis

Two samples were taken at each location, one for sediment analysis and one for foraminifera analysis. Sediment and foraminiferal analyses were used to provide insight into the erosion and transport patterns around Sugarloaf Island, as well as the changes in foraminiferal assemblages as a result of changing environmental conditions related to the shoreline stabilization project.

2.2.1 Sediments

Sediment samples were rinsed five times with DI water to remove any excess salt from the sample. Then the samples were placed in the oven at 90 degrees Celsius to dry overnight. This was repeated with every sample. Once the samples were dry, around 40 grams of each homogenized sample were measured out to the hundredth decimal place to perform the grain size analysis, using a metric scale.

2.2.2 Grain Size Analysis

The dry sediment sample (40 grams) was sieved for 15 minutes using a Ro-tap machine and a sieve stack ranging from 4 to -2 phi at 0.5 phi intervals. Each phi interval was weighed and the weight percent of each grain-size fraction in the sample was calculated. This was repeated for every sample. These values were then imported into a GRADISTAT (Blott and Pye, 2001) Excel spreadsheet to conduct a statistical analysis of the data to compare across the different sites. All data were reported using the Folk and Ward (ϕ) method (Folk and Ward, 1957).

2.2.3 Foraminifera

Immediately upon returning to the lab, the foraminifera samples were immersed in a mixture of rose Bengal and isopropyl alcohol (Walton, 1952). After at least five days, 50 mL of each

sample was then washed with DI water repeatedly to remove the rose Bengal-alcohol mixture. The samples were then washed over stacked 710- and 63-micron (μm) sieves to remove mud and retain the sand and gravel fractions (separated at 0.5 phi, 710 microns). To prevent cross contamination, the sieves were sprayed with a weak solution of Methylene Blue and DI water between samples. Sand and coarse sand and gravel fractions were then placed in the oven to dry overnight at 40 degrees Celsius. The >710-micron fraction of each sample was put into a labeled bottle and stored.

The sand samples were floated using the Sodium polytungstate (SPT) method (Munsterman and Kerstholt, 1996) to concentrate the foraminiferal tests. The samples were then rinsed of any remaining SPT liquid before being dried overnight at 40 degrees Celsius.

2.2.4 Foraminifera Analysis

Each floated foraminifera sample was split into fractions (i.e., $\frac{1}{2}$, $\frac{1}{4}$, etc.) using an Otto Microsplitter. This splitting was done as many times as necessary until the sample lightly covered a picking tray without grains overlaying each other. The remainder of each sample was bottled for reference. The samples were picked using a randomized method, wherein squares of the picking tray were selected using a random numbers table, and each square was fully picked until approximately 200 foraminifera specimens were picked. Foraminifera were identified by comparison with images in several publications (Andersen, 1952, Grossman and Benson, 1967, Schnitker, 1971, Todd and Low, 1981, Buzas et al., 1985, Abbene et al., 2006, Grand Pre, 2006, Pruitt et al., 2010). The specimens were then sorted into living, dead, and two categories of fossilized foraminifera, phosphatized and sugary (orange and yellow).

Relative abundance data for foraminifera species in each sample were calculated using Excel data for species that represented 2% or more relative abundance in one or more samples were entered into the IBM SPSS software after transforming the data using the formula:

$$2\arcsin\sqrt{p_i}$$

The foraminifera data were then run through a Q-mode cluster analysis using the IBM SPSS statistics software to identify patterns in the foraminiferal relative abundance data (Mello and Buzas, 1968). The cluster analysis dendrograms were constructed using Euclidean distances and Ward's linkage.

2.3 Side Scan Sonar

Side scan sonar data were collected using a Carolina Skiff, a Triton Starfish 450 kHz towfish, and a WAAS-enabled GPS unit (WGS84 coordinate system in meters) in March of 2024. The survey used a full swath width of 60 m with a 10% overlap of data to ensure a full mosaic of the area surrounding Sugarloaf Island. Data were processed using Chesapeake Technology SonarWiz software, involving bottom-tracking, slant-range correction, and gain enhancement. The bottom-tracking file was gridded to produce a bathymetric dataset which was overlain with the acoustic backscatter imagery. Tidal variation during sonar acquisition accounts for an error of ca. ± 0.5 m. The side-scan mosaic was then exported as a GeoTIFF file at a 0.1 m resolution so that decimeter scale bed forms could be seen and further analyzed using Google Earth to digitize sediment facies and features (e.g., ripple or dune fields, variations in acoustic backscatter, areas of erosion or deposition). Seafloor sediment samples (Fig. 7) were also collected and analyzed for grain-size characteristics and correlated to the acoustic backscatter intensity. This enabled the production of maps of sediment grain size.



Figure 7. Basemap of Sugarloaf Island with Side Scan Sonar sample locations. Made using Google Earth Pro. Imagery date 5/13/23.

3.0 Results

3.1 Sediments

3.1.1 2021

The GRADISTAT version 9 software (Blott and Pye, 2001) yielded the grain size data shown in Appendix A and illustrated in the histograms below (Figs. 8–11). The samples collected from the island in 2021 (Fig. 8) illustrate better sorting and finer grain size toward the east. The mean grain size of the 2021 samples was medium sand with a phi size of 1.85 ϕ . The data show moderately well sorted sediments with a sorting number of 0.69 ϕ . The average median grain size was 1.89 ϕ , with an average skewness of -0.39 ϕ , and an average kurtosis of 3.39 ϕ .

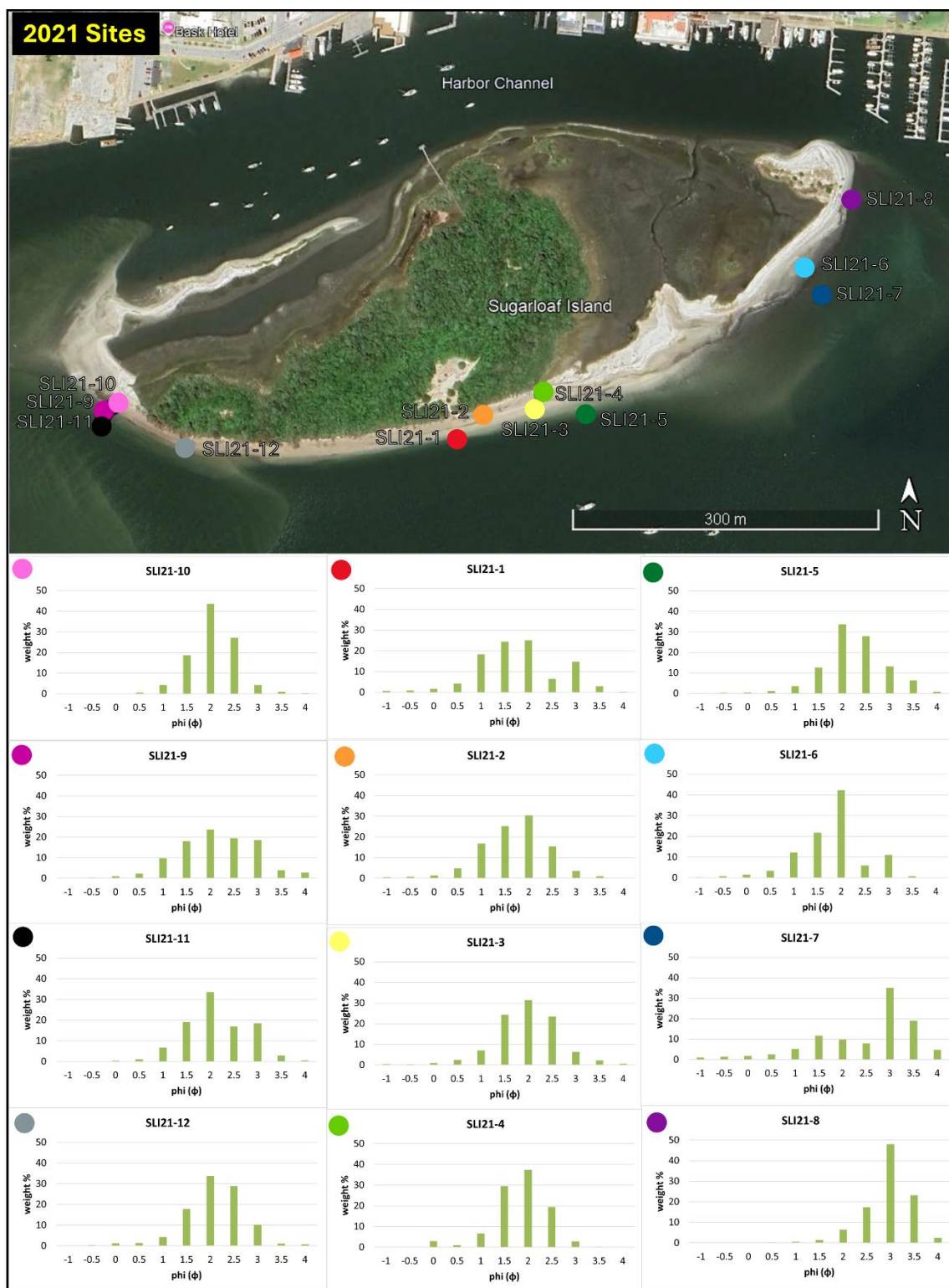


Figure 8. Aerial image of the study area, imagery sourced from MyErsi imagery basemap as of 2025, with the sediment sample sites and respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of sediment samples collected in 2021 by Mallinson (unpubl. data). In each image the colored dots relate to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A, Figure A1.

3.1.2 December 2023 – March 2024

In 2023, the sediments around Sugarloaf Island (Fig. 9 and 10) consisted of primarily fine to medium grained sand, with the finer sands being on, and close around the island. While the sediment improves in sorting from west to east, it only becomes moderately sorted. The mean grain size is similar to the 2021 samples of medium sand with a phi size of 1.77 ϕ . These samples exhibit moderate sorting, which is slightly less well sorted than in 2021, with an average sorting number of 0.85 ϕ . The average median grain size was 1.86 ϕ , the average skewness was -0.14 ϕ , and the average kurtosis was 1.22 ϕ .

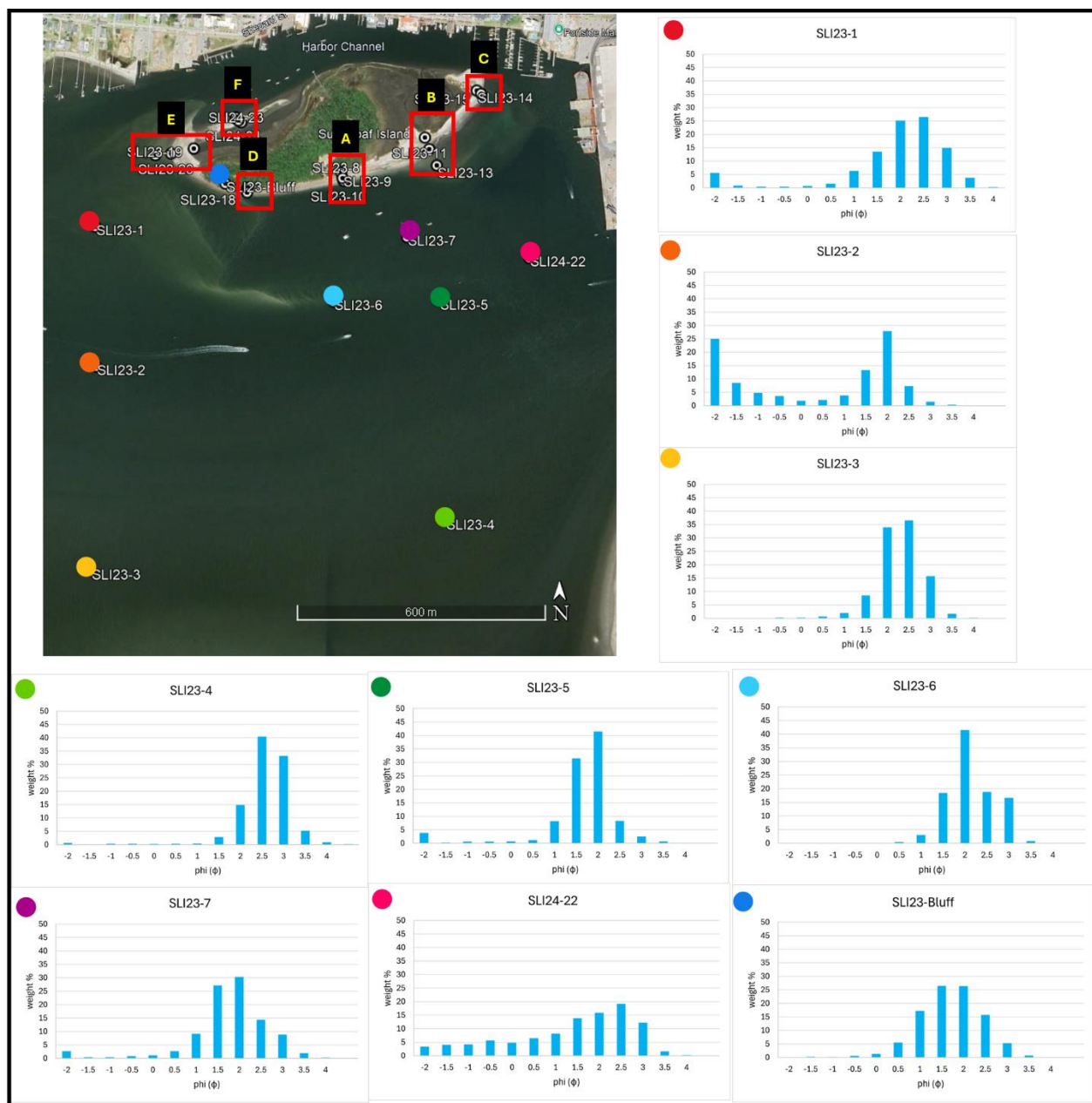
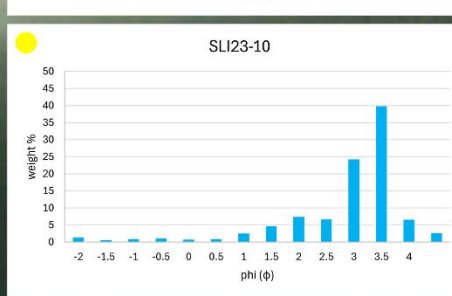
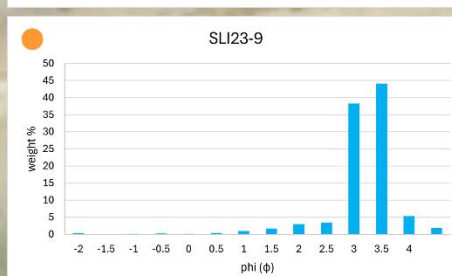
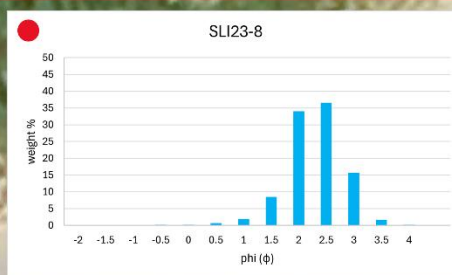
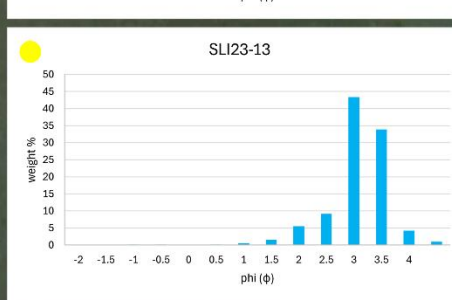
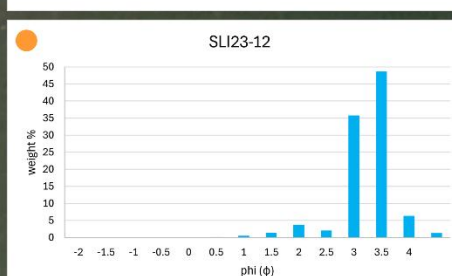
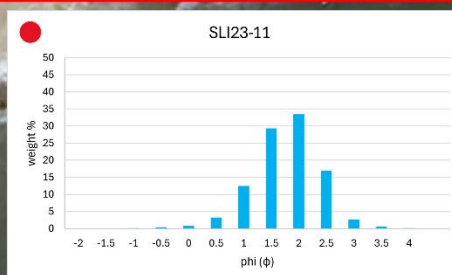
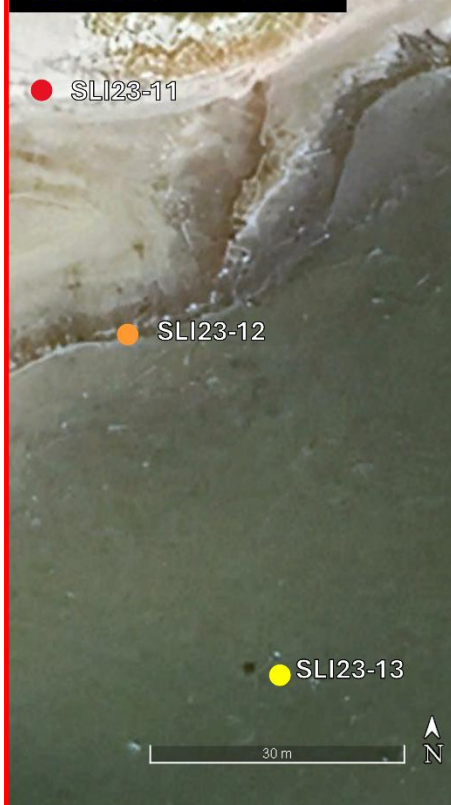


Figure 9. Aerial image of the study area with the sediment sample sites and respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the first round of sediment samples. Red boxes denote beach to nearshore transects of samples, shown up close in Figure 10. The letter above each box corresponds with the transect being referenced. In each image the colored dots relate to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A, Figure A2.

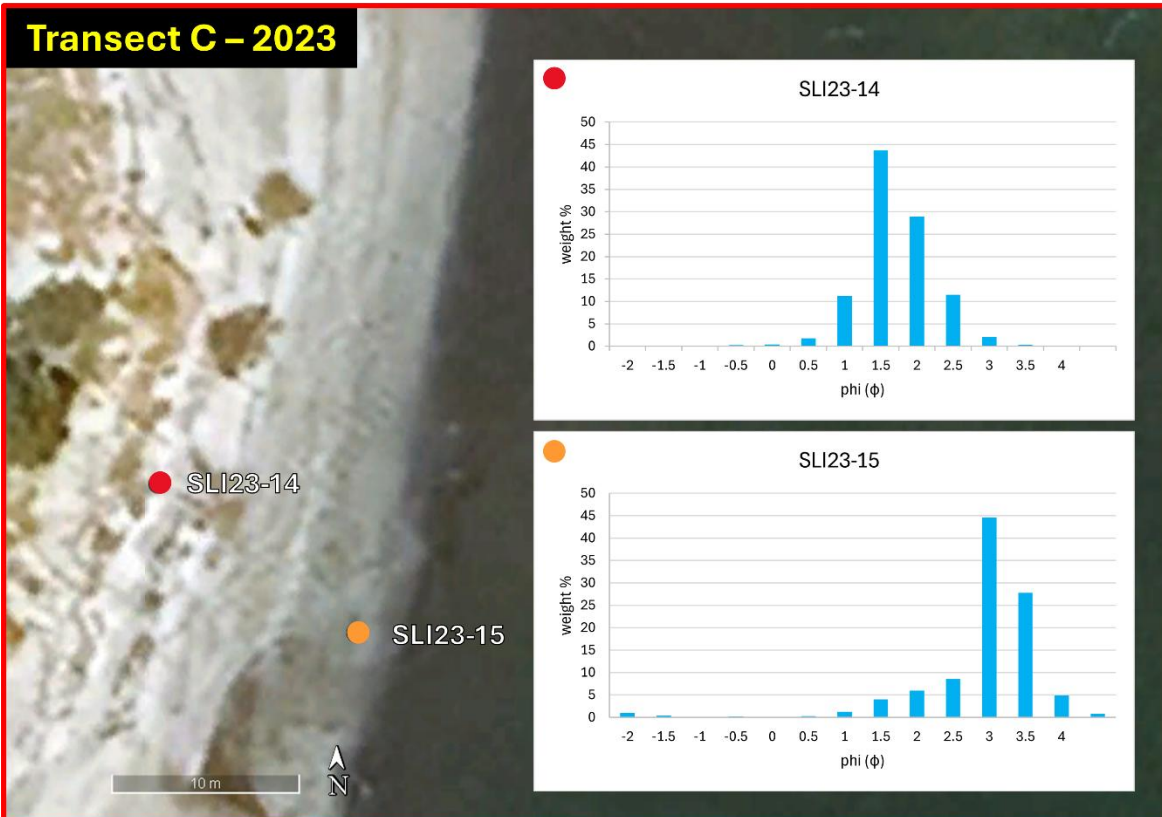
Transect A – 2023



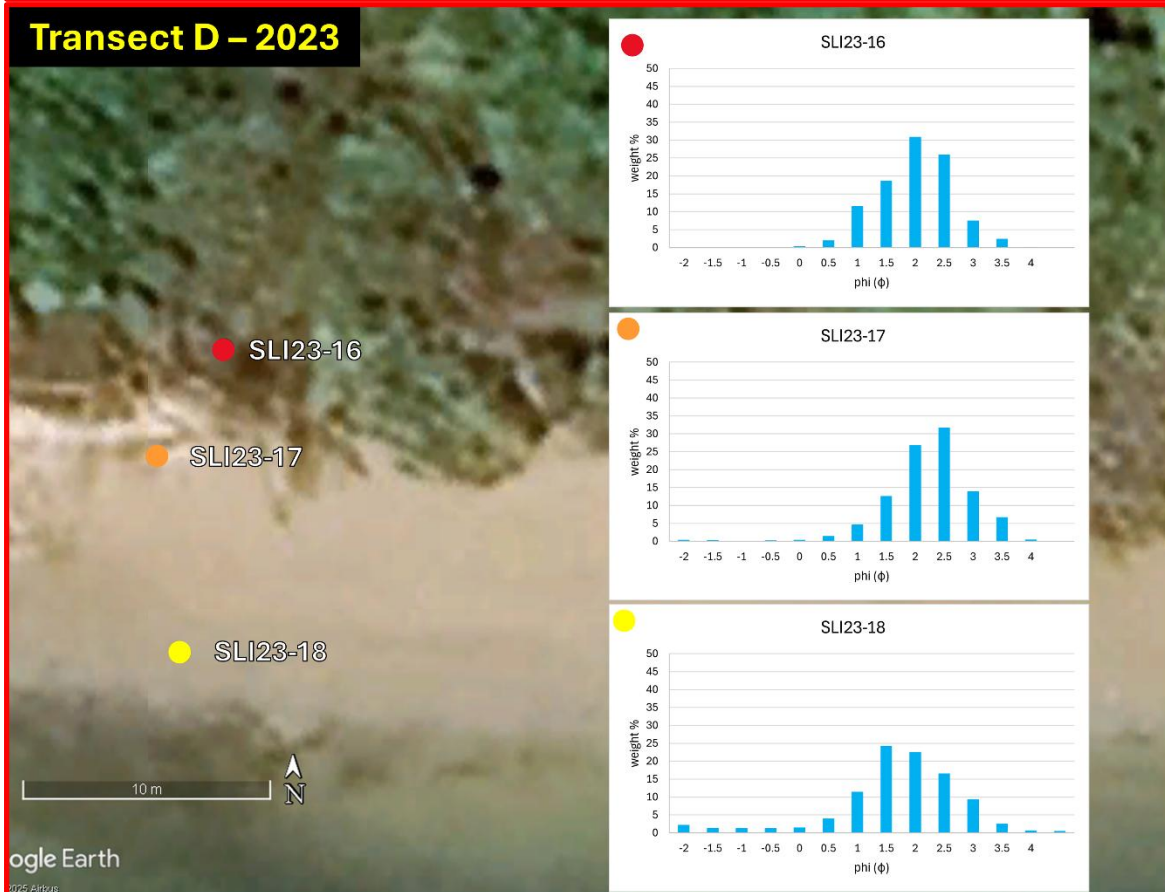
Transect B – 2023



Transect C – 2023



Transect D – 2023



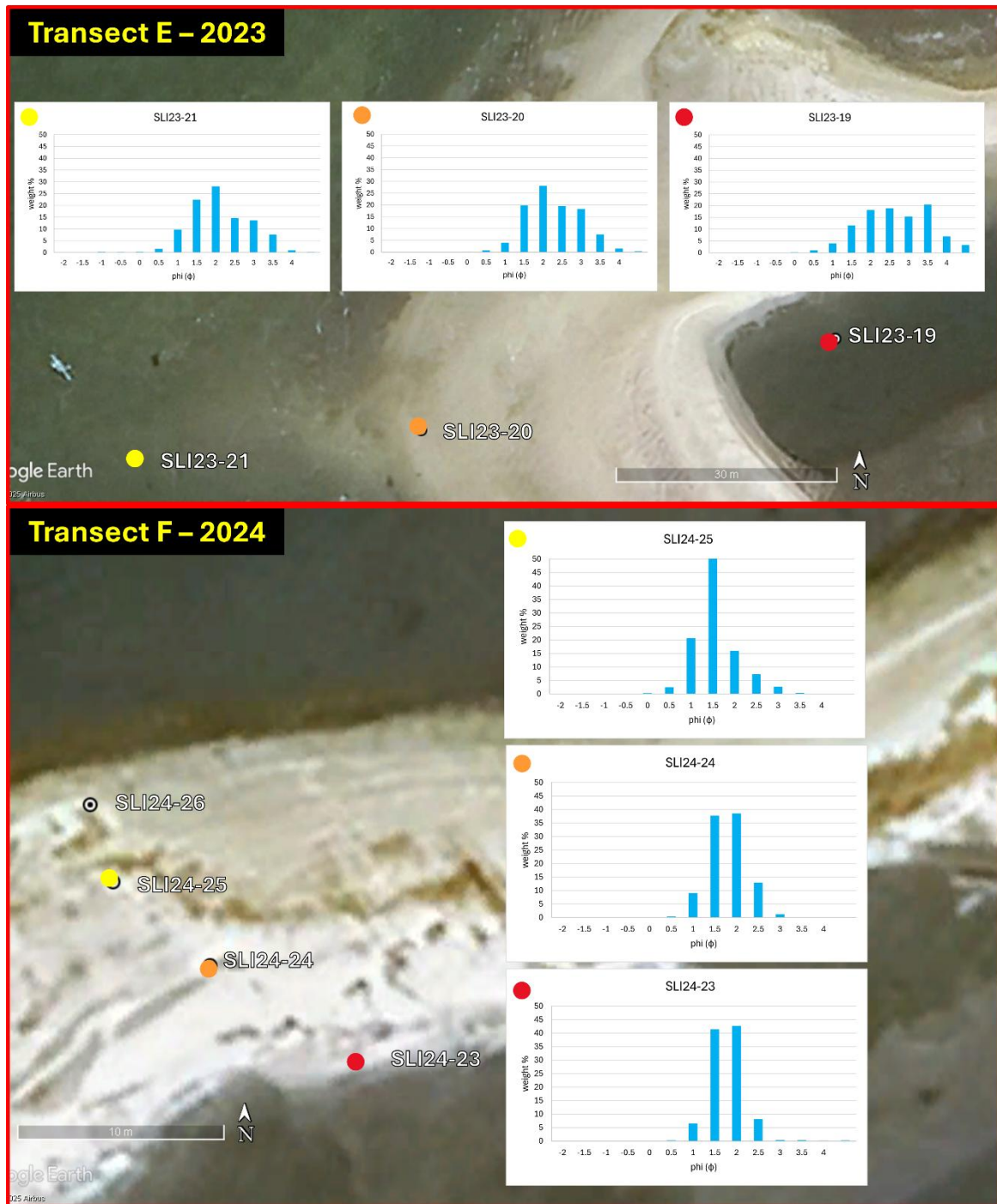


Figure 10. Close up aerial images of the transects labeled in figure 9 and respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the first round of sediment samples. In each image the colored dots relate to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A, Figure A2.

3.1.3 October 2024

The mean grain size for all sites (Fig. 11, 12, and 13) is once again medium sand with a phi size of 1.84 ϕ and a standard deviation of 0.53. The samples also have an average sorting of moderately sorted, similar to the first round of samples, with an average sorting number of 0.93 ϕ and a standard deviation of 0.48. The average median grain size was 1.79 ϕ with a standard deviation of 0.5, the average skewness was -0.07 ϕ with a standard deviation of 0.19, and the average kurtosis was 1.17 ϕ with a standard deviation of 0.4.

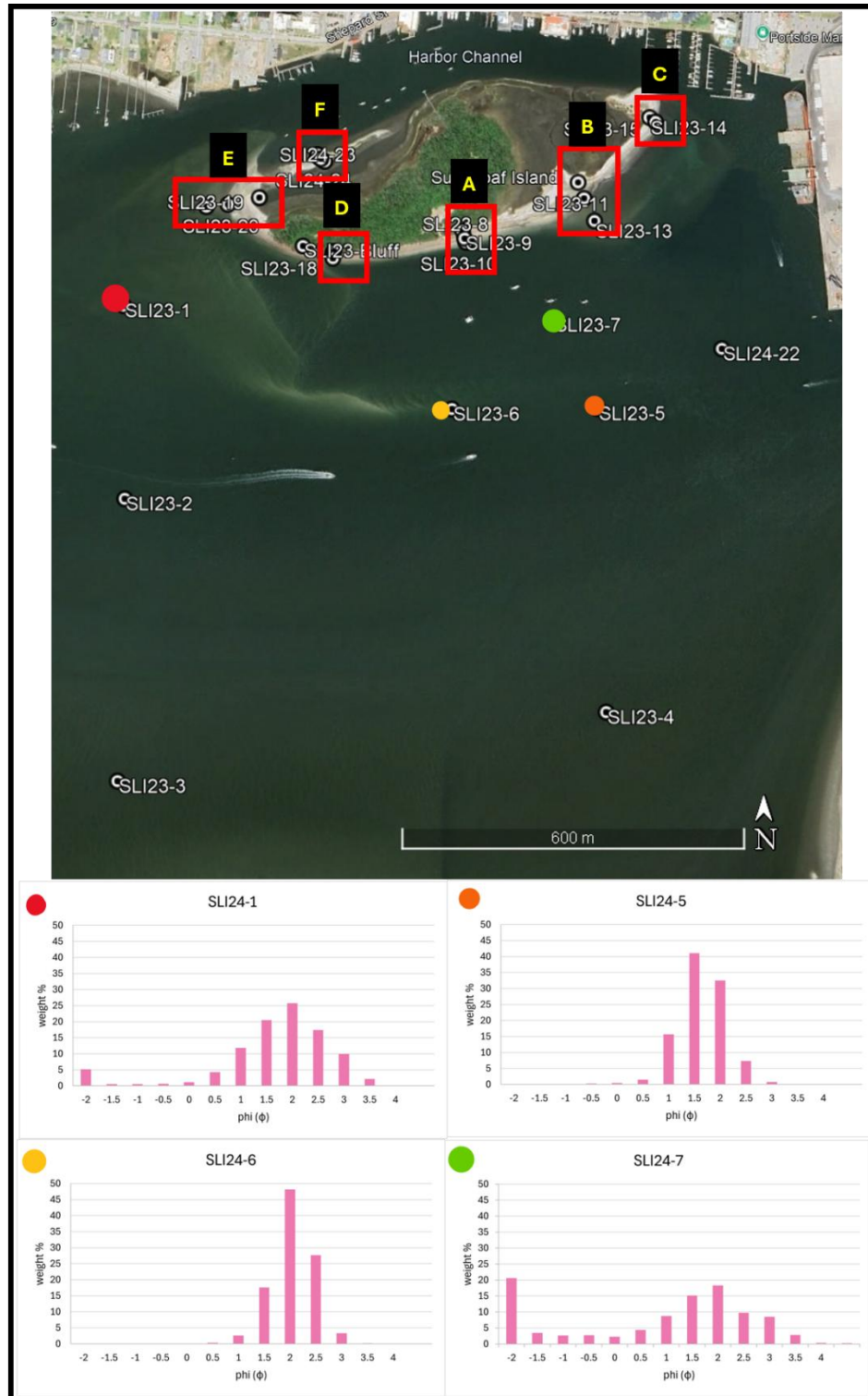
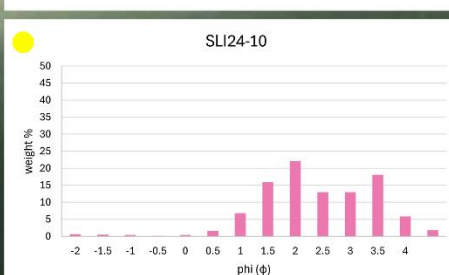
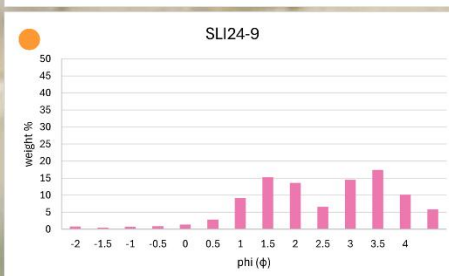
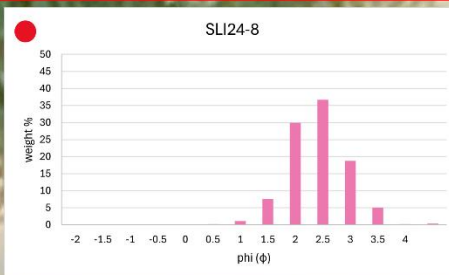
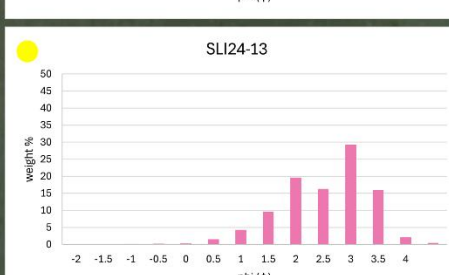
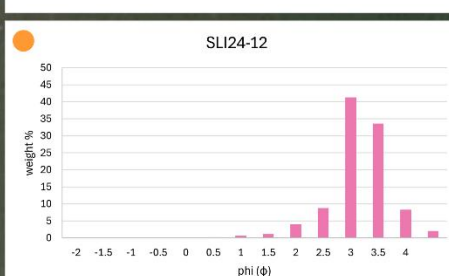
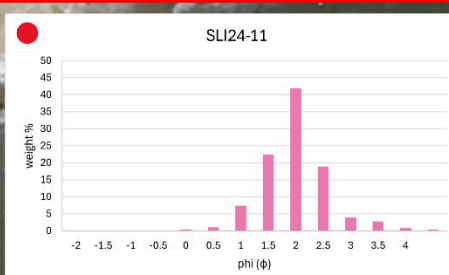


Figure 11. Aerial image of the study area, imagery sourced from MyErsi imagery basemap as of 2025, with the sediment sample sites and respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the second round of sediment samples. Red boxes denote beach to nearshore transects of samples, shown up close in figure 12. The letter above each box corresponds with the transect being referenced. In each image the colored dots relate to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A Figure A3.

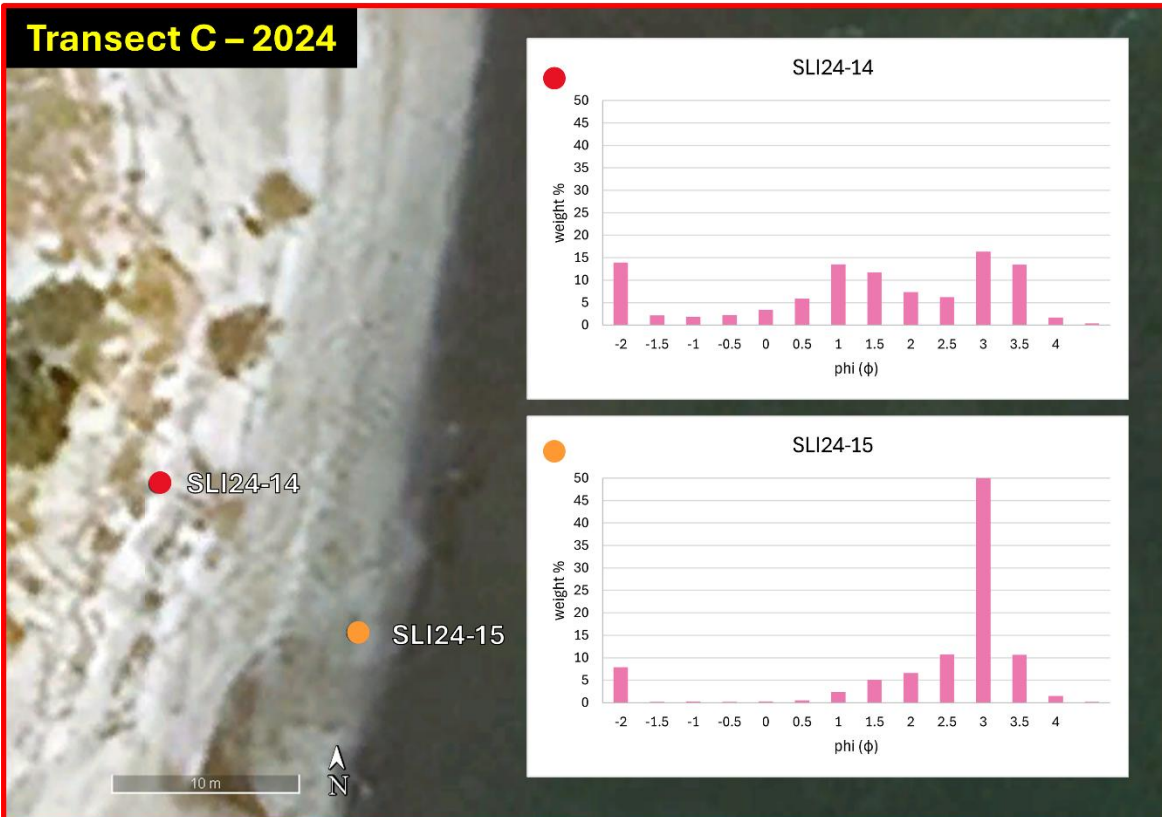
Transect A – 2024



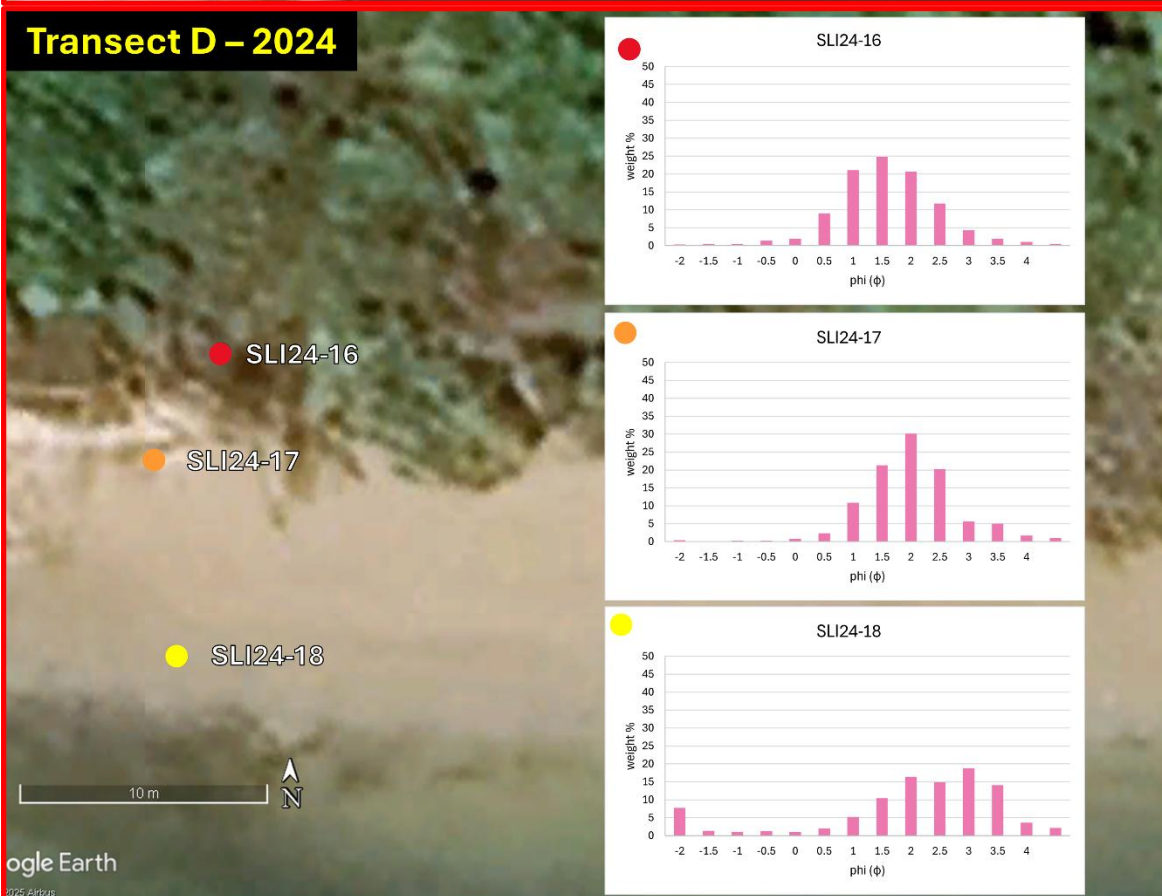
Transect B – 2024



Transect C – 2024



Transect D – 2024



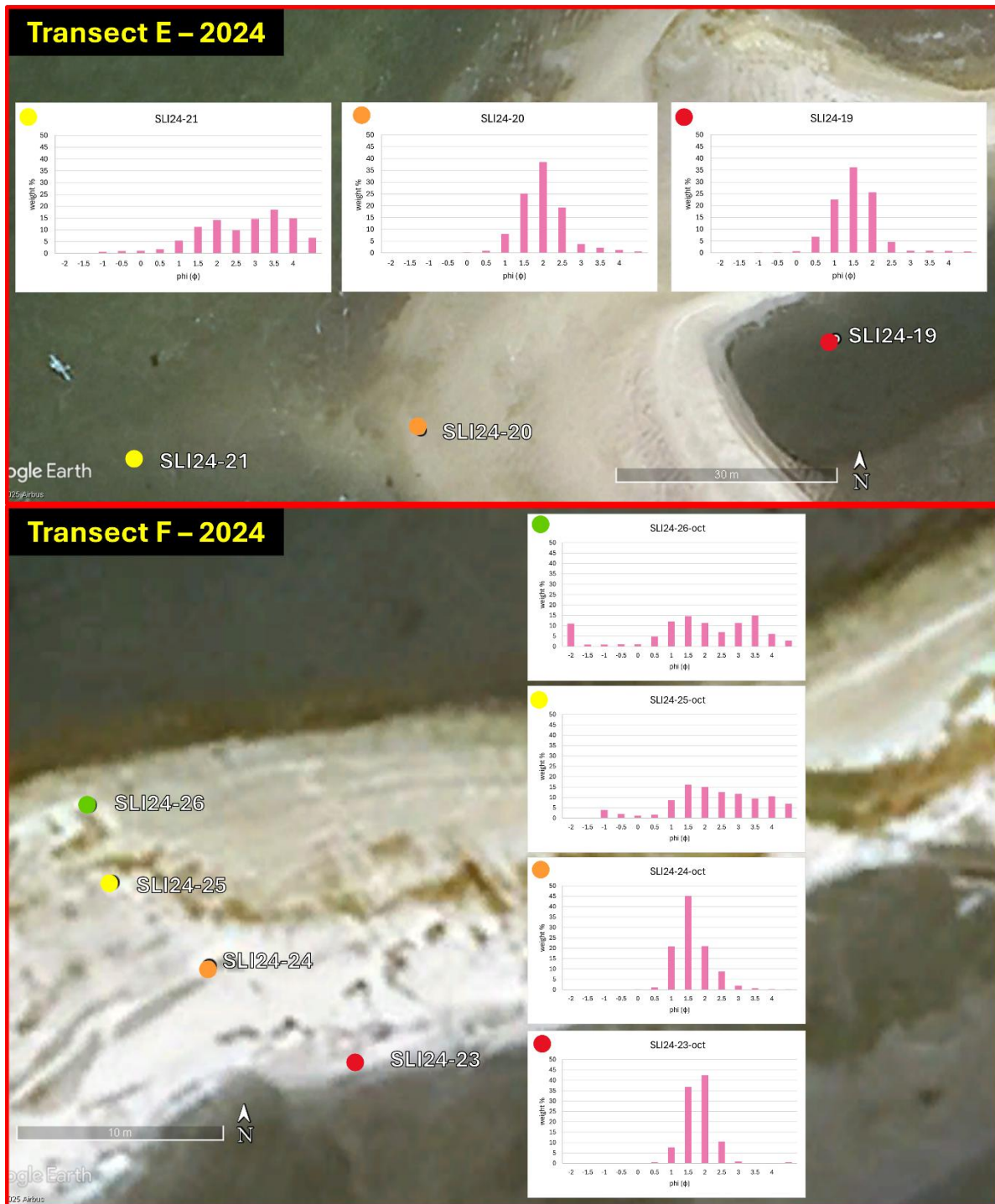


Figure 12. Close up aerial images of the transects labeled in figure 11 and respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the first round of sediment samples. In each image the colored dots relate to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A, Figure A3.



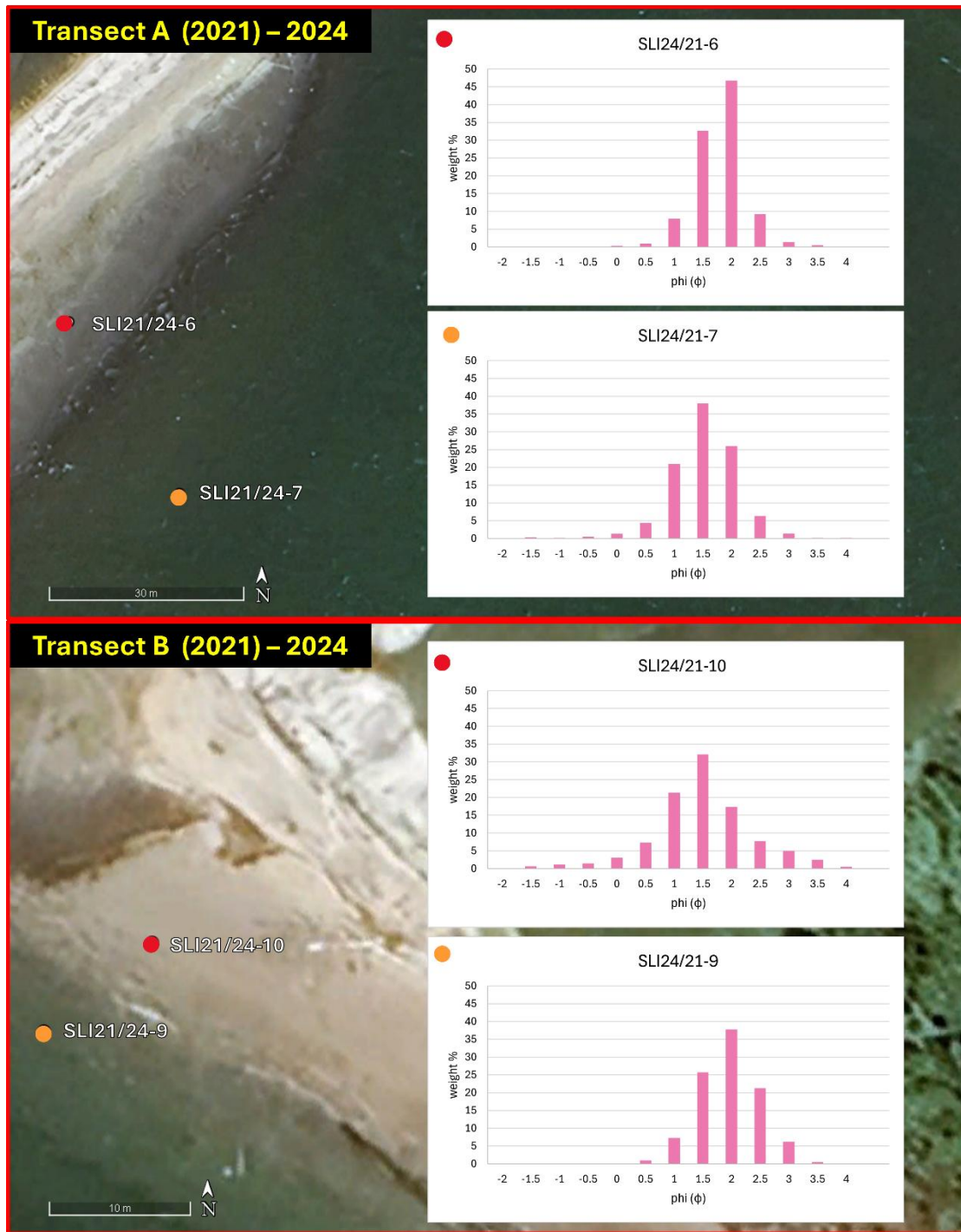


Figure 13. Map of the sediment sample sites, imagery sourced from MyErsi imagery basemap as of 2025, with respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the resampled 2021 sediment sites. Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001). Histograms made using Excel, 2025. Red boxes denote beach to nearshore transects of samples, shown up close in the images outlined in red. The letter above each box corresponds with the transect being referenced. In each image the colored dots relate to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A, Figure A5.

3.1.4 Side Scan Sonar

The side scan sonar mosaic (Fig. 14) gives an insight into the distribution of sediments and bedforms around Sugarloaf Island and further out into the channel.



Figure 14. Side-scan sonar mosaic. Darker shades represent finer sediments; lighter shades represent coarser sediment. Made using SonarWiz ver. 7 and Google Earth. Close-up images of points A, B, C, D, E, and F can be found in figure 16.

The side scan sonar mosaic was combined with the bathymetric dataset of the area to produce Figure 15, illustrating the bathymetry around the island. Based on the map, the average water depth ranges from 1 to 6 meters, with the depth increasing to 13 to 19 meters in the port channel to the east of Sugarloaf Island.

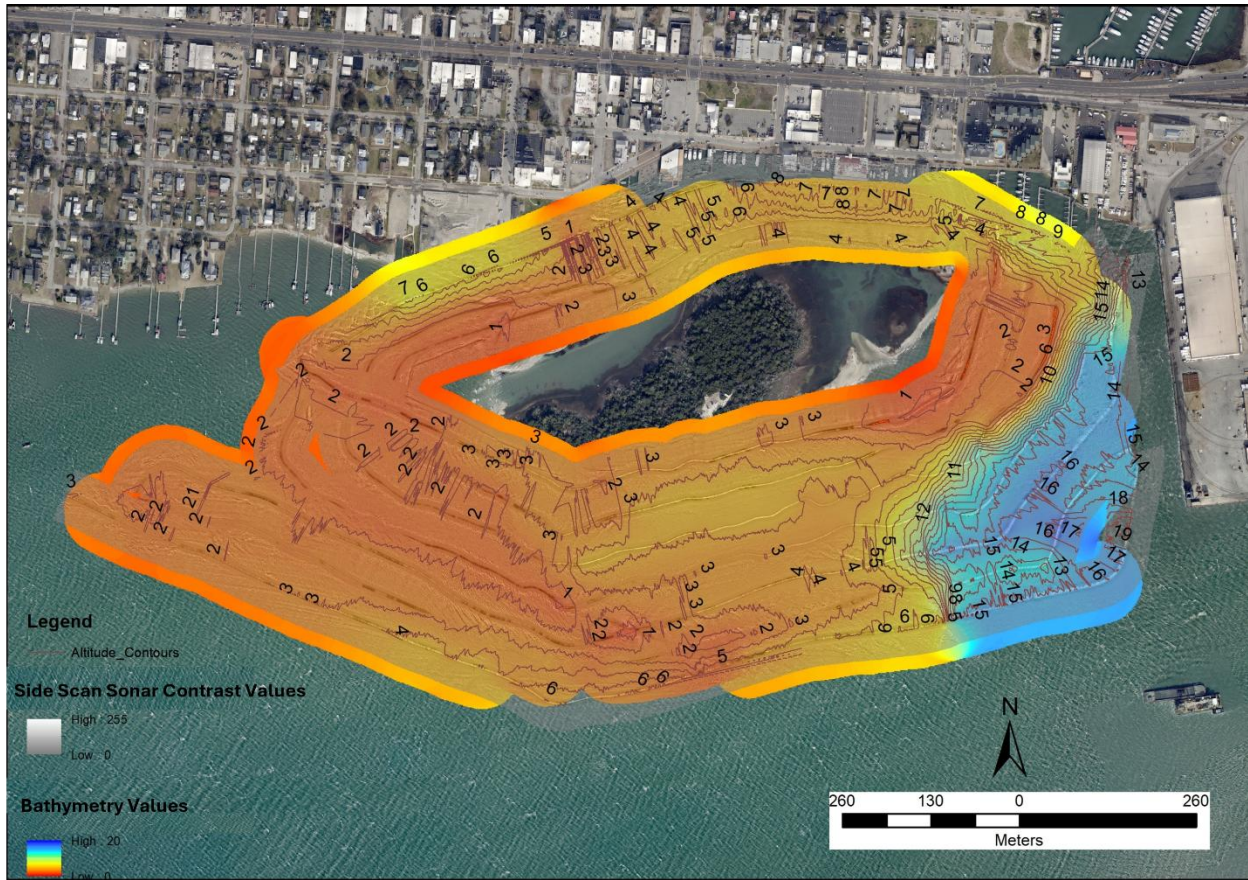


Figure 15. Side-scan sonar mosaic with the bathymetry (m) extracted and overlaid.

The close-ups of the locations noted in figure 14 illustrate a variety of unique and distinct bedforms (Fig. 16). These bedforms range from small scale ripples, 0.5-1 meters in wavelength (Fig. 16A), to larger subaqueous dunes ranging up to 16 meters in wavelength (Fig. 16B, D, E), to scour depressions (Fig. 16C).

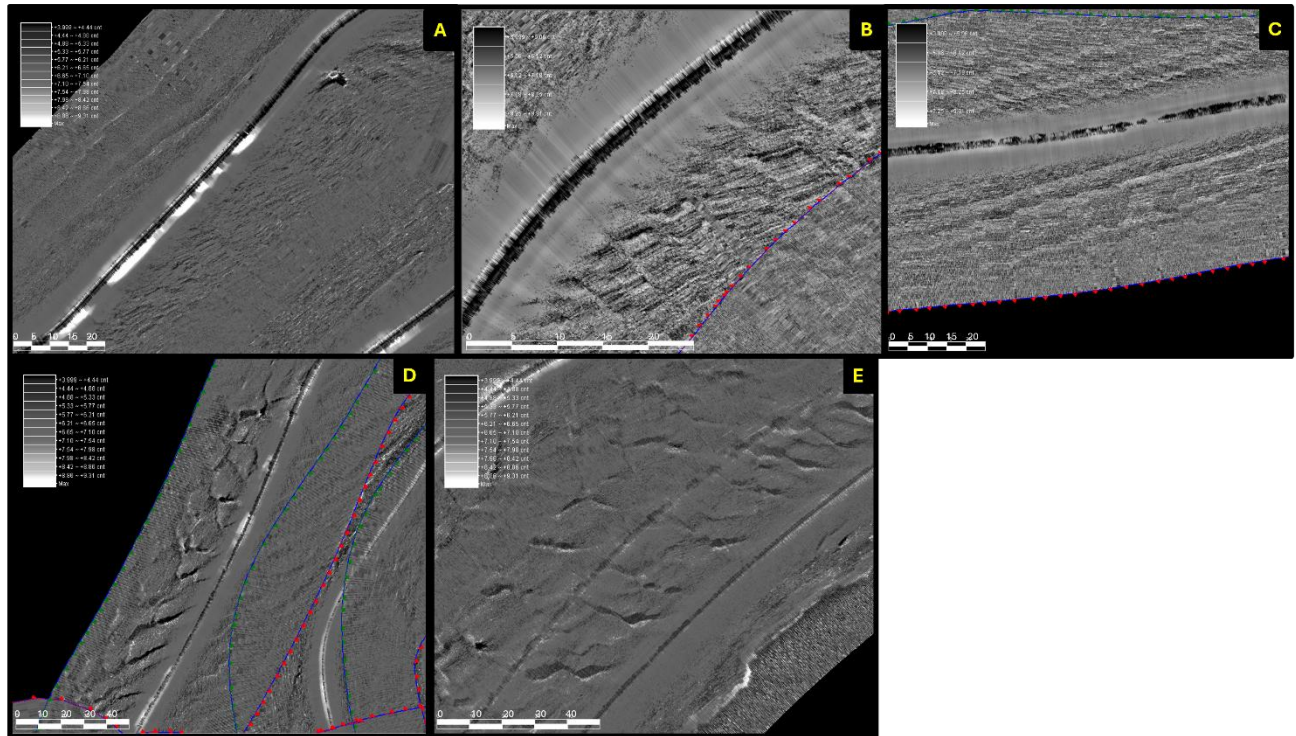


Figure 16. Close-up imagery of bedforms in side-scan sonar mosaic. A) Minor ripple bedforms ranging 0.5 to 1 meter. B) Subaqueous dunes formed by combined wave and tidal currents, found in shallow water (2-3 m) closer to the island, with wavelengths ranging from 1.5 to 2 meters. C) Current scour depressions formed by tidal currents at a 5-6 m depth, with lengths ranging from 3.5 to 4 meters. D) Large lingoid bedforms ranging from 7.5 to 10.5 meters in length. E) Large scale subaqueous dunes ranging from 8.5 to 16 meters in length.

The samples taken within the side scan area (Fig. 17) show a medium grain size (1.5 – 1.9 ϕ) with coarser grains (0.2 ϕ) in the deeper water of the Intracoastal Waterway, and fine sizes collected on the island from the beach face to the sand bar. The sorting in the Intracoastal Waterway is also worse than exhibited in the samples closer to the island.



Figure 17. Map of the sediment sample sites with respective histograms illustrating the distribution of sediment sizes (in phi) by weight percent of Side Scan Sonar sediment samples. Each colored dot relates to a corresponding histogram with the same-colored dot. Enlarged histograms are shown in Appendix A, Figure A4.

3.2 Foraminifera

3.2.1 First Round: December 2023 – March 2024; pre-WAD emplacement

The most abundant modern dead foraminiferal species within the first round of samples is either *Elphidium excavatum* or *Ammonia parkinsoniana* based on the highest relative percent in all samples. The third most abundant species varies between *Hanzawaia strattoni*,

Quinqueloculina seminula, *Elphidium mexicanum*, *Elphidium gunteri*, *Elphidium galvestonense*, *Buccella inusitata*, *Rosalina floridana*, and *Ammonia tepida* (Table B1).

The most abundant live species is *Ammonia parkinsoniana* with some samples exhibiting *Elphidium excavatum* as the dominant live species. The foraminifera samples in the marsh region of the island exhibit *Ammonia parkinsoniana* as the most abundant live species with *Elphidium excavatum* as the second most abundant. This region also exhibits very few specimens of fossil foraminifera (Table B1).

The first round (Fig. 18) exhibited 63 – 99% modern dead foraminifera, with the exception of SLI24-23, in the marsh of Sugarloaf Island, which exhibited only 8.42% modern dead foraminifera, and 91.58% of live foraminifera. The majority (16 of 27) of samples in round 1 contain both phosphatic and sugary fossilized foraminifera, with the exception of the marsh area, where either phosphatic, sugary, or both fossilized foraminifera were not recorded.

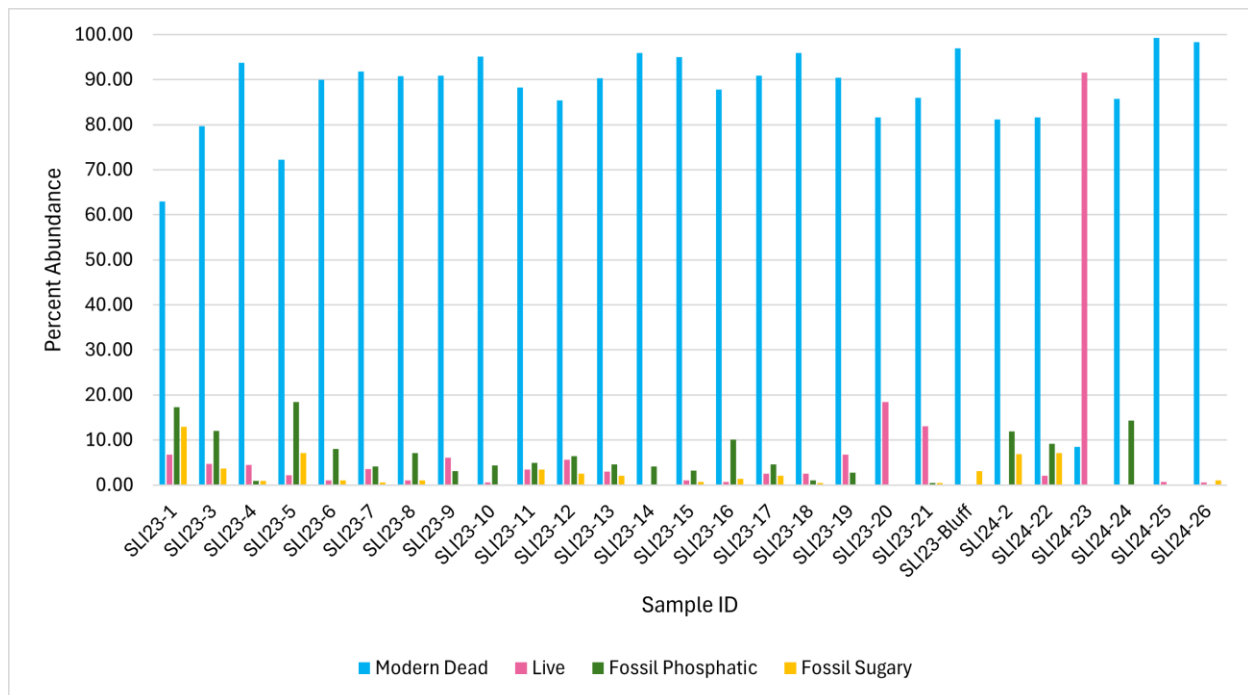


Figure 18. Bar graph illustrating the percentages of foraminiferal preservation types, between modern dead living, fossil phosphatic, and fossil sugary in the first round of samples. Made using Excel, 2025.

3.2.2 Second Round: October 2024; post-WAD emplacement

In the second round, like the first round, *Elphidium excavatum* is the most abundant species and *Ammonia parkinsoniana* is the next most dominant species. The third most abundant species varies between *Hanzawaia strattoni*, *Cibicides lobatulus*, *Elphidium mexicanum*, *Rosalina floridana*, *Bolivina lowmani*, *Ammonia tepida*, and *Gavelinopsis praeegeri* (Table B1).

The most abundant live species is *Ammonia parkinsoniana* with *Elphidium excavatum* as the most abundant species in only 2 samples. As in the first round of samples, the marsh region of the island in the second round of samples exhibits *Ammonia parkinsoniana* as the most abundant species with *Elphidium excavatum* as the second most abundant.

The second round (Fig. 19) still exhibited mostly modern dead foraminifera, except for marsh sample SLI24-23-oct once again, which showed mostly live foraminifera. Additionally, SLI24-8-oct, located on Sugarloaf Island on the sound island shore, contained a single fossil

sugary specimen and no modern foraminifera. Overall, the second round of samples exhibits a higher percentage of living foraminifera than the first. Round 1 had a mean of 85.4% modern dead foraminifera and 6.8% live foraminifera, whereas round 2 had a mean of 79.3% modern dead foraminifera and 13.5% live foraminifera. The second round of samples also exhibited a lower percentage of fossilized foraminifera (7.4% in round 1 and 2.6% in round 2).

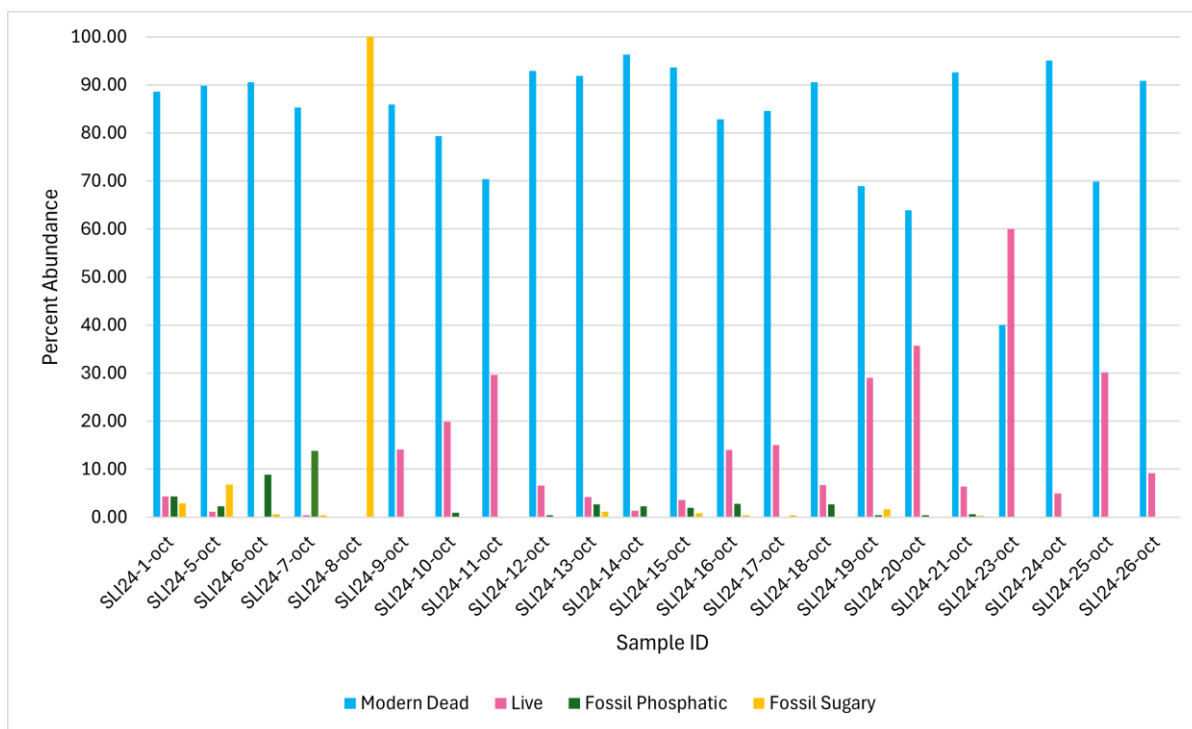


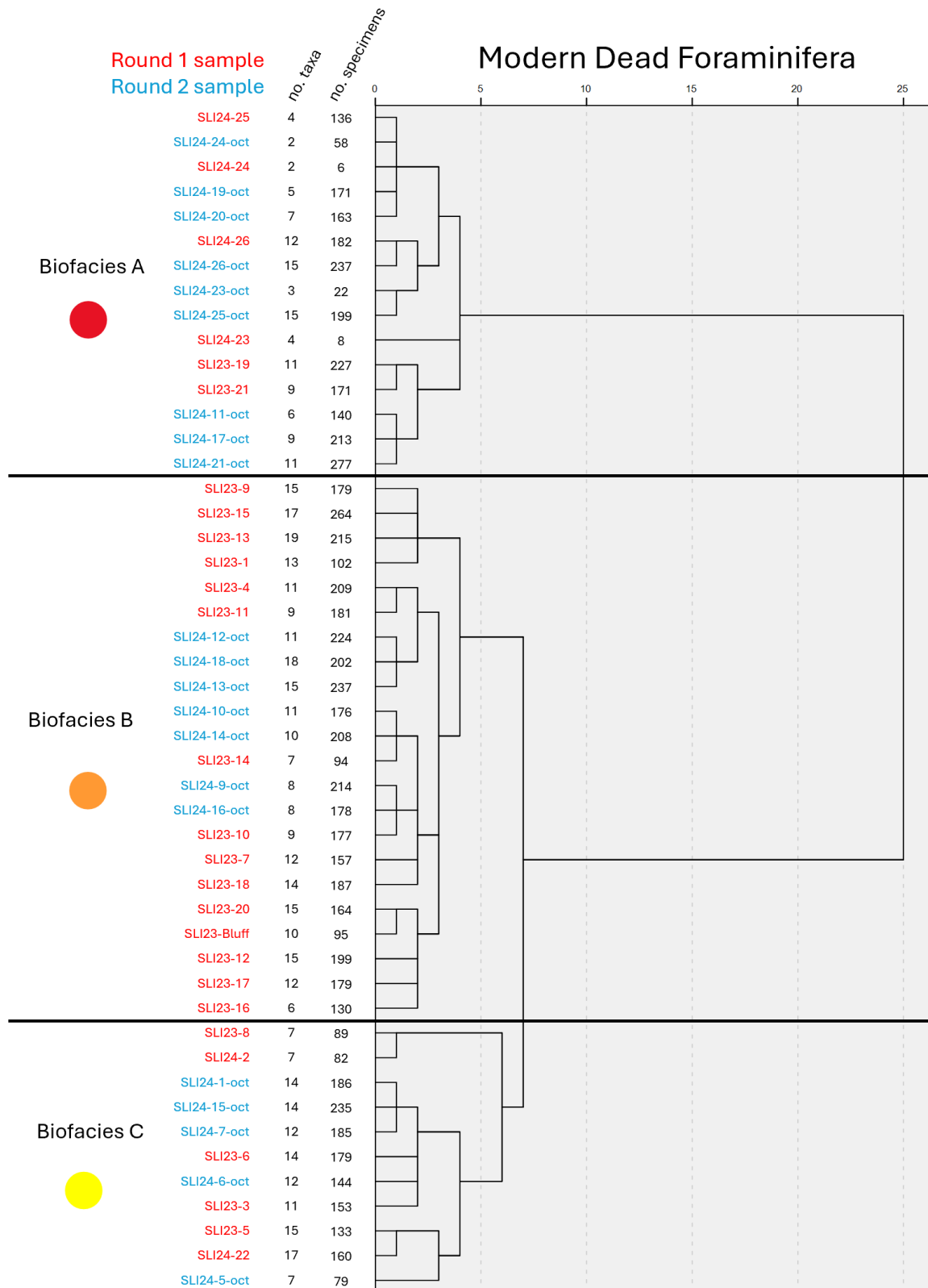
Figure 19. Bar graph illustrating the percentages of foraminiferal preservation types, between modern dead, living, fossilized phosphatic, and fossilized sugary of the second round of samples. Made using Excel, 2025.

3.2.3 Cluster Analysis

Three different Q-mode cluster analyses were conducted for both sampling rounds combined. The first cluster analysis consisted of modern dead specimens, the second consisted of live specimens, and the third consisted of both modern dead and live specimens.

3.2.3a Modern Dead Foraminifera

Modern dead foraminifera were found in 48 out of 49 samples (rounds 1 and 2 combined). The cluster analysis distinguished three groups within the data (Fig. 20), which are herein defined as Biofacies A – C. There are very few minor changes between the round one and round two samples, with said changes occurring in the areas directly around the island, at the SLI-20, 17, and 11 locations (Fig. 20). Biofacies A is co-dominated by *Ammonia parkinsoniana* (47.8%) and *Elphidium excavatum* (43.2%; Table 2). Biofacies B and C, more similar to each other than to biofacies A (Fig. 20), are both strongly dominated by *Elphidium excavatum* (65% and 60%, respectively). In both biofacies B and C, *Ammonia parkinsoniana* is the second most abundant species with 19% and 10%, respectively. Thus, biofacies B and C are differentiated by the rarer taxa (Table 2). Biofacies B has only two taxa that make up 2 to 5% of the assemblage, *Elphidium mexicanum* and *Hanzawaia strattoni*. In contrast, biofacies C has three taxa that make up 2 to 5% of the assemblage, *Hanzawaia strattoni*, *Quinqueloculina lamarckiana* and *Quinqueloculina seminula*. Thus, it is the relative abundance of these two *Quinqueloculina* species that is important in distinguishing biofacies B and C.





Round 1 ⊕ Round 2

Figure 20. Dendrogram resulting from cluster analysis of modern dead foraminifera specimens (those species that comprise 2% or more of the assemblage in any one sample). White correlates to samples without a round 2 sample. Made using IBM SPSS Statistics version 29.

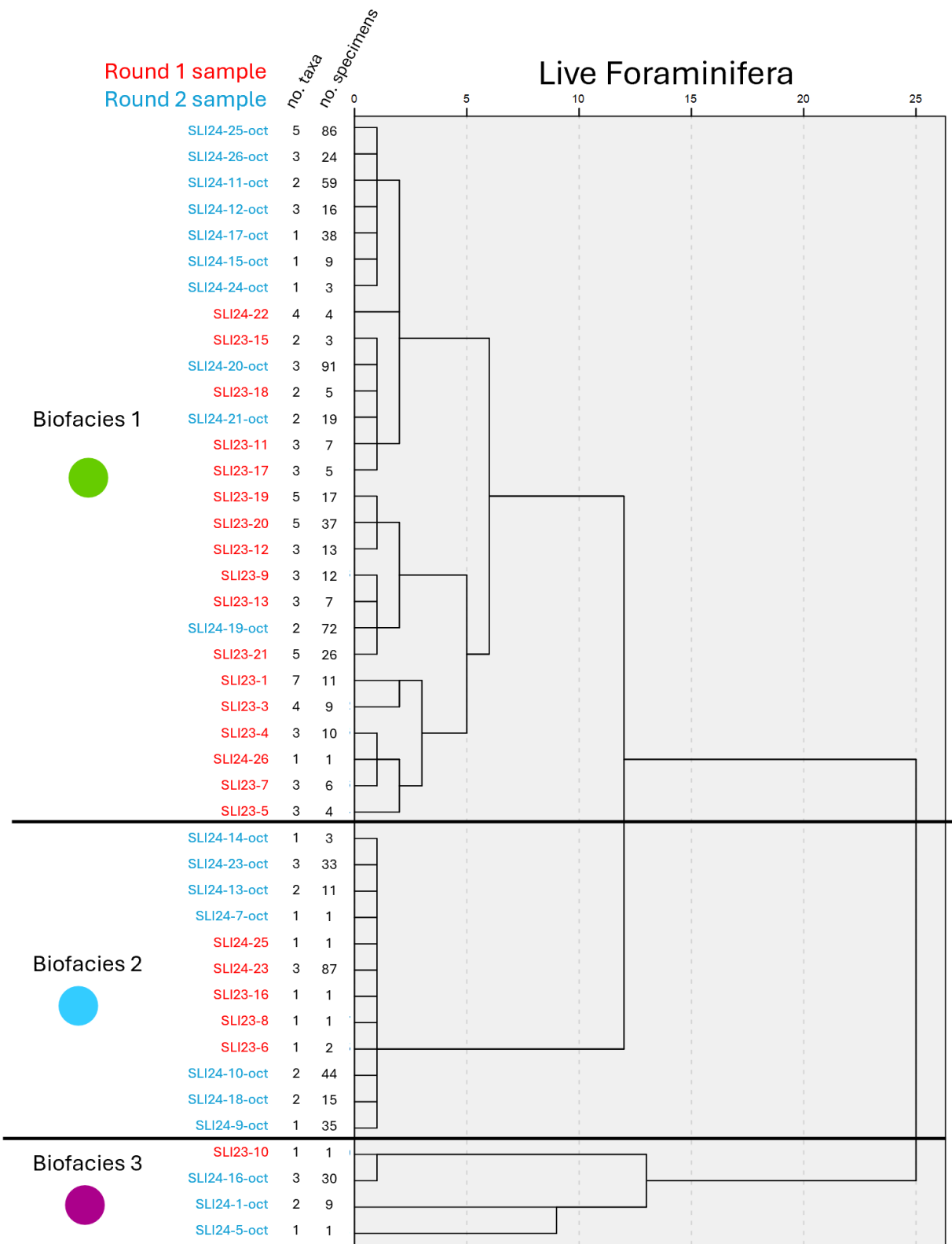
Table 2: Mean percent abundance and range for taxa in Biofacies A – C defined by cluster analysis of modern dead benthic foraminiferal relative abundance data for samples collected from Sugarloaf Island in 2023/2024 and late 2024. The distribution of Biofacies for each year is shown in Figure 20.

 Biofacies A (15 samples)	Mean %	Range %	 Biofacies B (22 samples)	Mean %	Range %	 Biofacies C (11 samples)	Mean %	Range %
<i>Ammonia parkinsoniana</i>	47.78	34.27-66.67	<i>Elphidium excavatum</i>	64.94	43.14-76.92	<i>Elphidium excavatum</i>	69.07	51.88-89.02
<i>Elphidium excavatum</i>	43.19	25.00-57.75	<i>Ammonia parkinsoniana</i>	19.34	13.88-26.14	<i>Ammonia parkinsoniana</i>	10.53	2.44-16.60
<i>Ammonia tepida</i>	1.33	0.00-7.49	<i>Elphidium mexicanum</i>	3.35	0.99-15.64	<i>Hanzawaia strattoni</i>	4.56	0.00-12.66
<i>Elphidium gunteri</i>	1.15	0.00-12.50	<i>Hanzawaia strattoni</i>	2.26	0.00-9.80	<i>Quinqueloculina lamarkiana</i>	3.91	0.00-22.78
<i>Elphidium mexicanum</i>	1.09	0.00-4.29	<i>Buccella inusitata</i>	1.24	0.00-4.26	<i>Quinqueloculina seminula</i>	3.05	0.00-8.27
<i>Quinqueloculina seminula</i>	0.83	0.00-12.50	<i>Cibicides lobatulus</i>	1.20	0.00-2.79	<i>Cibicides lobatulus</i>	1.44	0.00-3.78
<i>Cibicides lobatulus</i>	0.45	0.00-2.14	<i>Quinqueloculina seminula</i>	0.98	0.00-4.42	<i>Elphidium galvestonense</i>	0.89	0.00-3.66
<i>Gavelinopsis praegeri</i>	0.44	0.00-2.53	<i>Elphidium translucens</i>	0.85	0.00-3.92	<i>Nonionella atlantica</i>	0.86	0.00-2.13
<i>Hanzawaia strattoni</i>	0.33	0.00-2.35	<i>Ammonia tepida</i>	0.84	0.00-4.88	<i>Elphidium mexicanum</i>	0.76	0.00-2.53
<i>Bolivina lowmani</i>	0.31	0.00-2.53	<i>Nonionella atlantica</i>	0.64	0.00-2.33	<i>Quinqueloculina jugosa</i>	0.65	0.00-3.91
<i>Elphidium translucens</i>	0.24	0.00-1.17	<i>Rosalina floridana</i>	0.64	0.00-3.52	<i>Buccella inusitata</i>	0.58	0.00-1.88
<i>Rosalina floridana</i>	0.20	0.00-1.65	<i>Trifarina angulosa</i>	0.51	0.00-2.33	<i>Elphidium gunteri</i>	0.56	0.00-3.75
<i>Elphidium galvestonense</i>	0.19	0.00-1.17	<i>Elphidium galvestonense</i>	0.44	0.00-2.79	<i>Eponides repandus</i>	0.54	0.00-2.50
<i>Buccella inusitata</i>	0.10	0.00-1.10	<i>Gavelinopsis praegeri</i>	0.37	0.00-2.27	<i>Rosalina floridana</i>	0.44	0.00-1.50
<i>Trifarina angulosa</i>	0.09	0.00-0.55	<i>Elphidium gunteri</i>	0.36	0.00-2.94	<i>Elphidium translucens</i>	0.34	0.00-1.96
<i>Nonionella atlantica</i>	0.06	0.00-0.50	<i>Quinqueloculina jugosa</i>	0.20	0.00-1.96	<i>Ammonia tepida</i>	0.27	0.00-1.96
<i>Quinqueloculina jugosa</i>	0.04	0.00-0.55	<i>Bolivina lowmani</i>	0.15	0.00-1.07	<i>Trifarina angulosa</i>	0.15	0.00-1.12
<i>Quinqueloculina lamarkiana</i>	0.03	0.00-0.50	<i>Quinqueloculina lamarkiana</i>	0.13	0.00-1.86	<i>Gavelinopsis praegeri</i>	0.14	0.00-1.50
<i>Eponides repandus</i>	0.00	0.00-0.00	<i>Eponides repandus</i>	0.00	0.00-0.00	<i>Bolivina lowmani</i>	0.00	0.00-0.00

3.2.3b Live Foraminifera

Live foraminifera were found in 43 out of 49 samples. The Q-mode cluster analysis distinguished three clusters within the data (Fig. 21), which are herein defined as Biofacies 1 – 3. All three biofacies have samples that have few live specimens, especially biofacies 3. There is more variability between round 1 and 2 in the live assemblages versus the modern dead assemblages (Fig. 20). The modern dead cluster analysis only had six instances of change, and the live cluster analysis has 14 changes.

Biofacies 1 is strongly dominated by *Ammonia parkinsoniana* (65.74%) with *Elphidium excavatum* (12.26%) second in abundance. Two additional species (*Elphidium mexicanum* and *Tritaxis fusca*) make up 3 to 5% of the biofacies. Biofacies 2 is also dominated by *Ammonia parkinsoniana* (84.9%), with two additional species (*Tritaxis fusca* and *Elphidium excavatum*) that make up 3 to 8% of the biofacies. Biofacies 3 is dominated by *Ammonia Parkinsoniana* (45.56%) with *Elphidium excavatum* (25.83%) and *Rosalina floridana* (25%; Table 3) second in abundance. In this case, it is the abundant taxa that distinguish the three biofacies. Figure 21 illustrates that many of the beach to nearshore locations changed to Biofacies 1 from round 1 to round 2, suggesting an increase in *Ammonia parkinsoniana*, which is supported by the initial abundance data (Table B1). Sample locations SLI-5, 6, and 7 all experience a shift to Biofacies 3, showing an overall decrease in *Ammonia parkinsoniana* and *Elphidium excavatum* outside the WADs from round 1 to round 2.





Round 1 ⊕ Round 2

Figure 21. Dendrogram resulting from cluster analysis of live foraminifera specimens (those species that comprise 2% or more of the assemblage in any one sample). White correlates to samples without a round 2 sample. Made using IBM SPSS Statistics version 29.

Table 3: Mean percent abundance and range for taxa in Biofacies 1 – 3 defined by cluster analysis of live benthic foraminiferal relative abundance data for samples collected from Sugarloaf Island in 2023/2024 and late 2024. The distribution of Biofacies for each year is shown in Figure 21.

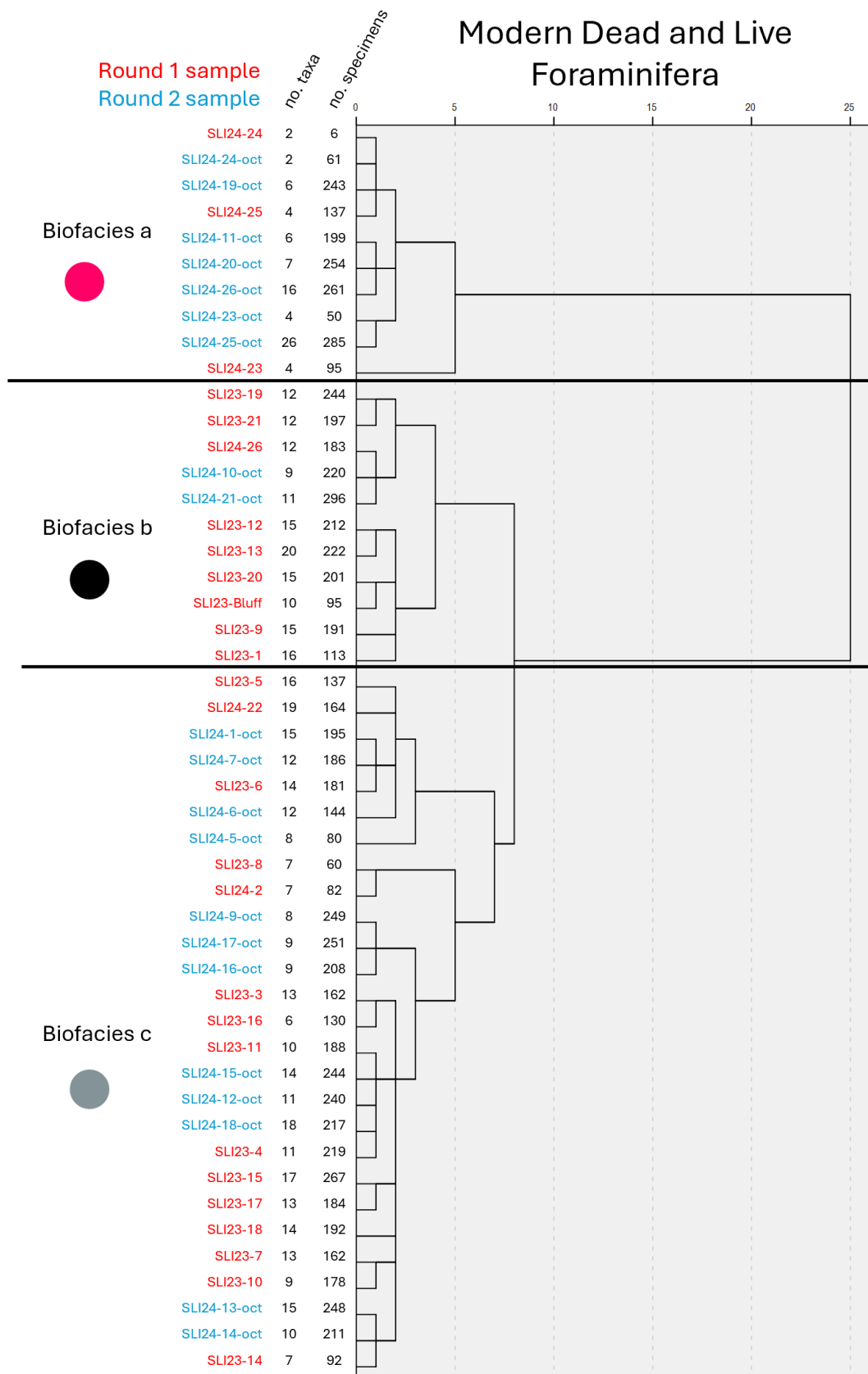
 Biofacies 1 (27 samples)	Mean %	Range %	 Biofacies 2 (12 samples)	Mean %	Range %	 Biofacies 3 (4 samples)	Mean %	Range %
<i>Ammonia parkinsoniana</i>	65.74%	0.00-100.00	<i>Ammonia parkinsoniana</i>	84.90%	0.00-100.00	<i>Ammonia parkinsoniana</i>	45.56%	0.00-93.33
<i>Elphidium excavatum</i>	12.26%	0.00-100.00	<i>Tritatixis fusca</i>	8.33%	0.00-100.00	<i>Elphidium excavatum</i>	25.83%	0.00-100.00
<i>Elphidium mexicanum</i>	5.24%	0.00-34.62	<i>Elphidium excavatum</i>	3.68%	0.00-27.27	<i>Rosalina floridana</i>	25.00%	0.00-100.00
<i>Tritatixis fusca</i>	3.88%	0.00-33.33	<i>Elphidium gunteri</i>	2.90%	0.00-28.74	<i>Tritatixis fusca</i>	2.78%	0.00-11.11
<i>Ammonia tepida</i>	2.65%	0.00-30.77	<i>Quinqueloculina impressa</i>	0.19%	0.00-2.27	<i>Textularia earlandi</i>	0.83%	0.00-0.00
<i>Quinqueloculina impressa</i>	2.49%	0.00-25.00	<i>Ammonia tepida</i>	0.00%	0.00-0.00	<i>Ammonia tepida</i>	0.00%	0.00-0.00
<i>Rosalina floridana</i>	1.88%	0.00-25.00	<i>Ammotium salsum</i>	0.00%	0.00-0.00	<i>Ammotium salsum</i>	0.00%	0.00-0.00
<i>Trochammina "squamata"</i>	1.26%	0.00-25.00	<i>Bolivina lowmani</i>	0.00%	0.00-0.00	<i>Bolivina lowmani</i>	0.00%	0.00-0.00
<i>Ammotium salsum</i>	0.93%	0.00-25.00	<i>Bolivina striatula</i>	0.00%	0.00-0.00	<i>Bolivina striatula</i>	0.00%	0.00-0.00
<i>Hanzawaia strattoni</i>	0.93%	0.00-25.00	<i>Elphidium mexicanum</i>	0.00%	0.00-0.00	<i>Elphidium gunteri</i>	0.00%	0.00-0.00
<i>Quinqueloculina seminula</i>	0.74%	0.00-20.00	<i>Hanzawaia strattoni</i>	0.00%	0.00-0.00	<i>Elphidium mexicanum</i>	0.00%	0.00-0.00
<i>Bolivina lowmani</i>	0.72%	0.00-9.09	<i>Laryngosigma wiliamsoni</i>	0.00%	0.00-0.00	<i>Hanzawaia strattoni</i>	0.00%	0.00-0.00
<i>Nonionella atlantica</i>	0.53%	0.00-14.29	<i>Nonionella atlantica</i>	0.00%	0.00-0.00	<i>Laryngosigma wiliamsoni</i>	0.00%	0.00-0.00
<i>Quinqueloculina jugosa</i>	0.34%	0.00-9.09	<i>Quinqueloculina jugosa</i>	0.00%	0.00-0.00	<i>Nonionella atlantica</i>	0.00%	0.00-0.00
<i>Bolivina striatula</i>	0.14%	0.00-3.85	<i>Quinqueloculina seminula</i>	0.00%	0.00-0.00	<i>Quinqueloculina impressa</i>	0.00%	0.00-0.00
<i>Laryngosigma wiliamsoni</i>	0.14%	0.00-3.85	<i>Rosalina floridana</i>	0.00%	0.00-0.00	<i>Quinqueloculina jugosa</i>	0.00%	0.00-0.00
<i>Elphidium gunteri</i>	0.04%	0.00-1.16	<i>Textularia earlandi</i>	0.00%	0.00-0.00	<i>Quinqueloculina seminula</i>	0.00%	0.00-0.00
<i>Textularia earlandi</i>	0.04%	0.00-3.33	<i>Trochammina "squamata"</i>	0.00%	0.00-0.00	<i>Trochammina "squamata"</i>	0.00%	0.00-0.00

3.2.3c Total Live and Modern Dead Foraminifera

Both live and modern dead foraminifera were found in 48 out of 49 samples. The Q-mode cluster analysis of both live and modern dead specimens distinguished three clusters within the data (Fig. 22), which will further be considered Biofacies a – c. These Biofacies are similar in distribution and composition to biofacies A – C of the dead foraminifera analysis because the live data are patchier and less abundant, allowing for the modern dead data to overwhelm the live data. Comparing figures 20 and 22 shows that there is a spatial similarity between the modern dead and the total cluster analyses, as many of the patterns between biofacies in the modern dead map are also reflected in the total. For example, many of the sample locations that remain the same biofacies between rounds of sampling in the modern dead also remain the same in the total. Additionally, there's a correlation between biofacies a locations with biofacies A, as well as being biofacies b and B, and biofacies c and C. Comparing tables 2 and 4 show that biofacies a – c is similar to biofacies A – C particularly in the distribution of the most abundance species, for example both biofacies a and A exhibit the highest mean percentage of *Ammonia parkinsoniana*.

Biofacies a is dominated by *Ammonia parkinsoniana* (61.24%) with the second most abundant species of *Elphidium excavatum* (31.13%; Table 4). Biofacies b and c, are both dominated by *Elphidium excavatum* (50.42% and 66.48%, respectively). In both biofacies b and c, *Ammonia parkinsoniana* is the second most abundant species with 30.5% and 17.95%, respectively. Thus, biofacies b and c are differentiated by the rarer taxa (Table 4). Biofacies b has three taxa that make up 2 to 5% of the assemblage, *Elphidium mexicanum*, *Ammonia tepida*, and *Hanzawaia strattoni*. In contrast, biofacies c has only one taxon that makes up 2 to 5% of the assemblage, *Hanzawaia strattoni*. The only real difference between Dead and Total analyses is

that the percents of *Ammonia* are increased in the total analysis due to their abundance in two of the live biofacies (Table 3). The samples in the back marsh once again exhibit the highest percentage of *Ammonia parkinsoniana*. The beach and nearshore locations as well as SLI-1 are the only locations that experienced change. In the lagoon region and western part of the island the samples change to Biofacies a from round 1 to round 2, due to the increase of *Ammonia parkinsoniana*. The island shore samples also experience change, from Biofacies b to Biofacies c, likely due to an increase in *Elphidium excavatum* from round 1 to round 2.





Round 1 ⊕ Round 2

Figure 22. Dendrogram resulting from cluster analysis of all (live and dead) foraminifera specimens (those species that comprise 2% or more of the assemblage in any one sample). White correlates to samples without a round 2 sample. Made using IBM SPSS Statistics version 29.

Table 4: Mean percent abundance and range for taxa in Biofacies a – b defined by cluster analysis of all benthic foraminiferal relative abundance data for samples collected from Sugarloaf Island in 2023/2024 and late 2024. The distribution of Biofacies for each year is shown in Figure 22.

 Biofacies a (10 samples)	Mean %	Range %	 Biofacies b (11 samples)	Mean %	Range %	 Biofacies c (27 samples)	Mean %	Range %
<i>Ammonia parkinsoniana</i>	61.24	54.01-68.42	<i>Elphidium excavatum</i>	50.42	40.71-61.05	<i>Elphidium excavatum</i>	66.48	51.22-89.02
<i>Elphidium excavatum</i>	31.13	3.16-44.53	<i>Ammonia parkinsoniana</i>	30.50	17.57-43.72	<i>Ammonia parkinsoniana</i>	17.95	2.44-35.34
<i>Elphidium gunteri</i>	3.44	0.00-27.37	<i>Elphidium mexicanum</i>	4.44	0.55-15.71	<i>Hanzawaia strattoni</i>	2.86	0.00-12.50
<i>Elphidium mexicanum</i>	1.12	0.00-5.91	<i>Ammonia tepida</i>	2.91	0.00-7.38	<i>Quinqueloculina seminula</i>	1.76	0.00-8.03
<i>Gavelinopsis praegeri</i>	0.41	0.00-2.30	<i>Hanzawaia strattoni</i>	2.00	0.00-8.85	<i>Elphidium mexicanum</i>	1.70	0.00-6.75
<i>Ammonia tepida</i>	0.36	0.00-1.82	<i>Buccella inusitata</i>	0.89	0.00-2.65	<i>Quinqueloculina lamarckiana</i>	1.60	0.00-22.50
<i>Cibicides lobatulus</i>	0.19	0.00-1.51	<i>Cibicides lobatulus</i>	0.86	0.00-2.70	<i>Cibicides lobatulus</i>	1.28	0.00-3.76
<i>Bolivina lowmani</i>	0.16	0.00-0.70	<i>Rosalina floridana</i>	0.78	0.00-3.30	<i>Buccella inusitata</i>	0.87	0.00-4.26
<i>Hanzawaia strattoni</i>	0.11	0.00-0.73	<i>Nonionella atlantica</i>	0.67	0.00-2.25	<i>Nonionella atlantica</i>	0.59	0.00-2.05
<i>Quinqueloculina seminula</i>	0.11	0.00-1.05	<i>Quinqueloculina impressa</i>	0.62	0.00-3.98	<i>Rosalina floridana</i>	0.55	0.00-2.19
<i>Elphidium galvestonense</i>	0.08	0.00-0.41	<i>Quinqueloculina seminula</i>	0.59	0.00-2.65	<i>Elphidium galvestonense</i>	0.54	0.00-3.66
<i>Rosalina floridana</i>	0.08	0.00-0.41	<i>Elphidium galvestonense</i>	0.53	0.00-1.42	<i>Tritaxis fusca</i>	0.36	0.00-1.85
<i>Buccella inusitata</i>	0.04	0.00-0.38	<i>Quinqueloculina jugosa</i>	0.47	0.00-2.65	<i>Elphidium gunteri</i>	0.34	0.00-3.66
<i>Nonionella atlantica</i>	0.04	0.00-0.35	<i>Elphidium gunteri</i>	0.46	0.00-2.65	<i>Trifarina angulosa</i>	0.32	0.00-1.21
<i>Quinqueloculina impressa</i>	0.04	0.00-0.35	<i>Trifarina angulosa</i>	0.42	0.00-2.25	<i>Gavelinopsis praegeri</i>	0.29	0.00-2.25
<i>Quinqueloculina lamarckiana</i>	0.04	0.00-0.35	<i>Tritaxis fusca</i>	0.41	0.00-3.54	<i>Quinqueloculina jugosa</i>	0.28	0.00-3.87
<i>Trifarina angulosa</i>	0.04	0.00-0.38	<i>Bolivina lowmani</i>	0.33	0.00-2.36	<i>Ammonia tepida</i>	0.21	0.00-1.85
<i>Eponides repandus</i>	0.00	0.00-0.00	<i>Gavelinopsis praegeri</i>	0.31	0.00-1.64	<i>Eponides repandus</i>	0.21	0.00-2.44
<i>Quinqueloculina jugosa</i>	0.00	0.00-0.00	<i>Quinqueloculina lamarckiana</i>	0.16	0.00-1.80	<i>Bolivina lowmani</i>	0.13	0.00-1.25
<i>Tritaxis fusca</i>	0.00	0.00-0.00	<i>Eponides repandus</i>	0.00	0.00-0.00	<i>Quinqueloculina impressa</i>	0.02	0.00-0.61

4.0 Discussion

4.1 Sediments

For discussion purposes, the samples can be grouped according to their occurrence within geomorphic/environmental regions within the sample area (Fig. 23) based on this study's interpretations. They have been organized into the western spit, eastern spit, marsh (including the shallow lagoon, marsh, and beach environment), island shore, southwest of the island, southeast of the island, and south of the Intracoastal Waterway (ICW) (Figs. 23 and 24). After the implementation of the wave attenuation devises, it is expected that the beach and nearshore samples situated behind the WADs would experience worsening sorting and coarsened grain size, as a result of the mitigation of incoming wave energy and sediment transport in the area.

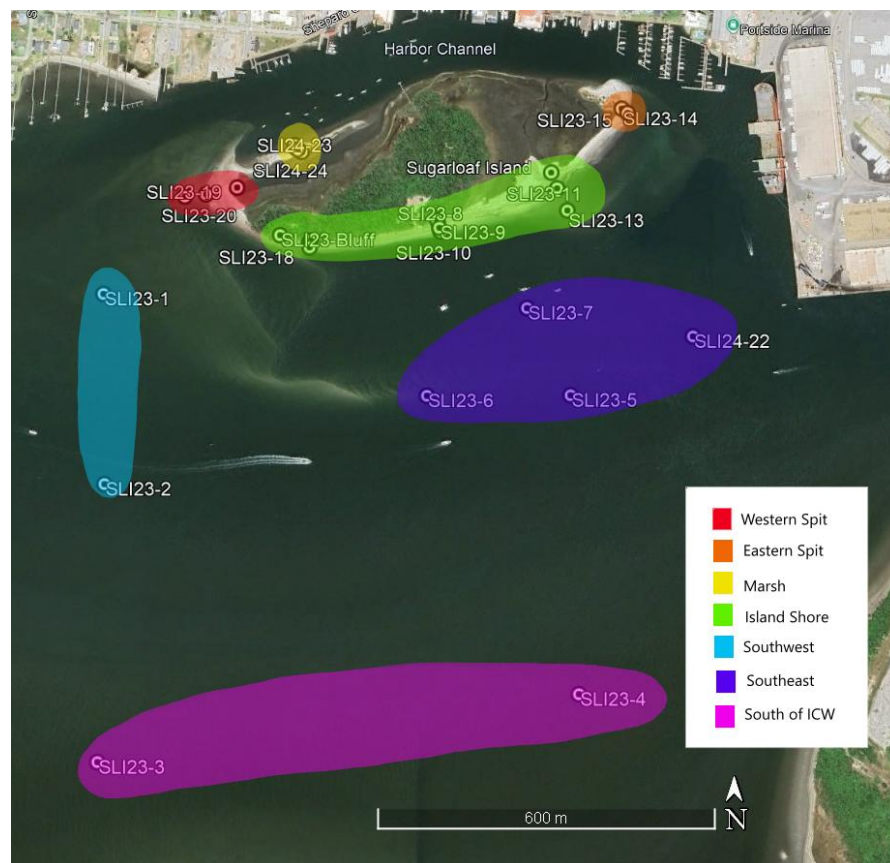


Figure 23. Map grouping samples by region using satellite imagery from Google Earth Pro.



Figure 24. Map illustrating the environments included under the term “marsh.” Includes the channel, shallow lagoon, beach, and marsh environments. Satellite imagery obtained using Google Earth Pro. Imagery date 5/13/23.

In general, the nearshore and beach sediments become better sorted and finer in an eastward direction along the island shore to the eastern spit (Fig. 24), suggesting that the majority of sediment is sourced from erosion of the upland areas (i.e., between transects D and A; Fig. 11) and a west to east trend of sediment transport. A significant source of the fining, however, may be related to the occurrence of an eroding submerged marsh headland at transect B which may provide fine sediments to the shoreline. The eastern spit stretches farther than the western spit as well, which suggests dominant eastward sediment transport, which is consistent with the long fetch to the west. Greater wave energy from the west to southwest results in greater

eastward sediment transport. The side scan sonar (Fig. 14) also shows an increase in finer sediments to the east of the island in March of 2024, shown by the dark coloring on the mosaic suggesting sediment transport in that direction.

The average mean, median, and mode for each region separated by year can be found in Table 5 below. The western spit experienced a decrease in mean, median, and modal grain size from 2021 to 2023/2024, and then an increase from 2023/2024 to the end of 2024. The eastern spit experienced an increase in mean and median grain size from 2021 to the end of 2024 but showed a decrease in the modal grain size from 2023/2024 to the end of 2024. The marsh area, including the oyster reef, beach, and marsh, experienced an increase in mean, median, and modal grain size from 2021 to the end of 2024. The southwest experienced an increase in mean and median grain size from 2021 to the end of 2024 but showed a decrease in the modal grain size from 2023/2024 to the end of 2024. The southeast experienced an overall decrease in mean, median, and modal grain size from 2021 to the end of 2024.

Table 5: Table illustrating the mean statistics for each region of the study area by year.

Region	Western Spit	Eastern Spit	Marsh	Island Shore	South West	South East	South of ICW
Year	Mean (ϕ)						
2021	1.8-1.89	1.57-2.69	-	1.45-2.0	-	-	-
2023/2024	1.86-2.39	1.47-2.75	1.3-1.53	1.46-3.01	0.24-1.83	1.1-1.89	2.05-2.35
2024	1.26-2.52	0.93-2.34	1.35-2.17	1.33-2.94	1.54	0.45-1.81	-
	Median (ϕ)						
2021	1.8-1.89	1.62-2.73	-	1.49-1.97	-	-	-
2023/2024	1.77-2.37	1.41-2.81	1.26-1.53	1.46-3.06	1.02-1.91	1.47-1.83	2.01-2.35
2024	1.23-2.64	1.29-2.63	1.31-2.05	1.3-2.92	1.60	1.17-1.8	-
	Mode (ϕ)						
2021	1.75	1.75-2.74	-	1.75	-	-	-
2023/2024	1.75-3.24	1.25-2.74	1.25-1.75	1.25-3.24	1.75-2.24	1.75-2.24	2.24
2024	1.25-3.24	1.25-2.74	1.25-3.24	1.25-3.25	1.75	-2.24-1.75	-
	Skewness						
2021	-0.43-0.02	-1.05-(-0.43)	-	-0.72-(-0.14)	-	-	-
2023/2024	0.02-0.15	-0.26-0.13	0.01-0.16	-0.52-0.001	-0.52-(-3.6)	-0.38-0.14	-0.04-(-0.03)
2024	-0.05-0.05	-0.66-(-0.02)	-0.14-0.16	-0.34-0.11	-0.29	-0.42-0.03	-

The environment of Sugarloaf Island has experienced a coarsening of grain size and poorer sorting in some areas and a fining of grain size and better sorting in others between round 1 and round 2. Coarsening sediments can indicate increasing environmental (i.e., hydraulic) energy. However, the coarsening trend on the island (beach and nearshore samples) could be due to the installation of the WADs, as they prevent onshore transport of fine sediments. When observing individual sample locations on the island, there are sites that experienced a fining of sediments, instead of a coarsening. These locations reside on the western spit of the island. This area is entirely enclosed with WADs and an oyster reef. In this area, the sediment fining is likely due to the lower energy present in these environments, as a result of the wave attenuation by the WADs. Fine grain sediments may move shoreward from the south or the west. Most of the beach and nearshore sites appear coarse; however, the area around sites 12 and 13 and offshore site 7 have more fines from the eroding marsh headland (Fig. 25). This is evident based on the

occurrence of lower backscatter data (darker shades) in these sample areas as shown on the side scan sonar mosaic (Fig. 14). It is possible that cutting off that supply is what made the east end coarsen the most dramatically. The ripple bedforms identified by the side scan sonar (Fig. 16) are all in a southwest to northeast orientation, this supports the hypothesis of south to north onshore transport of sediment.

The eastern spit showed a coarsening in grain size on the beach and remained fine grained nearshore. The Marsh environment remained at a medium grain size between rounds of sampling. The beach and nearshore samples from transects B and D (Fig. 25B) do not experience a change in grain size between rounds 1 and 2, with the island shore samples becoming coarser. The beach sample from Transect A shows a fining in grain size (1.6ϕ to 2.2ϕ) with the shoreline and nearshore sample remaining the same. Figure 26 shows the negative relationship between mean grain size (ϕ) and sorting level (ϕ) in the second round of sampling, meaning that as the mean grain size gets coarser, the sorting gets worse. This supports the hypothesis that the WADs are cutting off the finer sediments from offshore and reducing the incoming wave energy. Additionally, figure 27 shows significant change between the rounds of sampling when comparing the skewness (ϕ) and sorting (ϕ), and the skewness (ϕ) and mean grain size (ϕ). When observing the skewness vs. mean (Fig. 27A), there is a stronger correlation for the round 1 samples, with a r-squared value of 0.467. However, the correlation is no longer present for the round 2 samples, which had a r-squared value of 0.027. It is also clear that there is no good correlation for sorting vs. skewness in either round 1 or 2.

The sediments both on and around Sugarloaf Island exhibit a wide range of sorting. In 2021 the overall mean sediment sorting number from the sample locations resampled in 2024 was 0.75ϕ , the resampled sites had a sorting number of 0.6ϕ showing an improvement in

sorting between 2021 and 2024. In 2023 and early 2024 it was 0.67 ϕ , and at the end of 2024 it was 0.95 ϕ . After the installation of the shoreline restoration project, nearly all beach and nearshore sites (behind the WADs) on the east end of the island maintained the same degree of sorting or worse sorting, whereas the sites west of the island and offshore of the island showed no change or some degree of improvement (Fig. 23). The changes in sorting occurred in both the coarse and fine fractions of sediment samples. This is likely due to the installation of the WADs around the island. The attenuation of wave energy allows for less sorting to take place behind the WADs, where the offshore sample sites outside of the WADs still experience the wave energy necessary to efficiently sort the sediments.

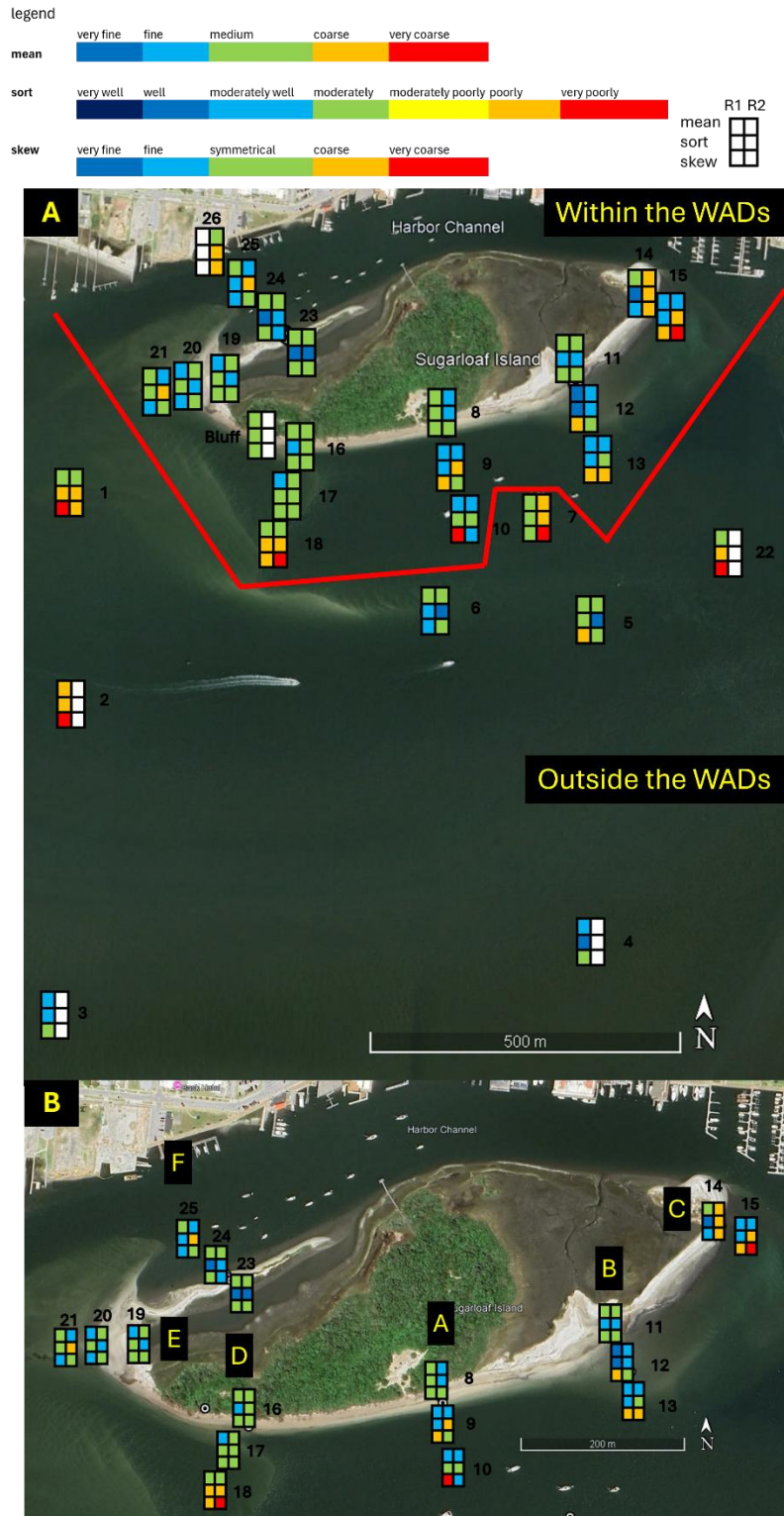


Figure 25. A) Map of the average mean grain size, average sorting, and average skewness for the Sugarloaf Island samples for the round one samples (R1) and the round two samples (R2). White correlates to samples without a round 2 sample. B) Close up map of the samples within the confines of the WADs. Letters correspond to the sample transects.

Sugarloaf Island also experienced a range of skewness changes between round 1 and round 2 (Fig. 25). The west and east spits of the island as well as the marsh environment show symmetrical or coarsening skewness between the sampling rounds. For the eastern spit, both sample sites show coarsening skewness, while the western spit shows more varied changes. Transect E (Fig. 25B) comprises a beach sample that remained symmetrical between rounds, followed by the remaining shoreline and nearshore samples that coarsened between rounds. Transect F (Fig. 25B) comprises a back marsh sample that remained symmetrical between rounds, a beach sample that shows fining skewness values, and a nearshore sample that shows a coarsening in skewness values. The samples on the southern island shore environment show a range of fining and coarsening skewness values from round 1 to round 2. Transects A and B (Fig. 25B) show the same level of skewness or a fining trend from round 1 to round 2. Transect D (Fig. 25B), however, shows symmetrical skewness values except for the offshore sample, which shows a coarsening in skewness values. During the second round of sampling, this sample was taken from right behind to the WADs, which could explain its coarsening while the other samples along the island shore show the same or fining skewness values. There are not any clear patterns to changes in skewness, but according to McLaren (1981) a fine skewness suggests selective deposition whereas a coarse skewness suggests rapid deposition of sediment from suspension.

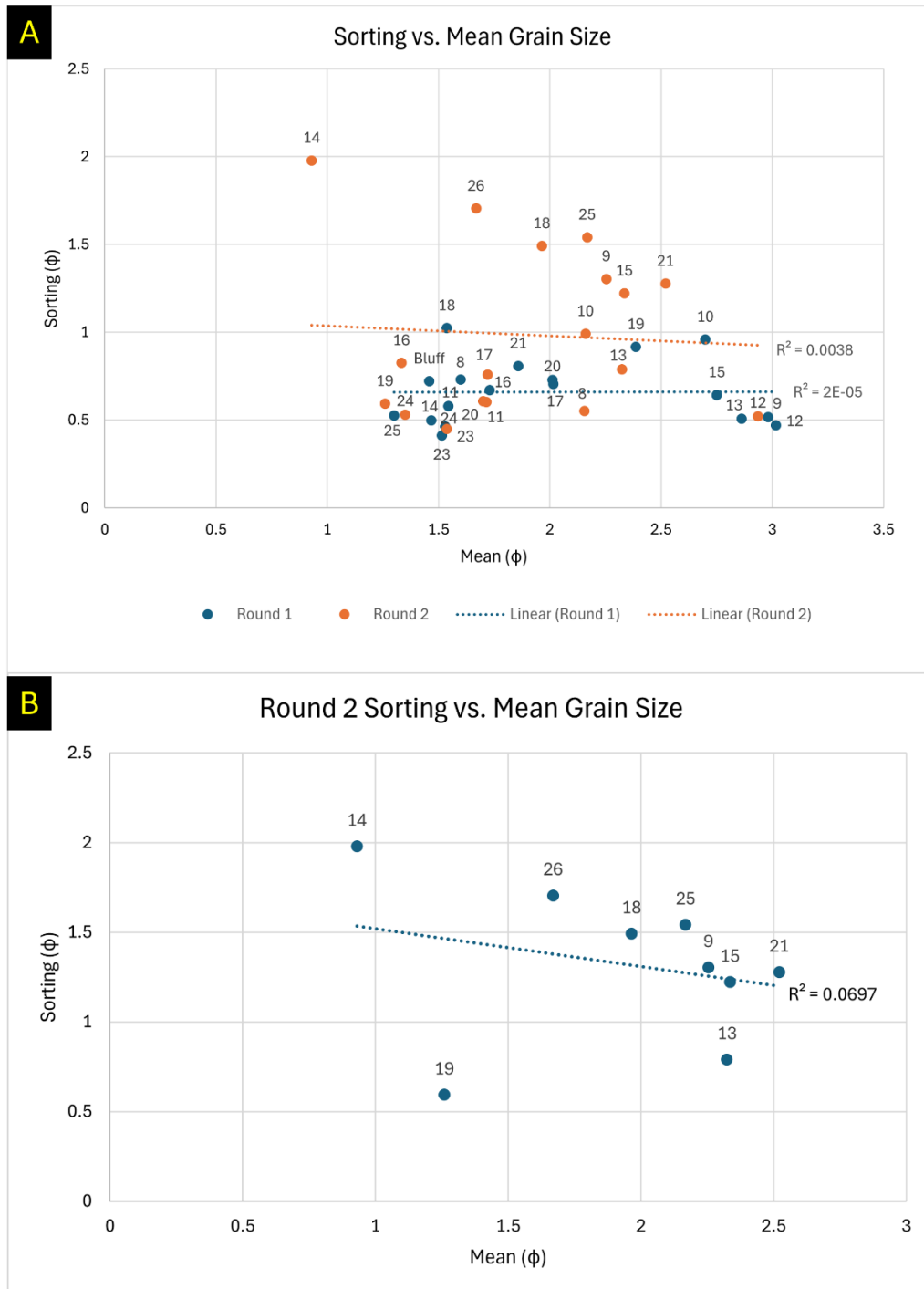


Figure 26. A) Scatter plot showing the correlation between the mean grain size in phi and the sorting values in phi of the beach and nearshore samples in round 1 and 2 of sampling. B) Scatter plot between the mean grain size in phi and the sorting values in phi of the beach and nearshore samples in round 2 of sampling that changed the most significantly. Made using Excel, 2025.

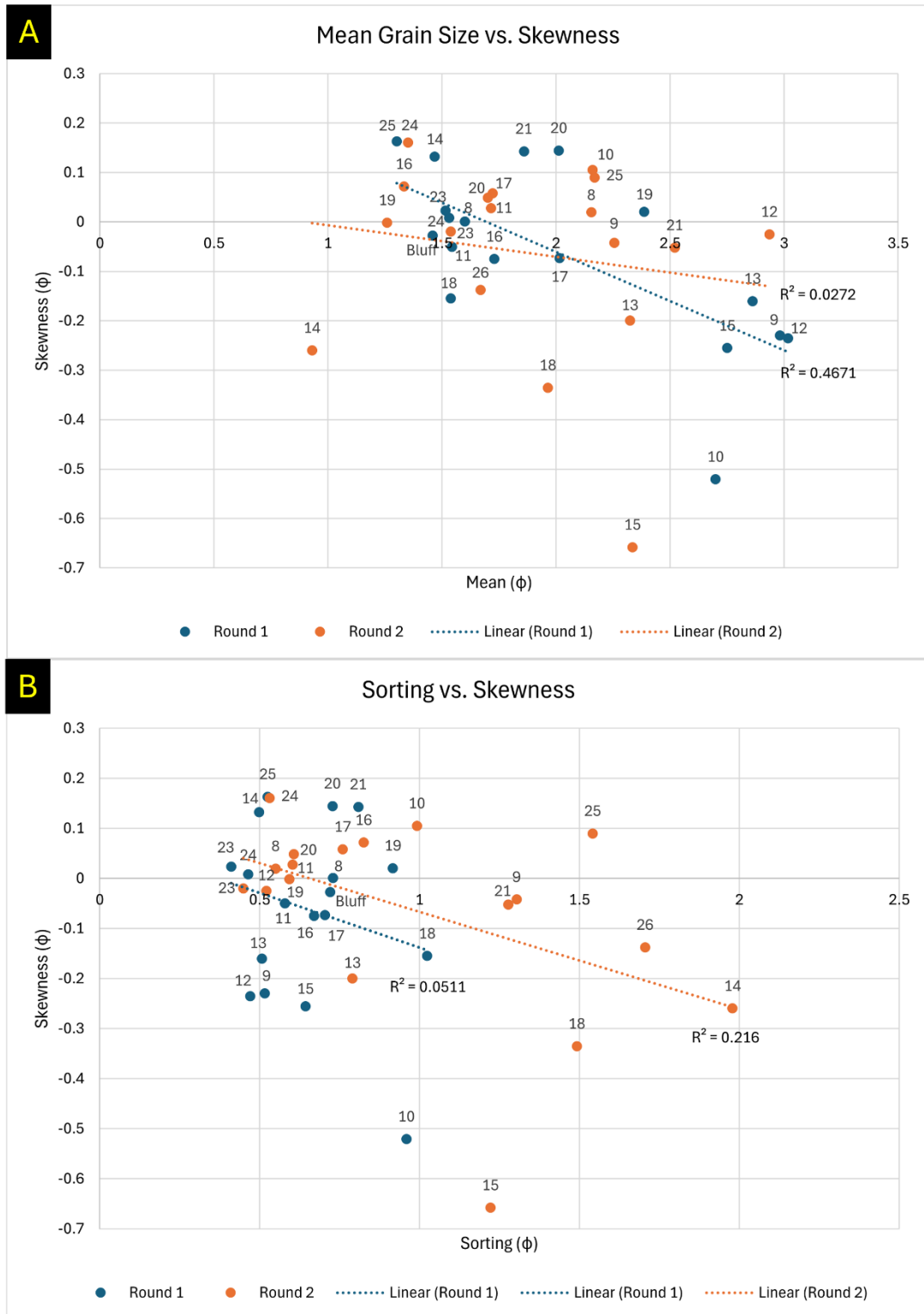


Figure 27. A) Scatter plot showing the correlation between the mean grain size in phi and the skewness in phi of the beach and nearshore samples in round 1 and round 2 of sampling. B) Scatter plot showing the correlation between the sorting values in phi and the skewness in phi of the beach and nearshore samples in round 1 and round 2 of sampling. Made using Excel, 2025.

4.2 Foraminifera

Within the modern dead foraminifera (Fig. 20), the most abundant species are *Elphidium excavatum* and *Ammonia parkinsoniana*. There is not much change in biofacies between round 1 and round 2 (pre-WAD emplacement and post-WAD emplacement, respectively). There are only six samples that experienced a shift in biofacies, and they differ in their location on and around Sugarloaf Island (Fig. 20). The locations were SLI-1, SLI-7, SLI-11, SLI-15, SLI-17, and SLI-20. Additionally, every location was Biofacies B during round 1, and experienced a shift to Biofacies A and C. The three beach and nearshore samples and to the west experienced a shift from Biofacies B to Biofacies A, and the three samples offshore and on the eastern spit of the island experienced a shift from Biofacies B to Biofacies C. The decrease in species richness of foraminifera on Sugarloaf Island is likely due to the decrease in onshore transport caused by the implementation of the WADs. The marsh environment also exhibits less species richness due to its enclosed nature and limited circulation, as it is a lagoon environment. Samples SLI-11, SLI-17, and SLI-20 shifted from Biofacies B to A (Fig. 20) due to a higher percentage of *Ammonia parkinsoniana*.

Within the live foraminifera (Fig. 21) the most abundant species is *Ammonia parkinsoniana* for Biofacies 1 and 2 (Table 3). Between round 1 and round 2, there is much more change exhibited than in the modern dead foraminifera analysis. The most notable difference is the abundant species of Biofacies 2, which has the highest abundance of *Ammonia parkinsoniana* (84.9%; Table 3). The sample sites southeast of the island shift primarily from Biofacies 1 to Biofacies 2 from round 1 to round 2, meaning that in that area there was an increase in *Ammonia parkinsoniana*.

Trochammina "squamata," Rosalina floridana, Quinqueloculina impressa, Ammonia tepida, Tritaxis fusca, and *Elphidium mexicanum* have relative abundances of 1% or greater in Biofacies 1. *Elphidium gunteri, Elphidium excavatum,* and *Tritaxis fusca* have relative abundances of 1% or greater in Biofacies 2. *Tritaxis fusca* has a relative abundance of 1% or greater in Biofacies 3.

Within the total live and modern dead foraminifera, the most abundant species are, once again, *Elphidium excavatum* (31.3%-66.5%) and *Ammonia parkinsoniana* (17.95%-61.24%; Table 4). This analysis exhibits less change than the live foraminifera, and more than the modern dead foraminifera, because it is a combination of the two analyses. The samples southeast of the island do not experience any change from round 1 to round 2. Three samples on the island shore experience a shift to Biofacies b, with one shifting to Biofacies a and another to Biofacies c (Fig. 22).

Elphidium gunteri, and *Elphidium mexicanum* have relative abundance of 1% or greater in Biofacies a. *Elphidium mexicanum, Ammonia tepida.,* and *Hanzawaia strattoni* have relative abundance of 1% or greater in Biofacies b. *Hanzawaia strattoni, Quinqueloculina seminula, Elphidium mexicanum, Quinqueloculina lamarkiana,* and *Cibicides lobatulus* have relative abundance of 1% or greater in Biofacies c. Biofacies a appears to have the least diversity within the species (Table 4) and the sites that make up Biofacies a reside in the marsh and western spit regions of the island (Fig. 22). Overall, these cluster analyses do not provide enough information to draw meaningful conclusions about the erosional patterns of Sugarloaf Island, as there is not much change in biofacies in the modern dead analysis, and the live foraminifera data are too sparse and patchy to show any patterns.

The foraminifera in the marsh exhibit the highest concentration of live specimens, likely due to the enclosed nature of the marsh habitat. Lower numbers of live foraminifera in round 1 was likely due to the time of sampling (mid-winter) when reproduction is reduced or paused. The second round of samples exhibited a lower percentage of fossilized foraminifera (Fig. 28), with the first round of data exhibiting 7.40% percent of fossilized forams and the second round exhibiting 2.64%. This could be a result of lessened sediment transport from Bogue Sound. This seems to be a direct result of the implementation of stabilization structures, particularly the WADs which directly block the island from incoming waves and sediment. This is consistent with the increase in sorting values and an increase in grain size for the sediments which also suggest a decrease in both wave energy and sediment flux of finer sediment from offshore.

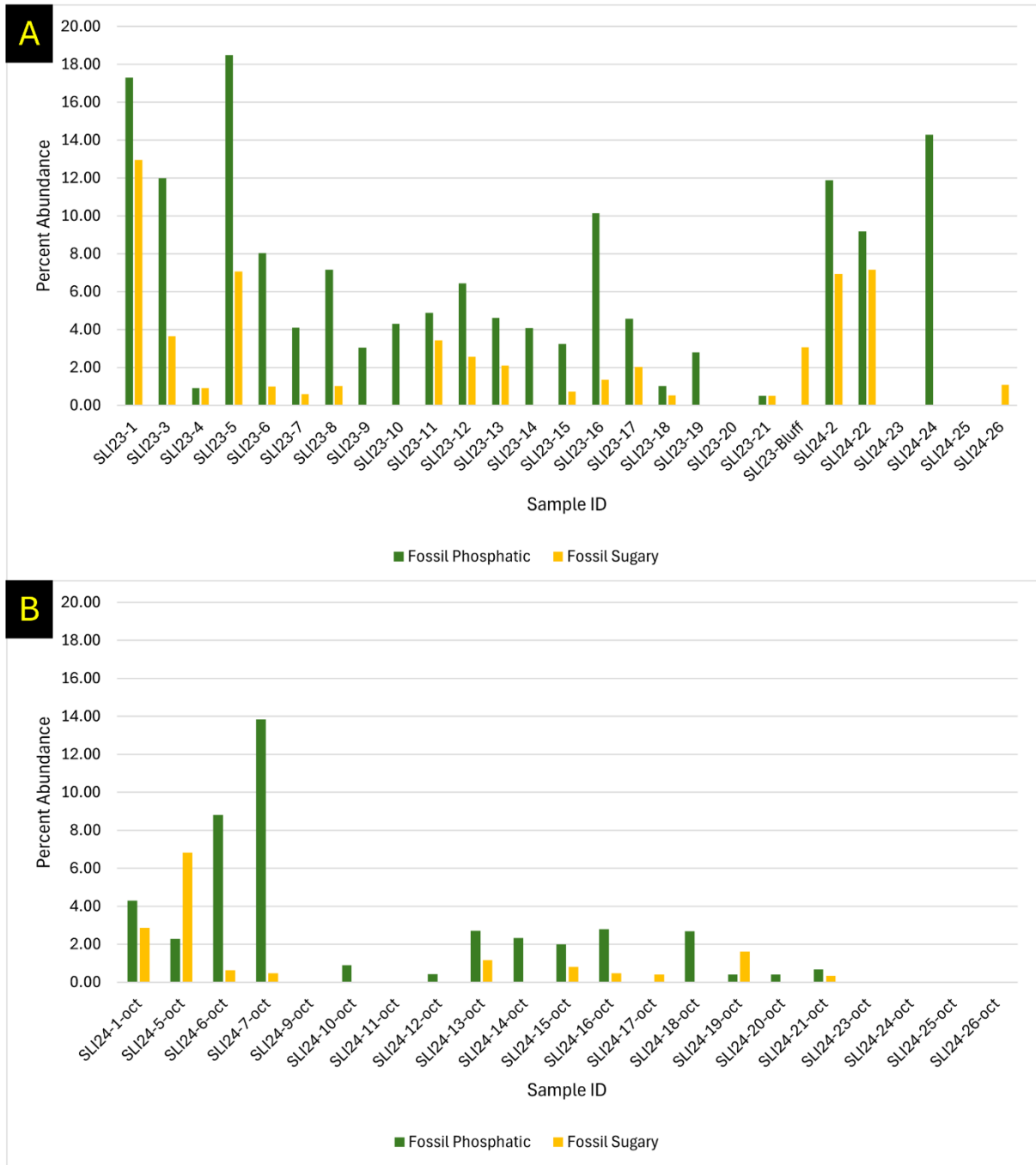


Figure 28. A) Bar graph illustrating the percentages of fossilized phosphatic and fossilized sugary of the first round of samples. B) Bar graph illustrating the percentages of fossilized phosphatic and fossilized sugary of the second round of samples. Made using Excel, 2025.

4.3 Storm impacts

Although the data suggest that changes have occurred to the sediments as a result of wave attenuation and disruption of onshore sediment transport, it is possible that storminess may have influenced the sites as well. Since the beginning of this study (2021) there have been only two significant storm events that have impacted the Bogue Banks, NC area. Hurricane Elsa, which occurred in July of 2021, caused sustained winds of 43 kt and a gust to 50 kt from July 8 to July 9, 2021, southeast of Cape Fear, NC, south of Sugarloaf Island, and 3-6 inches of rainfall in the state of NC (Cangialosi et al., 2022). Following Elsa, Tropical Storm Ophelia, which occurred in September of 2023, made landfall near Emerald Isle, NC which is slightly west of Sugarloaf Island, and caused significant levels of wind, rain, and storm surge. It was estimated to have a wind speed of 60 kt at the time it contacted Emerald Isle, NC, before slowing as it moved farther inland (Brown et al., 2024). Overall, Ophelia produced around 3 to 5 inches of rain across eastern North Carolina, and southeastern and central. At the center of the storm, 5 to 7 inches of rain was produced, with a maximum rainfall of 8 to 9.5 inches over southeastern North Carolina (Brown et al., 2024). The storm surge was measured at 0.9 to 1.5 meters above ground level, and it occurred along the Pamlico and Neuse Rivers, as well as the Pamlico Sound (Brown et al., 2024).

These storm events may explain the coarsening sediments between the 2021 and late 2023/early 2024 samples, as storm events tend to lead to coarser sediment particles (Lui et al., 2019). These two storms took place between the 2021 and the December 2023 sampling trips, however, so they are likely not responsible for the worsening sorting and coarsening grain size observed between December 2023 and October 2024 samples. There was, however, a nor'easter that impacted Morehead City, NC on December 17 and 18, 2023. This storm brought winds of

around 38 kt, 2 to 3 inches of rain, and coastal flooding to eastern North Carolina (National Weather Service, 2023). There was also a cold front that caused multiple severe thunderstorms with winds as high as 87 kt, resulting in multiple tornadoes in the Morehead City, NC area on January 9 to 10 of 2024 (National Weather Service, 2024).

5.0 Conclusion

This study aimed to identify the sediment transport and erosional patterns of Sugarloaf Island and evaluate the impact of installed shoreline stabilization methods, specifically Wave Attenuation Devices (WADs) and oyster reefs, by analyzing changes in foraminifera species distribution, grain size characteristics, and seafloor morphology.

This study also suggested differential impacts; while beach and nearshore showed worse or maintained sorting values, coarsening mean grain size, and coarsening or symmetrical skewness values, offshore sites outside the WADs either showed no change or some improvement in sorting, suggesting that these areas still experience the necessary wave energy for efficient sediment sorting. Since the beginning of the study in 2021, the overall mean sediment sorting on and around Sugarloaf Island has consistently worsened, with sorting numbers increasing from 0.70 ϕ in 2021 to 0.93 ϕ at the end of 2024. This worsening sorting is likely a direct consequence of the WADs being installed, as they reduce the wave energy reaching the island, and wave energy is crucial for efficiently sorting sediments. The overall skewness values on and around the island became more symmetrical between rounds 1 and 2, except for the eastern spit and the southeast environment offshore, which experienced a coarsening skewness level. The mean grain size on and around the island became coarser, except for the marsh and southwest environment offshore.

The coarsening of sediments, post-WAD emplacement, around the island may be a result of the WADs blocking onshore transport of fine sediments from the eroding marsh headland. This process is likely what caused the east end of the island to experience the highest values of coarsening.

The key findings regarding foraminiferal assemblage include conclusions about the dominant species in the study area. Across both sampling rounds (pre- and post-WAD emplacement), *Elphidium excavatum* and *Ammonia parkinsoniana* remained the most abundant modern dead and live foraminiferal species. There is also a limited change in the modern dead foraminifera between round 1 and round 2. The analysis of modern dead foraminifera showed minimal changes in species abundance between sampling rounds, with only six samples experiencing a shift in biofacies, primarily in areas directly around the island, Biofacies A (marsh and western spit) had the lowest species richness, while Biofacies C (farther offshore) exhibited the highest species richness.

Live foraminiferal assemblages exhibited greater variability between sampling rounds compared to modern dead assemblages. Many beach and nearshore locations shifted to Biofacies 2, indicating an increase in *Ammonia parkinsoniana* and a lower level of species richness, which could be attributed to the WADs successfully protecting the shore from external influence. Conversely, some offshore sites shifted to Biofacies 3, showing a complete loss of *Ammonia parkinsoniana* in those areas. Biofacies 1 notably exhibited the lowest level of variety and diversity among the foraminifera species.

This study indicates that the marsh region of Sugarloaf Island exhibited the highest concentration of live foraminifera specimens, likely due to its enclosed nature and longer sediment retention, which supports the survival of these organisms. Additionally, there is a reduced number of fossilized foraminifera found in round 2 as opposed to round 1. This is interpreted as a direct result of the stabilization structures, particularly the WADs, which likely lessened sediment transport from Bogue Sound by attenuating incoming wave energy.

In conclusion, the study utilized grain size analysis and foraminiferal analysis to assess the initial impact of the shoreline stabilization structures on Sugarloaf Island. The results indicate that the newly installed WADs and other structures are indeed influencing the island's environment, leading to changes in sediment sorting, grain size, and foraminiferal distribution, which provide clarity on how the environment has evolved over time.

Overall, more sampling is required to determine the impact of the shoreline stabilization structures. As of now (2025) the structures have only been in place for about six months, so the environment will need more time to adjust to these new variables. I propose additional sampling and side scan sonar surveys at the same locations after a year of the structures being installed, and again additional years after. This will give a more complete picture of the evolution of Sugarloaf Island and help to evaluate how successful the structures are at keeping the island from eroding away.

6.0 References

- Abbene, I.J., Culver, S.J., Corbett, D.R., Buzas, M.A., and Tully, L.S., 2006, Distribution of Foraminifera in Pamlico Sound, North Carolina, Over the Past Century: *Journal of Foraminiferal Research*, v. 36, p. 135–151.
- Anderson, C., Carter, G., and Funderburk, W., 2016, The Use of Aerial RGB Imagery and LIDAR in Comparing Ecological Habitats and Geomorphic Features on a Natural versus Man-Made Barrier Island: *Remote Sensing*, v. 8, p. 602.
- Andersen, H. 1952. “Buccella, a New Genus of the Rotaliid Foraminifera.” *Journal of the Washington Academy of Sciences*, 42, 5, 143–51.
- Blott, S.J., and Pye, K., 2001, GRADISTAT: A Grain Size Distribution and Statistics Package for The Analysis of Unconsolidated Sediments: *Earth Surface Processes and Landforms*, v. 26, p. 1237–1248.
- Boltovskoy, E., and Wright, R.C., 1976, Recent Foraminifera. Netherlands, Springer Netherlands, p. 1-515.
- Brown, C.W., 2020, The Effects of Hurricanes on the Sedimentologic and Foraminiferal Characteristics of Barrier Island: Department of Geological Sciences, East Carolina University, v. 1, p. 1–55.
- Brown, D.P., Hagen, A., and Alaka L., 2024, Tropical Storm Ophelia: National Hurricane Center Tropical Cyclone Report, NOAA, p. 1-70.
- Burone, L., Venturini, N., Sprechmann, P., Valente, P., And Muniz, P., 2006, Foraminiferal responses to polluted sediments in the Montevideo coastal zone, Uruguay: *Marine Pollution Bulletin*, v. 52, p. 61–73.
- Buzas, M.A., and Culver, S.J., 1991, Species Diversity and Dispersal of Benthic Foraminifera: *BioScience*, v. 41, p. 483–489.
- Buzas, M., Culver, S., Isham, L. 1985. A Comparison of fourteen Elphidid (foraminifera) taxa. *Journal of Paleontology*.

- Cangialosi, J.P., Delgado, S., and Berg, R., 2022, Hurricane Elsa: National Hurricane Center Tropical Cyclone Report, NOAA, p. 1-70.
- Conery, I., Walsh, J.P., Mallinson, D., and Corbett, D.R., 2022, Marine Geology and Sand Resources of the Southern North Carolina Inner Shelf: Marine Georesources & Geotechnology, v. 40, p. 1084–1107.
- Culver, S.J., Ames, D.V., Corbett, D.R., Mallinson, D.J., Riggs, S.R., Smith, G., and Vance, D.J., 2006, Foraminiferal and Sedimentary Record of Late Holocene Barrier Island Evolution, Pea Island, North Carolina: The Role of Storm Overwash, Inlet Processes, and Anthropogenic Modification: *Journal of Coastal Research*, v. 22, p. 836–846.
- Culver, S.J., Mallinson, D.J., Corbett, D.R., Leorri, E., Rouf, A.A., Shazili, N.A.M., Yaacob, R., Whittaker, J.E., Buzas, M.A., and Parham, P.R., 2012, Distribution of Foraminifera in the Setiu Estuary and Lagoon, Terengganu, Malaysia: *The Journal of Foraminiferal Research*, v. 42, p. 109–133.
- Culver, S.J., Twarog, M., Mallinson, D.J., Shazili, N.A.M., and Buzas, M.A., 2019, Rapid Change of Foraminiferal Communities and Assemblages in the Setiu Estuary, Terengganu, Malaysia: Anthropogenic Drivers: *Journal of Foraminiferal Research*, v. 49, p. 206–228.
- Culver, S.J., Mallinson, D.J., Allen, C., Brown, C., Shmorhun, N.M.-E., and Buzas, M.A., 2025, The Effects of Two Recent Hurricanes on Foraminiferal Assemblages and Sediments of a Wave-Dominated, Microtidal Barrier-Island System, North Carolina, USA: *Palaios*, v. 40, p. 35–61.
- Currin, C.A., Chappell, W.S., and Deaton, A., 2010, Developing alternative shoreline armoring strategies: The living shoreline approach in North Carolina, in Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, *Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009*: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 91-102.
- Davis, J.L.D., Takacs, R.L. Takacs, and Schnabel, R., 2006. Evaluating ecological impacts of living shorelines and shoreline habitat elements: an example from the upper western

- Chesapeake Bay: Management, Policy, Science, and Engineering of Nonstructural Erosion Control in Chesapeake Bay, no. 08-164, p. 1-136.
- Edwards, A.C., 2001, Grain Size and Sorting in Modern Beach Sands: *Journal of Coastal Research*, v. 17, p. 38–52.
- Ellis, A.M., Culver, S.J., Mallinson, D.J., Corbett, D.R., Leorri, E., Buzas, M.A., and Shazili, N.A.M., 2014, The Influence of Aquaculture on Modern Foraminifera and Sediments in The Setiu Estuary and Lagoon, Terengganu, Malaysia: A Spatial Investigation: *The Journal of Foraminiferal Research*, v. 44, p. 390–415.
- Feagin, R.A., Smith, W.K., Psuty, N.P., Young, D.R., Martínez, M.L., Carter, G.A., Lucas, K.L., Gibeaut, J.C., Gemma, J.N., and Koske, R.E., 2010, Barrier Islands: Coupling Anthropogenic Stability with Ecological Sustainability: *Journal of Coastal Research*, v. 26, p. 987–992.
- Folk RL, Ward WC. 1957. Brazos River bar: a study in the significance of grain size parameters. *Journal of Sedimentary Petrology* 27: 3–26.
- Grabowski, R.C., Droppo, I.G., and Wharton, G., 2011, Erodibility of cohesive sediment: The importance of sediment properties: *Earth-Science Reviews*, v. 105, p. 101–120.
- Grand Pre, C.A., 2006. Holocene paleoenvironmental change in Pamlico Sound, North Carolina: foraminiferal and stable isotopic evidence. Unpublished Master's Thesis, East Carolina University, Greenville, North Carolina. Action in Bogue Sound, North Carolina, USA: P.S.Z.N.1: Marine Ecology, v. 2, p. 245–270.
- Grossman, S., and Benson, R.H., 1967, Part 1 Living and Subfossil Rhizopod and Ostracode Populations: *Paleontological institute*, v. 1, p. 1–90.
- Hagerman, G.M. Jr., and Rieger, R.M., 1981, Dispersal of Benthic Meiofauna by Wave and Current
- Jackson, N.L. 1995. Wind and waves: influence of local and non-local ocean waves on meso-scale beach behavior in estuarine environments. *Annals of the Association of American Geographers*, 85, 21 37.

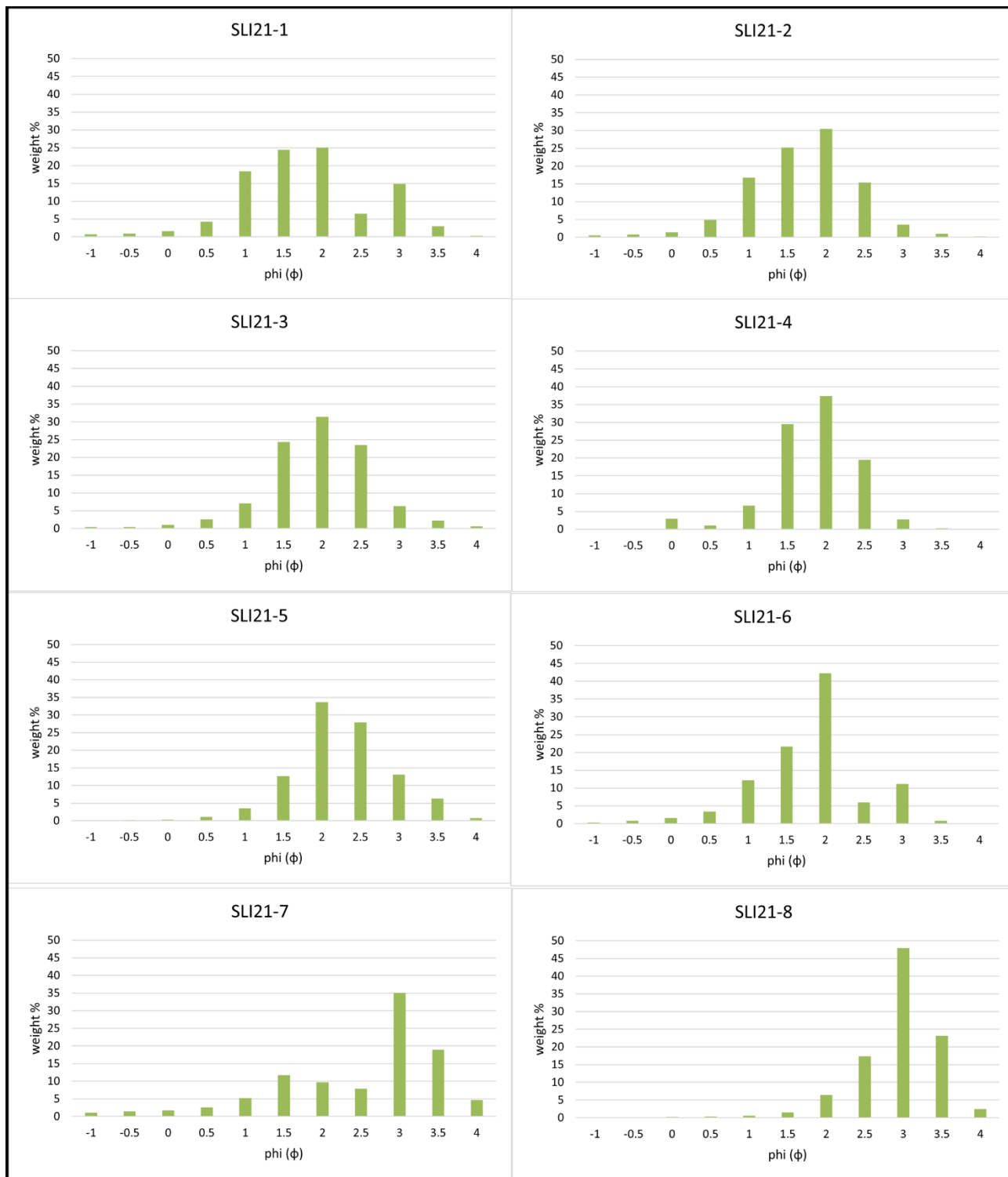
- Kana, T.W., White, T.E., Forman, Jr., J.W., and McKee, P.A., 2002, Shoreline Erosion along Bogue Banks, North Carolina, *in* Solutions to Coastal Disasters '02, San Diego, California, United States, American Society of Civil Engineers, p. 561–575.
- Kemp, A.C., Horton, B.P., and Culver, S.J., 2009, Distribution of modern salt-marsh foraminifera in the Albemarle–Pamlico estuarine system of North Carolina, USA: Implications for sea-level research: *Marine Micropaleontology*, v. 72, p. 222–238.
- Koiter, A.J., Owens, P.N., Petticrew, E.L., and Lobb, D.A., 2013, The behavioural characteristics of sediment properties and their implications for sediment fingerprinting as an approach for identifying sediment sources in river basins: *Earth-Science Reviews*, v. 125, p. 24–42.
- Lazar, K.B., 2016, Late Quaternary development of the Croatan Beach Ridge Complex, Bogue Sound, Bogue Banks, NC, USA and implications for coastal evolution: *Estuarine, Coastal and Shelf Science*, v. 174, p. 49–64.
- Lewis, D.A.; Cooper, J.A.G.; Pilkey, O.H. Fetch-limited barrier islands of Chesapeake Bay and Delaware Bay USA. *Southeast. Geol.* 2005, v. 44, pg. 1–17.
- Lewis, D.A., Cooper, J.A.G., Pilkey, O.H., and Short, A.D., 2007, Fetch-Limited Barrier Islands of Spencer Gulf, South Australia: *Journal of Coastal Research*, v. 50, p. 1-17.
- Liu, Y., Huang, H., Liu, X., Yan, L., Zhang, Z., Zhang, Y., and Song, Z., 2019, Response of seafloor sediment composition to a strong storm event in the inner-shelf of Heini Bay, China: *Continental Shelf Research*, v. 175, p. 1–11.
- Luijendijk, A., Hagenaars, G., Ranasinghe, R., Baart, F., Donchyts, G., and Aarninkhof, S., 2018, The State of the World's Beaches: *Scientific Reports*, v. 8, p. 295–315.
- McLaren, P., 1981, An Interpretation of Trends in Grain Size Measures: *Journal of Sedimentary Petrology*, v. 51, p. 611–624.
- Meyer, D.L., Townsend, E.C., and Thayer, G.W., 1997, Stabilization and Erosion Control Value of Oyster Cultch for Intertidal Marsh: *Restoration Ecology*, v. 5, p. 93–99.

- Munsterman, D., and Kerstholt, S., 1996, Sodium polytungstate, a new non-toxic alternative to bromoform in heavy liquid separation: Review of Palaeobotany and Palynology, v. 91, p. 417–422.
- Murray, A.B., and Thiel, E.R., 2004, A new hypothesis and exploratory model for the formation of large-scale inner-shelf sediment sorting and “rippled scour depressions”: Continental Shelf Research, v. 24, p. 295–315.
- Murray, J.W., 2001, The niche of benthic foraminifera, critical thresholds and proxies: Marine Micropaleontology, v. 41, p. 1–7.
- Murray, J. 2006. Ecology and applications of benthic foraminifera. Cambridge University Press, Cambridge, 1–426.
- National Weather Service, 2023, [December Nor'easter 2023](#)
- National Weather Service, 2024, [January 9-10, 2024 Wind and Severe Weather](#)
- Piazza, B.P., Banks, P.D., and La Peyre, M.K., 2005, The Potential for Created Oyster Shell Reefs as a Sustainable Shoreline Protection Strategy in Louisiana: Restoration Ecology, v. 13, p. 499–506.
- Pilkey, O.H., Cooper, J.A.G., and Lewis, D.A., 2009, Global Distribution and Geomorphology of Fetch-Limited Barrier Islands: Journal of Coastal Research, v. 25, p. 819–837.
- Polk, M.A., and Eulie, D.O., 2018, Effectiveness of Living Shorelines as an Erosion Control Method in North Carolina: Estuaries and Coasts, v. 41, p. 2212–2222.
- Pruitt, R.J., Culver, S.J., Buzas, M.A., Corbett, D.R., Horton, B.P., and Mallinson, D.J., 2010, Modern Foraminiferal Distribution and Recent Environmental Change in Core Sound, North Carolina, USA: Journal of Foraminiferal Research, v. 40, p. 344–365.
- Schnitker, D., 1971, Distribution of Foraminifera on the North Carolina Continental Shelf: Tulane Studies in Geology and Paleontology, v. 8, p. 1–169.
- Scyphers, S.B., Powers, S.P., Heck, K.L., and Byron, D., 2011, Oyster Reefs as Natural Breakwaters Mitigate Shoreline Loss and Facilitate Fisheries (H. Browman, Ed.): PLoS ONE, v. 6, p. 1–12,

- Semeniuk, V., 1981, Long-term erosion of the tidal flats King Sound, north western Australia: *Marine Geology*, v. 43, p. 21–48.
- Sen Gupta, Barun, 2003, *Modern Foraminifera*, Springer Dordrecht, v. 1. p. 1-371.
- Shmorhun, N.M.-E., Culver, S.J., Mallinson, D.J., Farrell, K.M., Cressman, A., Grove, A., Howie, L., Lynn, A., Sutton, S., Twarog, M., Riggs, S.R., 2022, Characterizing Modern And Holocene Barrier-Island Environments With Foraminiferal Assemblages: An Example From A Wave-Dominated, Microtidal Barrier-Island System, North Carolina, USA: *PALAIOS*, v. 37, p. 443–470.
- Sirianni, H., Sirianni, M.J., Mallinson, D.J., Lindquist, N.L., Valdes-Weaver, L.M., Moody, M., Henry, B., Colli, C., Rubino, B., Peñalver, M.M., Henne, C., 2022, Quantifying Recent Storm-Induced Change on a Small Fetch-Limited Barrier Island along North Carolina’s Crystal Coast Using Aerial Imagery and LiDAR: *Coasts*, v. 2, p. 302–322.
- Thomas, E., Gapotchenko, T., Varekamp, J. C., Mecray, E. L., And Buchholtz Ten Brink, M. R., 2000, Benthic foraminifera and environmental changes in Long Island Sound: *Journal of Coastal Research*, v. 16, p. 641–655.
- Thornberg, H.M., Culver, S.J., Corbett, D.R., Mallinson, D.J., Buzas, M.A., and Shazili, N.A.M., 2014, The Influence of Aquaculture on Modern Foraminifera and Sediments in The Setiu Estuary and Lagoon, Terengganu, Malaysia: A Temporal Investigation: *The Journal of Foraminiferal Research*, v. 44, p. 365–389.
- Timmons, E.A., Rodriguez, A.B., Mattheus, C.R., and DeWitt, R., 2010, Transition of a regressive to a transgressive barrier island due to back-barrier erosion, increased storminess, and low sediment supply: Bogue Banks, North Carolina, USA: *Marine Geology*, v. 278, p. 100–114.
- Todd, R., and Low, D., 1982, Marine Flora and Fauna of The North-Eastern United States. Protozoa: Sarcodina: Benthic Foraminifera.: *The Journal of Foraminiferal Research*, v. 12, p. 90–90.

- Twarog, M.R. et al., 2021, Depositional environments and sequence stratigraphy of post-last glacial maximum incised valley-fill, Malay Basin, northern Sunda Shelf: *Marine Geology*, v. 436, p. 106457.
- United States Coast and Geodetic Survey. Coast Chart No. 147, Core Sound to Bogue Inlet Including Cape Lookout, North Carolina; United States Coast and Geodetic Survey: Washington, DC, USA, 1888.
- United States Environmental Protection Agency; United States Army Corps of Engineers. Morehead City Ocean Dredged Material Disposal Site (ODMDS) Site Management and Monitoring Plan; United States Environmental Protection Agency: Washington, DC, USA; Fort Belvoir, VA, USA, 2020.
- US Coast and Geodetic Survey, 1933. Chart 420, Beaufort Harbor, North Carolina
- Walton, W. R., 1952, Techniques for recognition of living foraminifera: Contributions from the Cushman Foundation for Foraminiferal Research, v. 3, p. 56–60.
- Woo, H. J., Culver, S. J., and Oertel, G. F., 1997, Benthic foraminiferal communities of a barrier-lagoon system, Virginia, U.S.A.: *Journal of Coastal Research*, v. 13, p. 1192–1200.
- Zaggia, L., Lorenzetti, G., Manfé, G., Scarpa, G.M., Molinaroli, E., Parnell, K.E., Rapaglia, J.P., Gionta, M., and Soomere, T., 2017, Fast shoreline erosion induced by ship wakes in a coastal lagoon: Field evidence and remote sensing analysis (J. M. Dias, Ed.): *PLOS ONE*, v. 12, p. 1-23.
- Zreik, D.A., Krishnappan, B.G., Germaine, J.T., Madsen, O.S., Ladd, C.C., 1998. Erosional and mechanical strengths of deposited cohesive sediments. *Journal of Hydraulic Engineering*, v. 124, p. 1076–1085.

Appendix A: Sediment Data



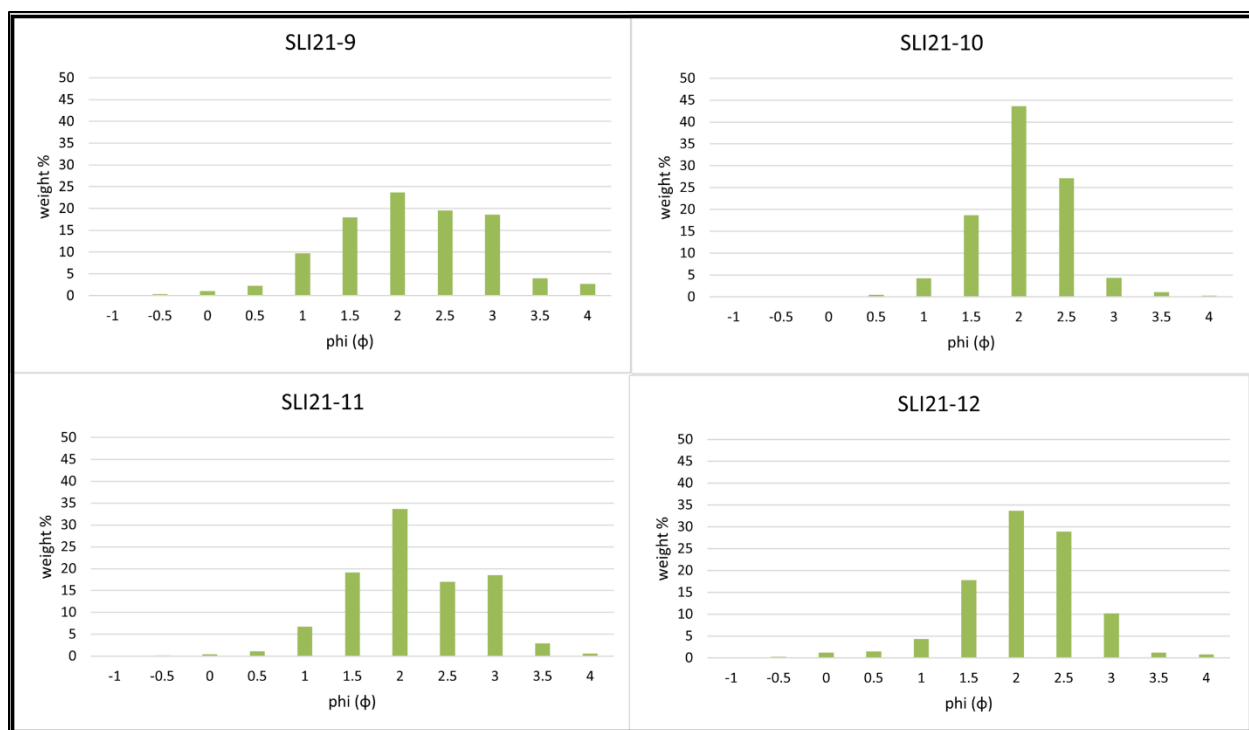
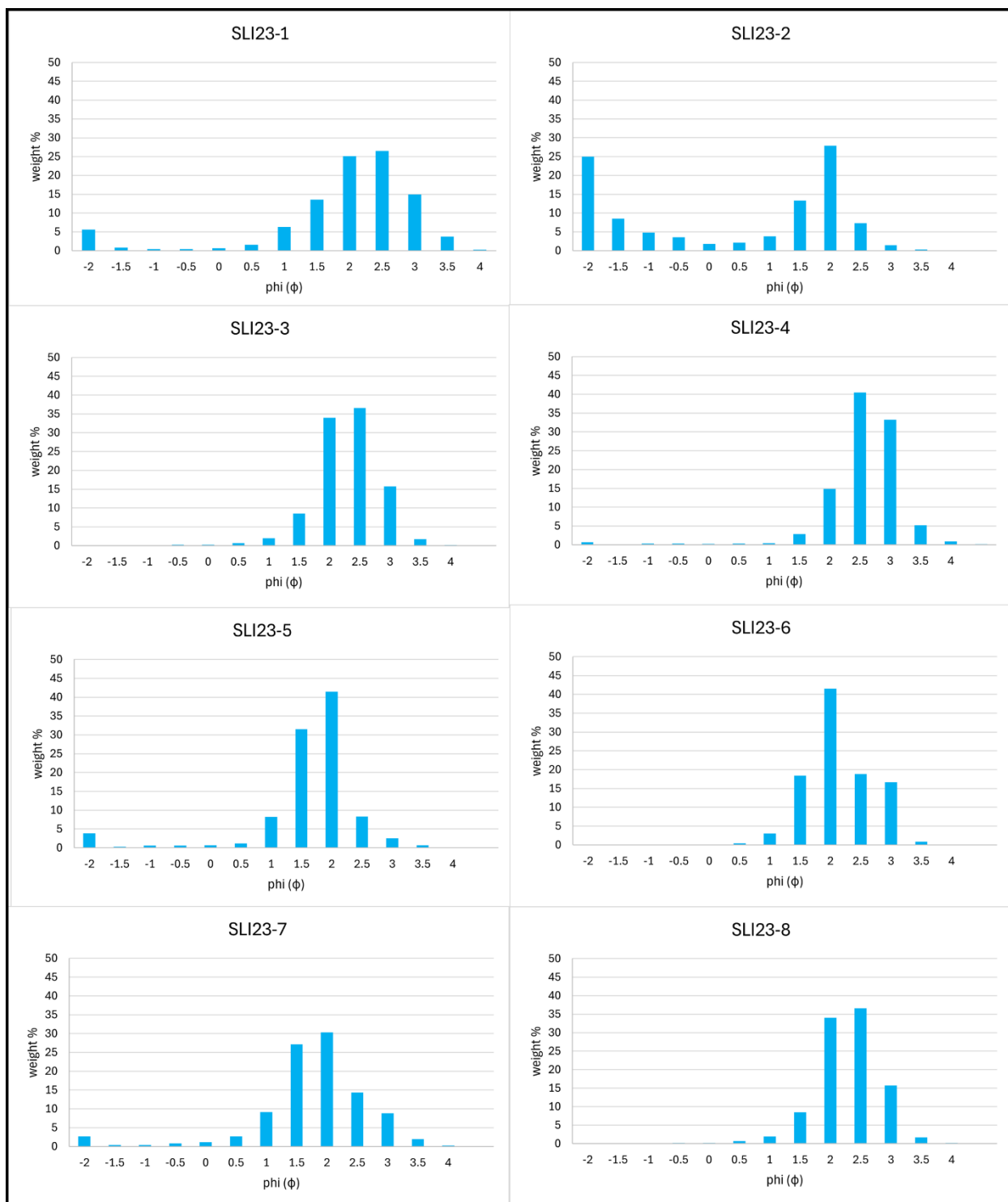
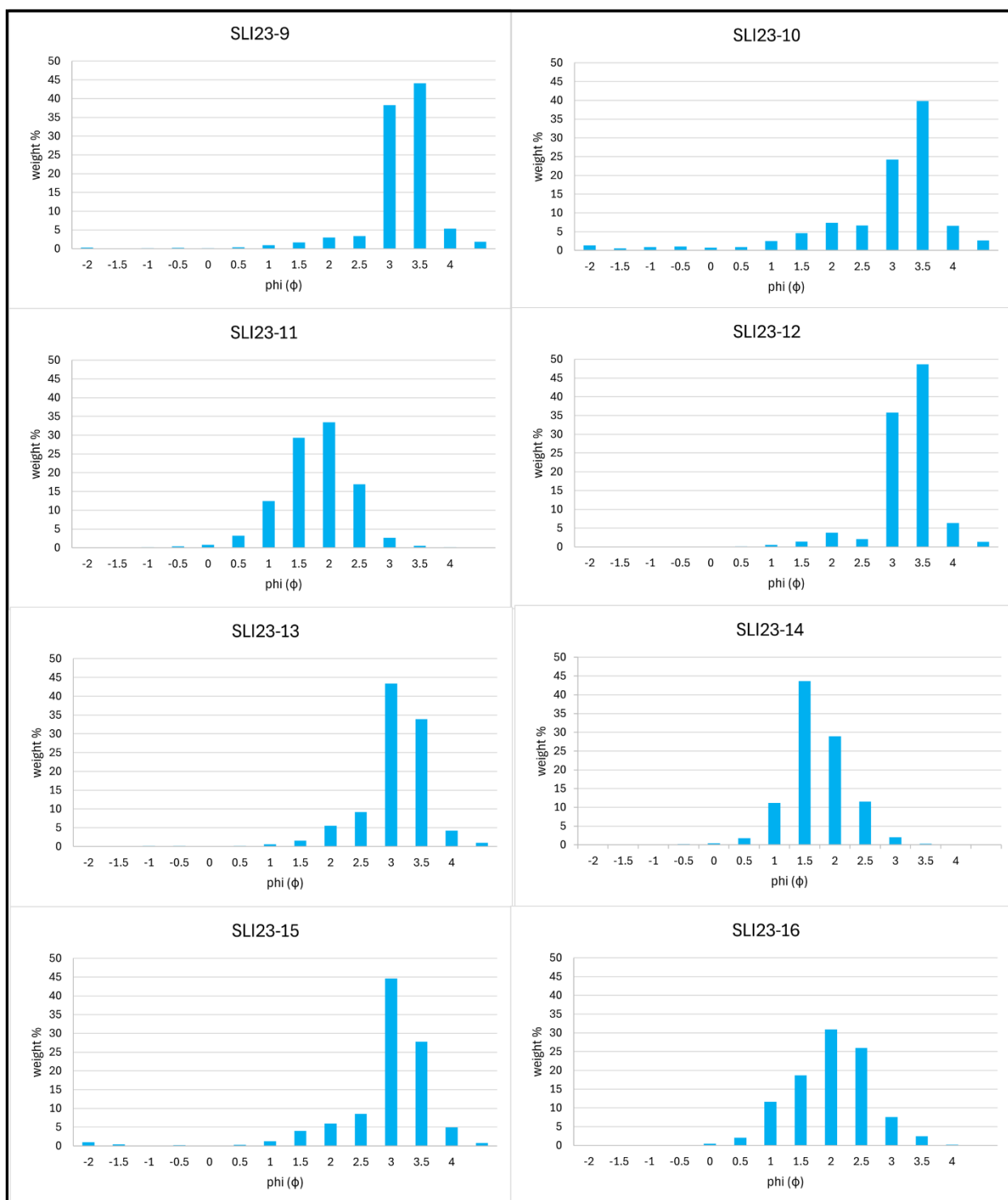
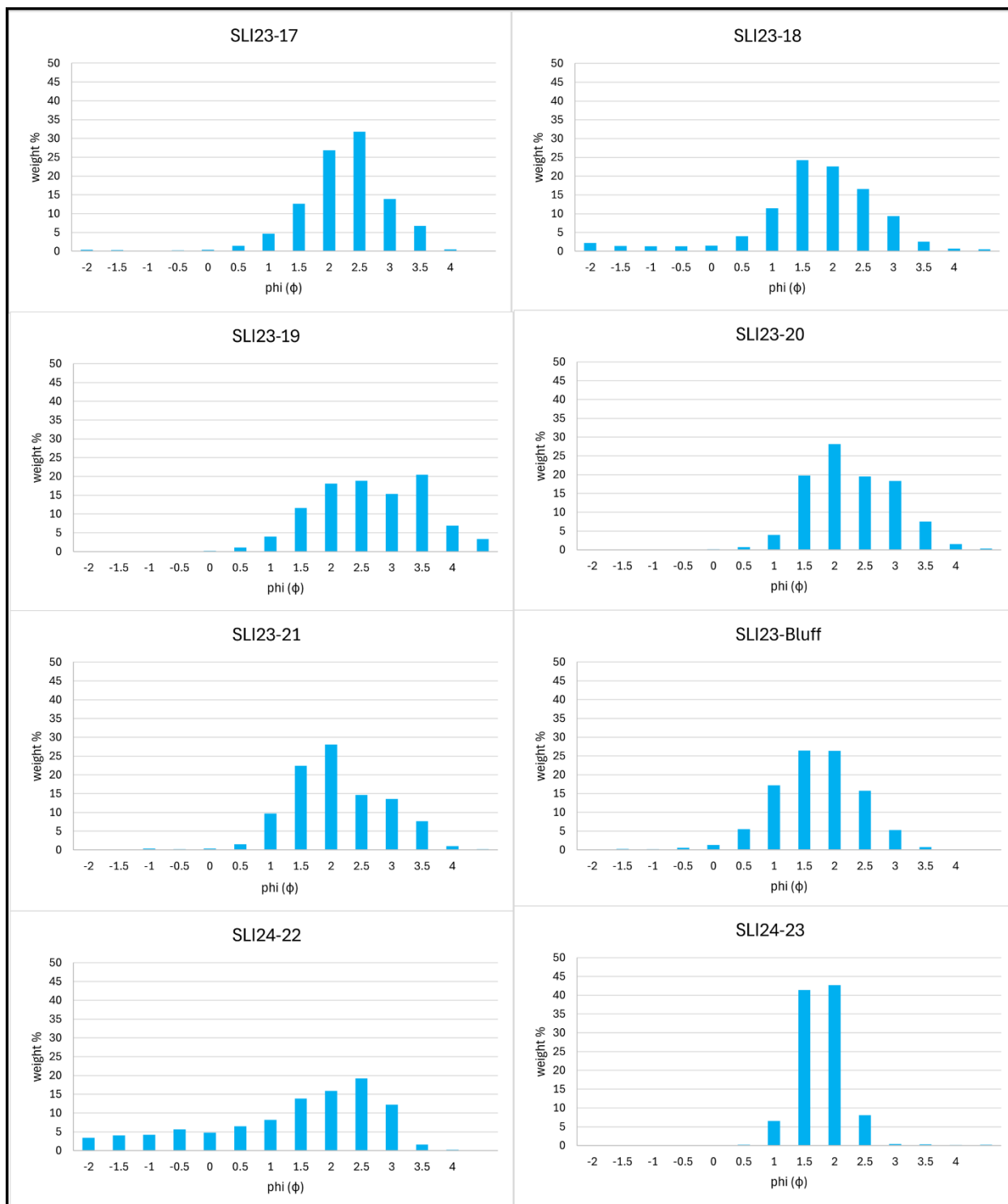


Figure A1. Histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the samples taken by David Mallinson in 2021. Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001). Histograms made using Excel, 2021.







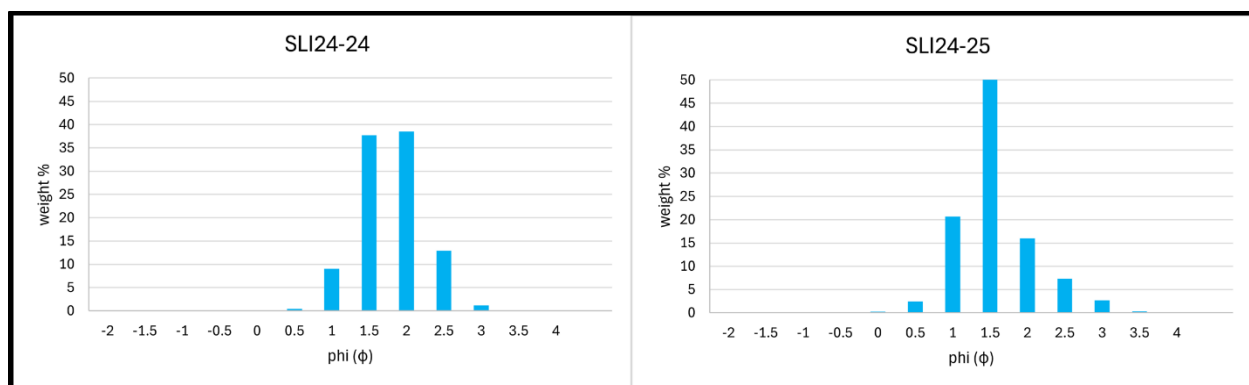
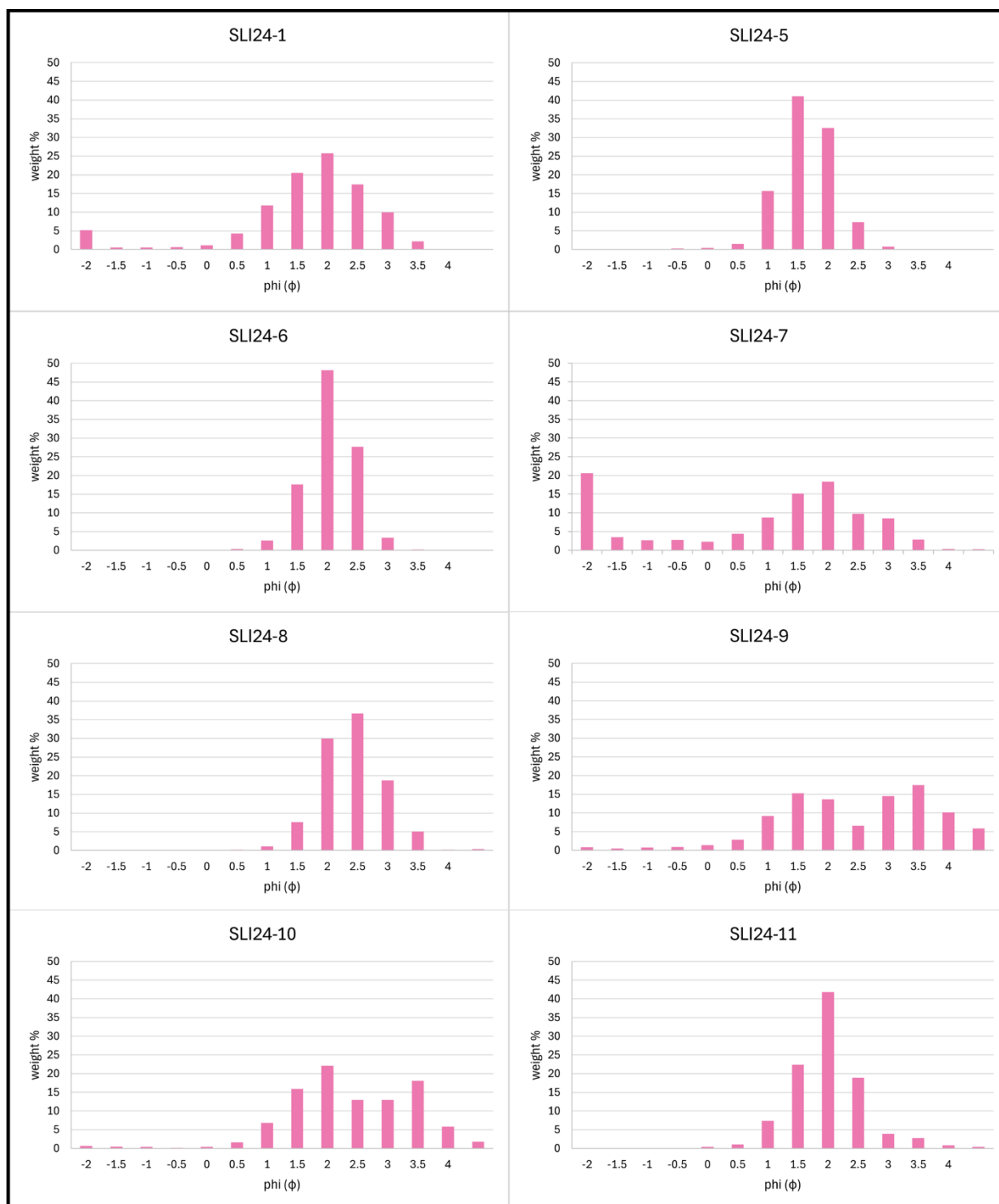
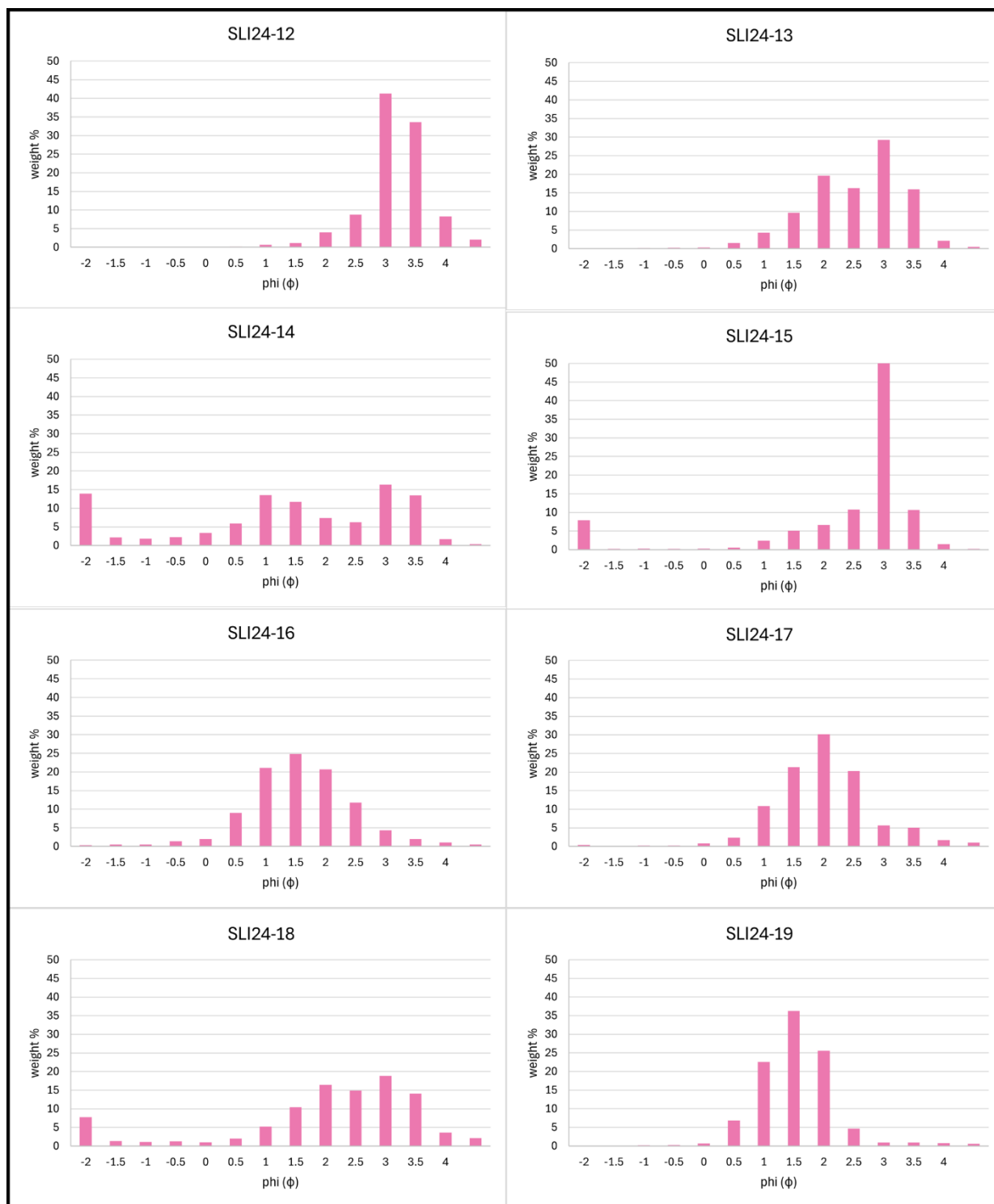


Figure A2. Histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the first round of sediment samples taken in December 2023 through March 2024. Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001). Histograms made using Excel, 2025.





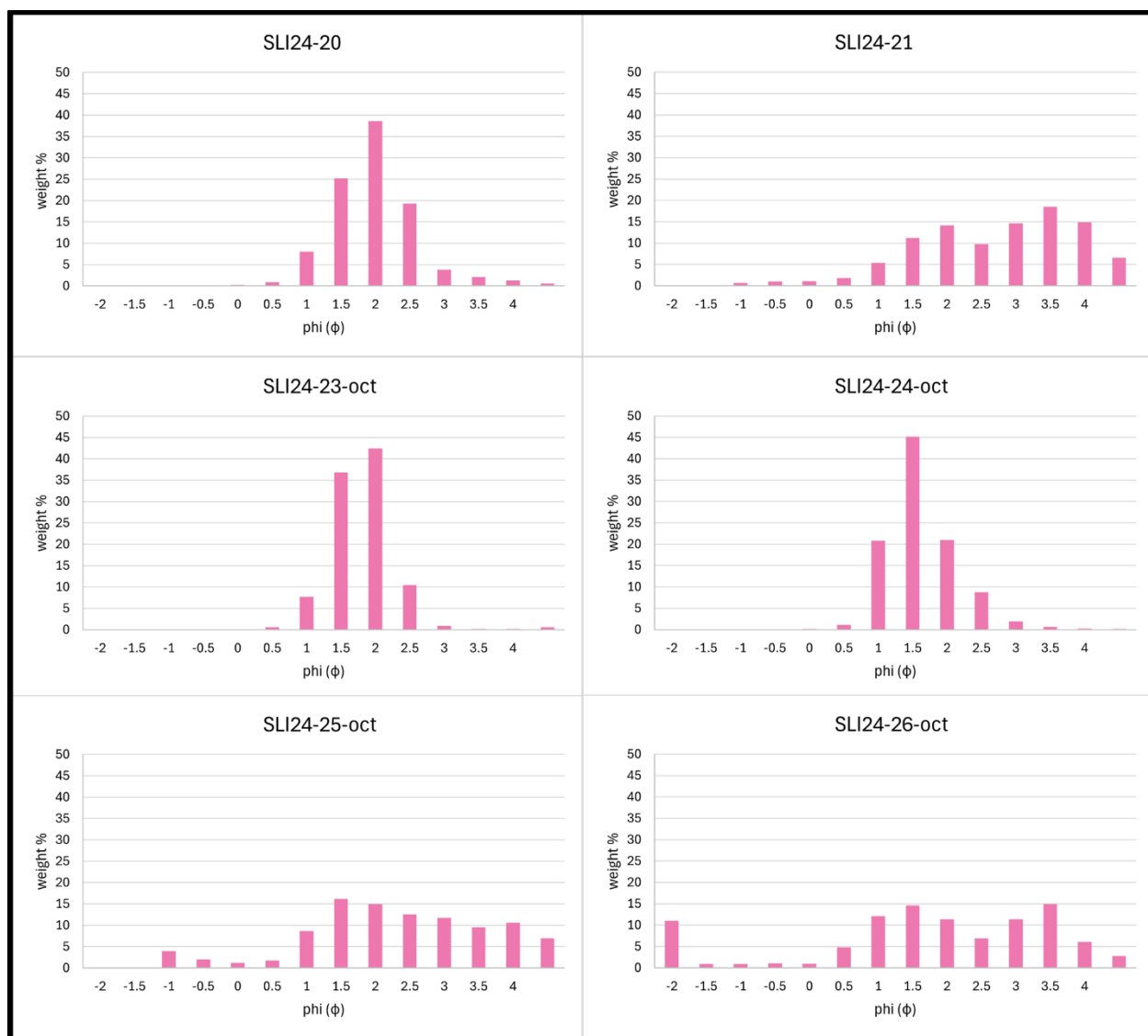


Figure A3. Histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the second round of sediment samples taken in October of 2024. Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001). Histograms made using Excel, 2025.

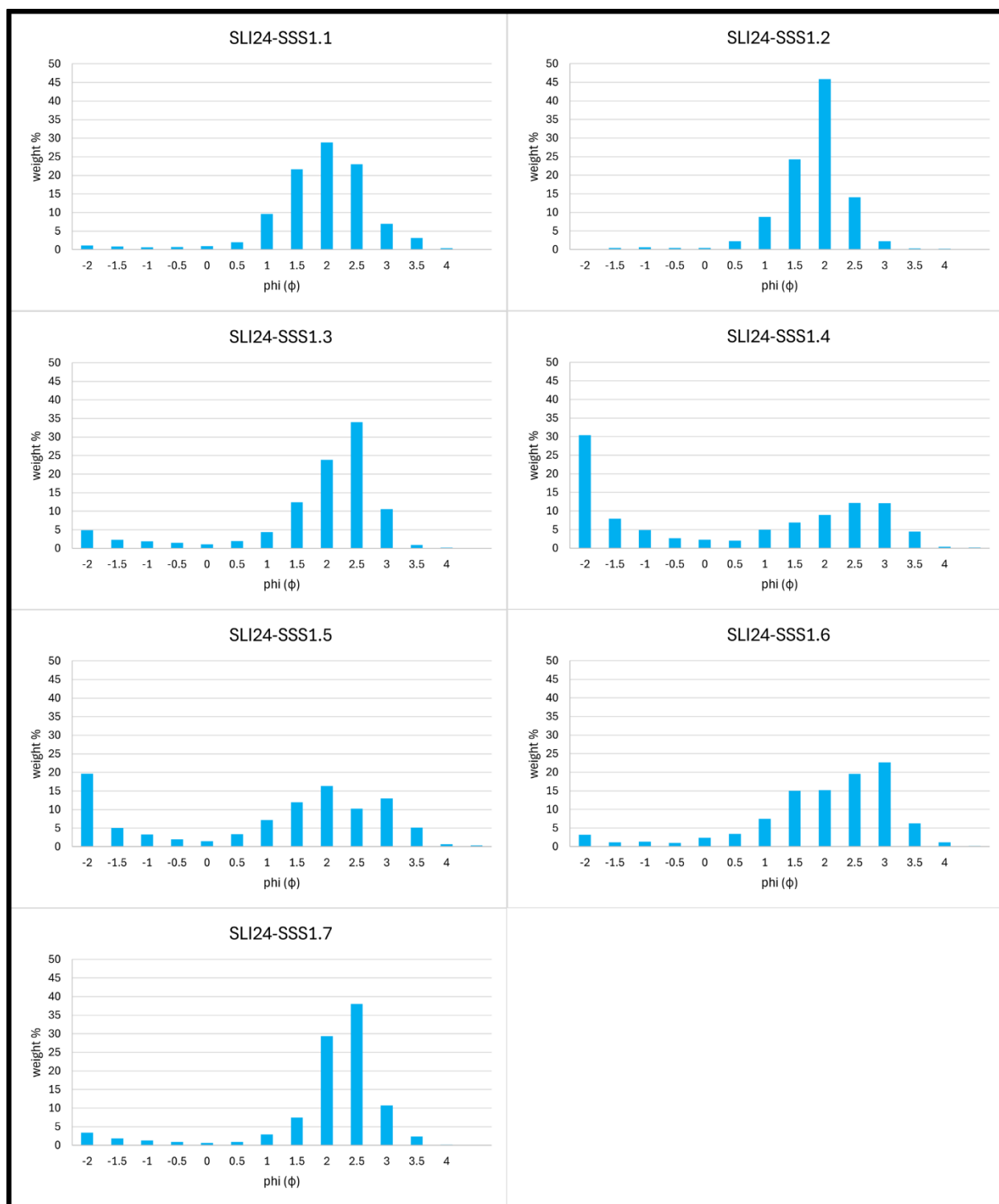


Figure A4. Histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the side scan sonar truth samples taken in April 2024. Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001). Histograms made using Excel, 2025.

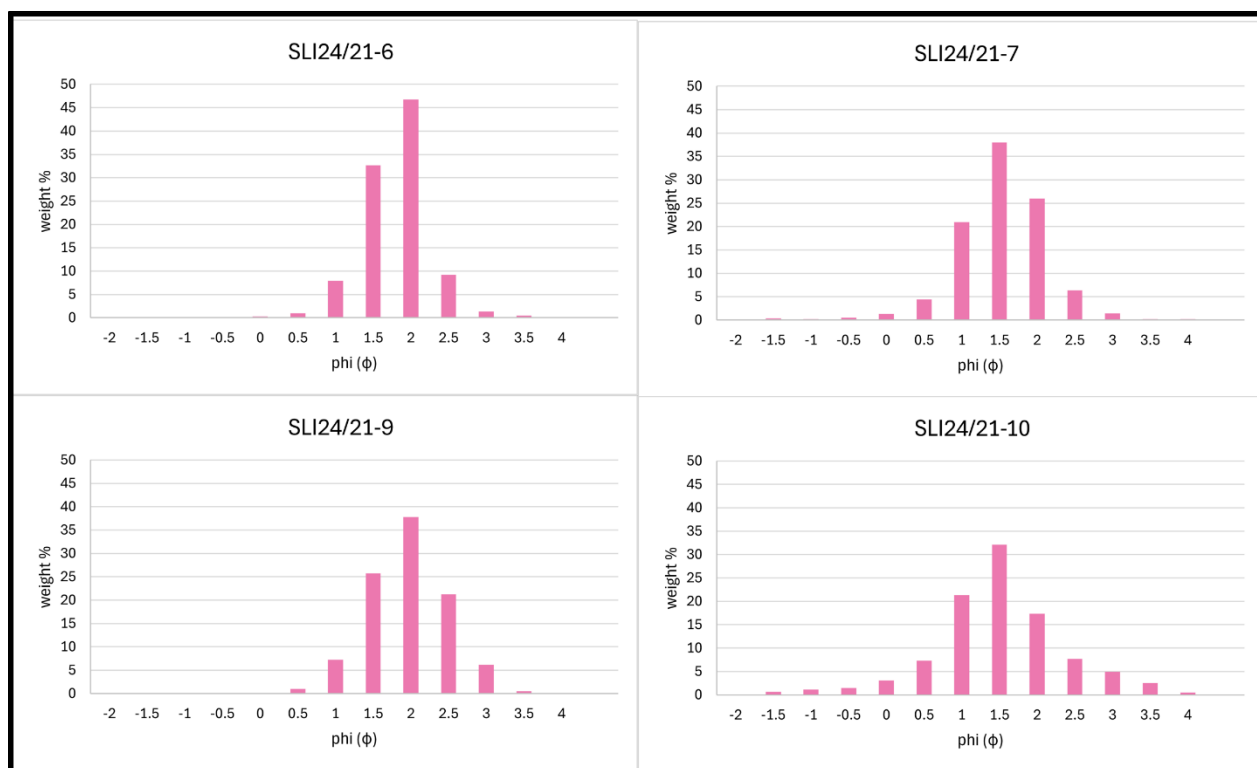


Figure A5. Histograms illustrating the distribution of sediment sizes (in phi) by weight percent of the resampled 2021 sample sites of SLI21-6/7/9/10 taken in October 2024. Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001). Histograms made using Excel, 2025.

Table A1: Table of grain size analysis data made using Data obtained using GRADISTAT ver. 9 (2020) (Blott and Pye, 2001), made using Excel, 2025.

Sample ID	Mean (φ)	Mean	Median (φ)	Median	Mode (φ)	Mode	Sorting (φ)	Sorting	Skewness (φ)	Skewness
SLI21-1	1.589	Medium Sand	1.488	Medium Sand	1.747	Medium Sand	0.869	Moderately Sorted	0.114	Fine Skewed
SLI21-2	1.460	Medium Sand	1.503	Medium Sand	1.747	Medium Sand	0.681	Moderately Well Sorted	-0.116	Coarse Skewed
SLI21-3	1.716	Medium Sand	1.721	Medium Sand	1.747	Medium Sand	0.658	Moderately Well Sorted	-0.026	Symmetrical
SLI21-4	1.626	Medium Sand	1.628	Medium Sand	1.747	Medium Sand	0.548	Moderately Well Sorted	-0.071	Symmetrical
SLI21-5	2.009	Fine Sand	1.973	Fine Sand	1.747	Medium Sand	0.645	Moderately Well Sorted	0.076	Symmetrical
SLI21-6	1.561	Medium Sand	1.616	Medium Sand	1.747	Medium Sand	0.683	Moderately Well Sorted	-0.081	Symmetrical
SLI21-7	2.322	Fine Sand	2.604	Fine Sand	2.737	Fine Sand	0.515	Poorly Sorted	-0.449	Very Coarse Skewed
SLI21-8	2.707	Fine Sand	2.733	Fine Sand	2.737	Fine Sand	0.819	Moderately Well Sorted	-0.143	Coarse Skewed
SLI21-9	1.899	Medium Sand	1.890	Medium Sand	1.747	Medium Sand	0.484	Moderately Sorted	0.005	Symmetrical
SLI21-10	1.796	Medium Sand	1.800	Medium Sand	1.747	Medium Sand	0.697	Well Sorted	-0.022	Symmetrical
SLI21-11	1.891	Medium Sand	1.833	Medium Sand	1.747	Medium Sand	0.615	Moderately Well Sorted	0.068	Symmetrical
SLI21-12	1.839	Medium Sand	1.866	Medium Sand	1.747	Medium Sand	1.153	Moderately Well Sorted	-0.076	Symmetrical
SLI23-1	1.833	Medium Sand	1.910	Medium Sand	2.237	Fine Sand	1.719	Poorly Sorted	-0.363	Very Coarse Skewed
SLI23-2	0.240	Coarse Sand	1.018	Medium Sand	1.747	Medium Sand	0.515	Poorly Sorted	-0.518	Very Coarse Skewed
SLI23-3	2.048	Fine Sand	2.055	Fine Sand	2.237	Fine Sand	0.497	Moderately Well Sorted	-0.043	Symmetrical
SLI23-4	2.354	Fine Sand	2.351	Fine Sand	2.237	Fine Sand	0.719	Well Sorted	-0.033	Symmetrical
SLI23-5	1.496	Medium Sand	1.532	Medium Sand	1.747	Medium Sand	0.576	Moderately Sorted	-0.294	Coarse Skewed
SLI23-6	1.895	Medium Sand	1.834	Medium Sand	1.747	Medium Sand	0.794	Moderately Well Sorted	0.141	Fine Skewed
SLI23-7	1.612	Medium Sand	1.589	Medium Sand	1.747	Medium Sand	0.730	Moderately Sorted	-0.057	Symmetrical
SLI23-8	1.600	Medium Sand	1.616	Medium Sand	1.747	Medium Sand	0.516	Moderately Sorted	0.001	Symmetrical
SLI23-9	2.981	Fine Sand	3.014	Very Fine Sand	3.237	Very Fine Sand	0.959	Moderately Well Sorted	-0.230	Coarse Skewed
SLI23-10	2.699	Fine Sand	2.980	Fine Sand	3.237	Very Fine Sand	0.579	Moderately Sorted	-0.521	Very Coarse Skewed
SLI23-11	1.544	Medium Sand	1.550	Medium Sand	1.747	Medium Sand	0.471	Moderately Well Sorted	-0.050	Symmetrical
SLI23-12	3.016	Very Fine Sand	3.062	Very Fine Sand	3.237	Very Fine Sand	0.507	Well Sorted	-0.235	Coarse Skewed
SLI23-13	2.862	Fine Sand	2.868	Fine Sand	2.737	Fine Sand	0.499	Moderately Well Sorted	-0.160	Coarse Skewed
SLI23-14	1.468	Medium Sand	1.413	Medium Sand	1.247	Medium Sand	0.643	Well Sorted	0.132	Fine Skewed
SLI23-15	2.751	Fine Sand	2.805	Fine Sand	2.737	Fine Sand	0.670	Moderately Well Sorted	-0.255	Coarse Skewed
SLI23-16	1.729	Medium Sand	1.773	Medium Sand	1.747	Medium Sand	0.704	Moderately Well Sorted	-0.075	Symmetrical
SLI23-17	2.015	Fine Sand	2.044	Fine Sand	2.237	Fine Sand	1.024	Moderately Sorted	-0.073	Symmetrical
SLI23-18	1.537	Medium Sand	1.546	Medium Sand	1.247	Medium Sand	0.917	Poorly Sorted	-0.155	Coarse Skewed
SLI23-19	2.387	Fine Sand	2.373	Fine Sand	3.237	Very Fine Sand	0.728	Moderately Sorted	0.021	Symmetrical
SLI23-20	2.012	Fine Sand	1.950	Medium Sand	1.747	Medium Sand	0.809	Moderately Sorted	0.145	Fine Skewed
SLI23-21	1.859	Medium Sand	1.769	Medium Sand	1.747	Medium Sand	0.721	Moderately Sorted	0.143	Fine Skewed
SLI23-Bluff	1.458	Medium Sand	1.464	Medium Sand	1.247	Medium Sand	1.467	Moderately Sorted	-0.028	Symmetrical
SLI24-22	1.099	Medium Sand	1.470	Medium Sand	2.237	Medium Sand	0.411	Poorly Sorted	-0.383	Very Coarse Skewed
SLI24-23	1.515	Medium Sand	1.516	Medium Sand	1.747	Medium Sand	0.464	Well Sorted	0.023	Symmetrical
SLI24-24	1.530	Medium Sand	1.530	Medium Sand	1.247	Medium Sand	0.525	Well Sorted	0.008	Symmetrical
SLI24-25	1.301	Medium Sand	1.262	Medium Sand	1.247	Medium Sand	0.754	Moderately Well Sorted	0.163	Fine Skewed
SLI24-SSS1.1	1.693	Medium Sand	1.713	Medium Sand	1.747	Medium Sand	0.524	Moderately Sorted	-0.087	Symmetrical
SLI24-SSS1.2	1.575	Medium Sand	1.635	Medium Sand	1.747	Medium Sand	1.136	Moderately Well Sorted	-0.181	Coarse Skewed
SLI24-SSS1.3	1.697	Medium Sand	1.909	Medium Sand	2.237	Fine Sand	2.006	Poorly Sorted	-0.505	Very Coarse Skewed
SLI24-SSS1.4	0.253	Coarse Sand	0.467	Coarse Sand	-2.243	Fine Gravel	2.005	Very Poorly Sorted	-0.099	Symmetrical
SLI24-SSS1.5	0.614	Coarse Sand	1.324	Medium Sand	-2.243	Fine Gravel	1.189	Very Poorly Sorted	-0.399	Very Coarse Skewed
SLI24-SSS1.6	1.844	Medium Sand	1.993	Medium Sand	2.737	Fine Sand	0.965	Poorly Sorted	-0.337	Very Coarse Skewed
SLI24-SSS1.7	1.909	Medium Sand	2.016	Fine Sand	2.237	Fine Sand	1.168	Moderately Sorted	-0.443	Very Coarse Skewed
SLI24-1	1.542	Medium Sand	1.601	Medium Sand	1.747	Medium Sand	0.484	Poorly Sorted	-0.293	Coarse Skewed
SLI24-5	1.397	Medium Sand	1.383	Medium Sand	1.247	Medium Sand	0.435	Well Sorted	0.026	Symmetrical
SLI24-6	1.808	Medium Sand	1.802	Medium Sand	1.747	Medium Sand	1.894	Well Sorted	-0.026	Symmetrical

SLI24-7	0.445	Coarse Sand	1.168	Medium Sand	-2.243	Fine Gravel	0.550	Poorly Sorted	-0.419	Very Coarse Skewed
SLI24-8	2.155	Fine Sand	2.143	Fine Sand	2.237	Fine Sand	1.304	Moderately Well Sorted	0.020	Symmetrical
SLI24-9	2.255	Fine Sand	2.324	Fine Sand	3.237	Very Fine Sand	0.992	Poorly Sorted	-0.042	Symmetrical
SLI24-10	2.160	Fine Sand	2.056	Fine Sand	1.747	Medium Sand	0.603	Moderately Sorted	0.105	Fine Skewed
SLI24-11	1.714	Medium Sand	1.719	Medium Sand	1.747	Medium Sand	0.521	Moderately Well Sorted	0.028	Symmetrical
SLI24-12	2.935	Fine Sand	2.922	Fine Sand	2.737	Fine Sand	0.790	Moderately Well Sorted	-0.025	Symmetrical
SLI24-13	2.324	Fine Sand	2.412	Fine Sand	2.737	Fine Sand	1.979	Moderately Sorted	-0.200	Coarse Skewed
SLI24-14	0.930	Coarse Sand	1.300	Medium Sand	2.737	Fine Sand	1.222	Poorly Sorted	-0.260	Coarse Skewed
SLI24-15	2.335	Fine Sand	2.629	Fine Sand	2.737	Fine Sand	0.825	Poorly Sorted	-0.658	Very Coarse Skewed
SLI24-16	1.333	Medium Sand	1.302	Medium Sand	1.247	Medium Sand	0.760	Moderately Sorted	0.072	Symmetrical
SLI24-17	1.721	Medium Sand	1.725	Medium Sand	1.747	Medium Sand	1.492	Moderately Sorted	0.058	Symmetrical
SLI24-18	1.964	Medium Sand	2.114	Fine Sand	2.737	Fine Sand	0.593	Poorly Sorted	-0.335	Very Coarse Skewed
SLI24-19	1.259	Medium Sand	1.266	Medium Sand	1.247	Medium Sand	0.607	Moderately Well Sorted	-0.001	Symmetrical
SLI24-20	1.701	Medium Sand	1.699	Medium Sand	1.747	Medium Sand	1.277	Moderately Well Sorted	0.049	Symmetrical
SLI24-21	2.520	Fine Sand	2.641	Fine Sand	3.237	Very Fine Sand	0.449	Poorly Sorted	-0.052	Symmetrical
SLI24-23-oct	1.538	Medium Sand	1.552	Medium Sand	1.747	Medium Sand	0.531	Well Sorted	-0.020	Symmetrical
SLI24-24-oct	1.351	Medium Sand	1.305	Medium Sand	1.247	Medium Sand	1.541	Moderately Well Sorted	0.160	Fine Skewed
SLI24-25-oct	2.168	Fine Sand	2.050	Fine Sand	1.247	Medium Sand	1.705	Poorly Sorted	0.090	Symmetrical
SLI24-26-oct	1.669	Medium Sand	1.652	Medium Sand	3.237	Very Fine Sand	0.454	Poorly Sorted	-0.138	Coarse Skewed
SLI24/21-6	1.543	Medium Sand	1.581	Medium Sand	1.747	Medium Sand	0.580	Well Sorted	-0.102	Coarse Skewed
SLI24/21-7	1.284	Medium Sand	1.289	Medium Sand	1.247	Medium Sand	0.564	Moderately Well Sorted	-0.019	Symmetrical
SLI24/21-9	1.706	Medium Sand	1.706	Medium Sand	1.747	Medium Sand	0.814	Moderately Well Sorted	-0.006	Symmetrical
SLI24/21-10	1.258	Medium Sand	1.233	Medium Sand	1.247	Medium Sand		Moderately Sorted	0.049	Symmetrical

Appendix B: Foraminiferal Census Data

Table B1: Number of modern dead and live foraminifera in Sugarloaf Island samples. Modern dead are denoted by ‘D,’ and live are denoted by ‘L.’

[illegible]

Species 'D'	SL123-1	SL123-3	SL123-4	SL123-5	SL123-6	SL123-7	SL123-8	SL123-9	SL123-10	SL123-11	SL123-12	SL123-13	SL123-14	SL123-15	SL123-16	SL123-17	SL123-18	SL123-19	SL123-20	SL123-21	SL123-Bluff	SL124-2	SL124-22	SL124-23	SL124-24
<i>Elphidium mexicanum</i>	8		3	2		11	1	28	2	2	5	5	1	12	3	5	4	3	5	3	3		1		
<i>Elphidium</i> sp. A																									
<i>Elphidium translucens</i>	4	3	1					5	1			6	1	7				1	2	2					
<i>Eponides repandus</i>				2																			4		
<i>Gavelinopsis praegeri</i>				2								1		6			3		1						
<i>Glabratella laurei</i>																									
<i>Guttulina australis</i>														1									1		
<i>Guttulina glacialis</i>																					1				
<i>Hanzawaia strattoni</i>	10	4	7	7	7	7	1	2	5	5	7	10		3		1	5		2	1	2		13		
<i>Haynesina germanica</i>												2													
Indeterminate agglutinated																									
Indeterminate rotaliid						1							2		1										
<i>Nonionella atlantica</i>	1	1		2	1	3		1	1		3	5		1		3					1		2		
<i>Oolina melo</i>														1											
<i>Poroeponides lateralis</i>																							3		
<i>Quinqueloculina bosciana</i>					1	2					1	3							1						
<i>Quinqueloculina compta</i>																	1								
<i>Quinqueloculina frigida</i>				1																					
<i>Quinqueloculina impressa</i>																			1						
<i>Quinqueloculina jugosa</i>	2	1			7							2					1				1		1		
<i>Quinqueloculina lamarckiana</i>		2		9	2							4				1							8		
<i>Quinqueloculina poliana</i>						1																			
<i>Quinqueloculina seminula</i>	3	1	3	11	7	1				8	1	2	1	5					1		1	1	9	1	
<i>Quinqueloculina</i> sp. A																							2		
<i>Rosalina floridana</i>			3	2	1		1	1	1	4	7	1		3	1	2			2			1			
<i>Textularia earlandi</i>																									
<i>Tiphotrocha comprimata</i>																		1							

Species 'D'	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
<i>Trifarina angulosa</i>			2		1		1	1		2	1	5				1									
<i>Triloculina</i> sp. A											1														
<i>Tritaxis fusca</i>	2		1	1		1													1	1					
<i>Trochammina "squamata"</i>																						1			
<i>Trochammina inflata</i>																		1							
<i>Uvigerina subperegrina</i>																									
<i>Valvulineria</i> sp. A						2		2						2					1						
<i>Wiesnerella auriculata</i>																	1								
Total	102	153	209	133	179	157	89	179	177	181	199	215	94	264	130	179	187	227	164	171	95	82	160	8	6
Species 'D'	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct	
<i>Ammonia parkinsoniana</i>	73	79	26	2	11	29		53	46	56	43	35	53	39	40	73	31	83	85	105	10	33	111	126	
<i>Ammonia tepida</i>		3							1					1			1			2	1		4		
<i>Ammotium salsum</i>																			1						
<i>Asterigerina carinata</i>															1										
<i>Asterigerinata pulchella</i>																	1								
<i>Bolivina lowmani</i>								1		1	2		1				1			7			2		
<i>Bolivina pseudoplicata</i>																								1	
<i>Bolivina</i> sp. A																									
<i>Bolivina spathulata</i>																								1	
<i>Bolivina striatula</i>													1											1	
<i>Buccella inusitata</i>		2	1		1	2		1	3			2	3	2	1									1	
<i>Buliminella elegantissima</i>											1						1					1		1	
<i>Buliminella</i> sp. A																									
<i>Cassidulina globulosa</i>																									

Species 'D'	SL124-25	SL124-26	SL124-1-oct	SL124-5-oct	SL124-6-oct	SL124-7-oct	SL124-8-oct	SL124-9-oct	SL124-10-oct	SL124-11-oct	SL124-12-oct	SL124-13-oct	SL124-14-oct	SL124-15-oct	SL124-16-oct	SL124-17-oct	SL124-18-oct	SL124-19-oct	SL124-20-oct	SL124-21-oct	SL124-23-oct	SL124-24-oct	SL124-25-oct	SL124-26-oct
<i>Cassidulina</i> sp. A																								
<i>Cibicides fletcheri</i>																								
<i>Cibicides lobatulus</i>		1	5			7		2	1	3	5	2	5	8		4	5						1	
<i>Cibicides</i> sp. A																								
<i>Coryphostoma georgiana</i>																1								
<i>Discorbinella bertheloti</i>											1						3		1				1	
<i>Elphidium excavatum</i>	61	85	128	45	106	126		150	112	73	157	168	133	155	127	123	139	85	72	149	6	25	66	90
<i>Elphidium galvestonense</i>			1		1									3				1	1					
<i>Elphidium gunteri</i>	1		1							1					1				1				2	2
<i>Elphidium macellum</i>																								
<i>Elphidium mexicanum</i>		1		2	1	2		4	6	6	6	6	5	2	3	4	2	1	2	7			2	3
<i>Elphidium</i> sp. A																								1
<i>Elphidium translucens</i>		2	1								1	4		3			2						1	1
<i>Eponides repandus</i>			1		2																			
<i>Gavelinopsis praegeri</i>		3							1		1	4					1			1			4	6
<i>Glabratella laurei</i>												2												
<i>Guttulina australis</i>																								
<i>Guttulina glacialis</i>																1								
<i>Hanzawaia strattoni</i>	1		10	10	8	4		2			5	2	2	8	3	5	6			2			1	
<i>Haynesina germanica</i>																								
Indeterminate agglutinated																					5			
Indeterminate rotaliid																								
<i>Nonionella atlantica</i>			3		1	2			2		1		1	5			2			1			1	
<i>Oolina melo</i>																								
<i>Poroeponides lateralis</i>			1																					
<i>Quinqueloculina bosciana</i>																1	1							

Species 'D'	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct
<i>Quinqueloculina compta</i>												1		1			1							
<i>Quinqueloculina frigida</i>																								
<i>Quinqueloculina impressa</i>																							1	
<i>Quinqueloculina jugosa</i>		1			2	1																		
<i>Quinqueloculina lamarckiana</i>			2	18	4	4						1											1	
<i>Quinqueloculina poliana</i>														1										
<i>Quinqueloculina seminula</i>			5	1	6	6			2			5	4	6			2							
<i>Quinqueloculina</i> sp. A																								
<i>Rosalina floridana</i>		3							1					1			1	1		1				1
<i>Textularia earlandi</i>																			1					1
<i>Tiphotrecha comprimata</i>																								
<i>Trifarina angulosa</i>		1						1	1		2	3			2		2			1				1
<i>Triloculina</i> sp. A																								
<i>Tritaxis fusca</i>				1	1	1						1												
<i>Trochammina "squamata"</i>																								
<i>Trochammina inflata</i>																								
<i>Uvigerina subperegrina</i>																1								
<i>Valvulineria</i> sp. A		1	1			1																		
<i>Wiesnerella auriculata</i>																								
Total	136	182	186	79	144	185	0	214	176	140	224	237	208	235	178	213	202	171	163	277	22	58	199	237

Species 'L'	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
<i>Ammonia parkinsoniana</i>	3	2	7	2	2	3	1	9		5	8	4		2	1	3	4	12	22	12				61	
<i>Ammonia tepida</i>								1			4	1						1	4						
<i>Ammotium salsum</i>				1																					
<i>Bolivina lowmani</i>	1																								
<i>Bolivina striatula</i>																				1					
<i>Elphidium excavatum</i>	2	1	1						1	1	1			1		1	1	1	1				1	1	
<i>Elphidium gunteri</i>																								25	
<i>Elphidium mexicanum</i>		3						2				2						1	3	9					
<i>Gavelinopsis praegeri</i>																									
<i>Hanzawaia strattoni</i>																							1		
<i>Laryngosigma williamsoni</i>																				1					
<i>Nonionella atlantica</i>										1															
<i>Quinqueloculina impressa</i>																		2	7	3			1		
<i>Quinqueloculina jugosa</i>	1																								
<i>Quinqueloculina seminula</i>																1									
<i>Rosalina floridana</i>	1			1		1																			
<i>Textularia earlandi</i>																									
<i>Tritatix fusca</i>	2	3	2			2																			
<i>Trochammina "squamata"</i>	1																						1		
<i>Total</i>	11	9	10	4	2	6	1	12	1	7	13	7	0	3	1	5	5	17	37	26	0	0	4	87	0

Species 'L'	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct
<i>Ammonia parkinsoniana</i>	1	1	8					35	43	58	13	10	3	9	28		14	71	71	13	22	3	82	21
<i>Ammonia tepida</i>																		1						
<i>Ammotium salsum</i>																								
<i>Bolivina lowmani</i>											1													1
<i>Bolivina striatula</i>																								
<i>Elphidium excavatum</i>										1	2	1			1	38	1		7	6	9		1	2
<i>Elphidium gunteri</i>																				2			1	
<i>Elphidium mexicanum</i>																		13						
<i>Gavelinopsis praegeri</i>																							1	
<i>Hanzawaia strattoni</i>																								
<i>Laryngosigma williamsoni</i>																								
<i>Nonionella atlantica</i>																								
<i>Quinqueloculina impressa</i>								1																
<i>Quinqueloculina jugosa</i>																								
<i>Quinqueloculina seminula</i>																								
<i>Rosalina floridana</i>				1																				
<i>Textularia earlandi</i>															1								1	
<i>Tritaxis fusca</i>			1			1																		
<i>Trochammina "squamata"</i>																								
Total	1	1	9	1	0	1	0	35	44	59	16	11	3	9	30	38	15	72	91	19	33	3	86	24

Table B2: Number of fossilized phosphatic and sugary foraminifera in Sugarloaf Island samples. Phosphatic foraminifera are denoted by 'P' and sugary foraminifera are denoted by 'S.'

Species 'P'	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
<i>Ammonia parkinsoniana</i>	4	3		3	1				1	1	1		1	2	3	2		2							
<i>Bolivina lowmani</i>																1									
<i>Buccella inusitata</i>																		2				1	1		
<i>Buccella</i> sp. A				2																					
<i>Cibicides lobatulus</i>					1	1																			
<i>Cibicides</i> sp. A	1			2												1	1								
<i>Elphidium excavatum</i>	16	20	2	16	9	4	5	5	7	9	12	9	2	6	12	4	1	3		1		10	11		
<i>Elphidium galvestonense</i>																							1		
<i>Elphidium mexicanum</i>														1		1									
<i>Eponides repandus</i>	2																								
<i>Hanzawaia strattoni</i>	2			1		1						2	1									1	1		
<i>Nonionella atlantica</i>				1	1		1																		
<i>Quinqueloculina bosciana</i>							1																		
<i>Quinqueloculina jugosa</i>				3																					
<i>Quinqueloculina lamarckiana</i>				1																			4		
<i>Quinqueloculina seminula</i>	3			3	4			1			2														1
<i>Textularia</i> sp. A				2		1																			
<i>Trifarina angulosa</i>																									
Total	28	23	2	34	16	7	7	6	8	10	15	11	4	9	15	9	2	7	0	1	0	12	18	0	1

Species 'P'	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct
<i>Ammonia parkinsoniana</i>						7						2	1		1									
<i>Bolivina lowmani</i>																								
<i>Buccella inusitata</i>						1																		
<i>Buccella</i> sp. A																								
<i>Cibicides lobatulus</i>						1								1										
<i>Cibicides</i> sp. A																								
<i>Elphidium excavatum</i>			8		8	19			1		1	5	4	3	2		6		1	2				
<i>Elphidium galvestonense</i>																								
<i>Elphidium mexicanum</i>																								
<i>Eponides repandus</i>																								
<i>Hanzawaia strattoni</i>					1	1									3									
<i>Nonionella atlantica</i>					1																			
<i>Quineloculina bosciana</i>																								
<i>Quineloculina jugosa</i>																								
<i>Quineloculina lamarckiana</i>					2																			
<i>Quineloculina seminula</i>			1	2	2	1			1					1										
<i>Textularia</i> sp. A																								
<i>Trifarina angulosa</i>																		1						
Total	0	0	9	2	14	30	0	0	2	0	1	7	5	5	6	0	6	1	1	2	0	0	0	0

Species 'S'	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
<i>Ammonia parkinsoniana</i>	1			2						2	2	1		1											
<i>Asterigerina carnata</i>																	1								
<i>Bolivina</i> sp. A																									
<i>Bolivina striatula</i>	1																								
<i>Buccella inusitata</i>												1													
<i>Buccella</i> sp. A																									
<i>Cassidulina</i> sp. A																									
<i>Cibicides fletcheri</i>				1																					
<i>Elphidium excavatum</i>	14	3	1	7	1		1			4	4	2				3					1	3	6		
<i>Elphidium galvestonense</i>																						1			
<i>Elphidium</i> sp. A														1							1				
<i>Eponides repandus</i>				1																					
<i>Hanzawaia</i> sp. A																							1		
<i>Hanzawaia strattoni</i>	1	1		1												1									
<i>Nonionella atlantica</i>	1									1										1					
<i>Nonionella</i> sp. A		2																							
<i>Quinqueloculina bosciana</i>															1										
<i>Quinqueloculina jugosa</i>																						3	1		
<i>Quinqueloculina lamarckiana</i>				1	1	1																		2	
<i>Quinqueloculina seminula</i>	3											1			1									4	
<i>Rosalina floridana</i>			1																						
<i>Trifarina angulosa</i>		1																							
<i>Trochammina inflata</i>																					1				
Total	21	7	2	13	2	1	1	0	0	7	6	5	0	2	2	4	1	0	0	1	3	7	14	0	0

Table B3: Percentage data for the modern dead foraminifera specimens in Sugarloaf Island used in calculating the cluster analysis found in figure 20.

Species 'D'	SL123-1	SL123-3	SL123-4	SL123-5	SL123-6	SL123-7	SL123-8	SL123-9	SL123-10	SL123-11	SL123-12	SL123-13	SL123-14	SL123-15	SL123-16	SL123-17	SL123-18	SL123-19	SL123-20	SL123-21	SL123-Bluff	SL124-2	SL124-22	SL124-23	SL124-24
<i>Ammonia parkinsoniana</i>	12.35	6.77	13.00	9.78	14.57	16.96	5.10	13.20	20.97	19.51	16.74	14.71	20.41	13.31	13.51	13.71	20.51	37.45	15.92	32.16	23.47	1.98	10.71	4.21	57.14
<i>Ammonia tepida</i>		1.56			0.50			1.52			2.58	1.26		0.72	1.35			6.77	3.98	3.02	4.08				
<i>Ammotium salsum</i>																									
<i>Asterigerina carnata</i>																									
<i>Asterigerinata pulchella</i>											0.42														
<i>Bolivina lowmani</i>																	1.03	0.40							
<i>Bolivina pseudopicata</i>																									
<i>Bolivina</i> sp. A																					1.02				
<i>Bolivina spathulata</i>																									
<i>Bolivina striatula</i>											0.42														
<i>Buccella imunitata</i>	1.85			0.54	0.50	1.17		0.51	1.61	0.49	1.29	2.10	4.08	2.16		1.02	3.08						1.53		
<i>Buliminella elegantissima</i>									0.54																
<i>Buliminella</i> sp. A											0.43														
<i>Casidulina globulosa</i>			0.45																						
<i>Casidulina</i> sp. A																	0.51								
<i>Cibicides fletcheri</i>								1.02					1.02												
<i>Cibicides lobatulus</i>	0.62	1.56	0.90	1.63	1.01			1.02		1.95	2.15	2.52		1.80	2.03	0.51	1.54	0.40		1.01			0.51		
<i>Cibicides</i> sp. A						1.17																			
<i>Coryphostoma gerorgiana</i>																									
<i>Discorbinella berteloti</i>																									
<i>Elphidium excavatum</i>	27.16	62.50	70.40	38.59	59.30	55.56	79.59	51.27	66.67	56.10	49.79	49.58	65.31	60.07	67.57	65.99	59.49	41.83	52.24	45.23	59.18	72.28	42.35	2.11	28.57
<i>Elphidium galvestonense</i>	0.62			0.54			2.04	0.51			1.29			1.08		2.54	1.03	0.40	0.50	1.01	1.02	2.97	0.51		
<i>Elphidium gunteri</i>	1.85	1.04			0.50			1.52						1.08		0.51	1.03	0.80					3.06	1.05	
<i>Elphidium macellum</i>																							0.51		

Species 'D'	SL123-1	SL123-3	SL123-4	SL123-5	SL123-6	SL123-7	SL123-8	SL123-9	SL123-10	SL123-11	SL123-12	SL123-13	SL123-14	SL123-15	SL123-16	SL123-17	SL123-18	SL123-19	SL123-20	SL123-21	SL123-Bluff	SL124-2	SL124-22	SL124-23	SL124-24
<i>Elphidium mexicanum</i>	4.94		1.35	1.09		6.43	1.02	14.21	1.08	0.98	2.15	2.10	1.02	4.32	2.03	2.54	2.05	1.20	2.49	1.51	3.06		0.51		
<i>Elphidium</i> sp. A																									
<i>Elphidium translucens</i>	2.47	1.56	0.45					2.54	0.54			2.52	1.02	2.52				0.40	1.00	1.01					
<i>Eponedes ropandus</i>				1.09																			2.04		
<i>Gavilinospos preageri</i>				1.09								0.42		2.16			1.54	0.00	0.50						
<i>Glaberatela laurai</i>																									
<i>Gutulina estralis</i>														0.36									0.51		
<i>Gutulina glacialis</i>																						0.99			
<i>Hanzawaia strattoni</i>	6.17	2.08	3.14	3.80	3.52	4.09	1.02	1.02	2.69	2.44	3.00	4.20		1.08		0.51	2.56		1.00	0.50	2.04		6.63		
<i>Hanzena germanica</i>												0.84													
Indeterminate agglutinated																									
Indeterminate rotaliid													2.04		0.68										
<i>Nonionella atlantica</i>	0.62	0.52		1.09	0.50	1.75		0.51	0.54		1.29	2.10		0.36		1.52					1.02		1.02		
<i>Oolina melo</i>														0.36											
<i>Proeponedes lateralis</i>																							1.53		
<i>Quinqueloculina bosciana</i>					0.50	1.17					0.43	1.26							0.50						
<i>Quinqueloculina compta</i>				0.00													0.51								
<i>Quinqueloculina frigida</i>				0.54																					
<i>Quinqueloculina impressa</i>																			0.50						
<i>Quinqueloculina jugosa</i>	1.23	0.52			3.52							0.84					0.51				1.02		0.51		
<i>Quinqueloculina lamarkiana</i>		1.04		4.89	1.01							1.68				0.51							4.08		
<i>Quinqueloculina poliana</i>						0.58																			
<i>Quinqueloculina seminula</i>	1.85	0.52	1.35	5.98	3.52	0.58				3.90	0.43	0.84	1.02	1.80					0.50		1.02	0.99	4.59		
<i>Quinqueloculina</i> sp. A																							1.02		
<i>Rosalina floridana</i>			1.35	1.09	0.50		1.02	0.51	0.54	1.95	3.00	0.42		1.08	0.68	1.02			1.00			0.99			
<i>Textularia earlandi</i>																									
<i>Tiphotrecha comprimata</i>																		0.40							

	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
Species 'D'																									
Triferina angulosa			0.90		0.50		1.02	0.51		0.98	0.43	2.10				0.51									
Triloculina sp. A											0.43														
Tritatixis fusca	1.23		0.45	0.54		0.58													0.50	0.50					
Trochammina "squamata"																						0.99			
Trochammina inflata																		0.40							
Uvigerina subperegrina																									
Valvuleneria sp. A						1.17		1.02					0.72						0.50						
Wiesnerella auriculata																	0.51								
Total	62.96	79.69	93.72	72.28	89.95	91.81	90.82	90.86	95.16	88.29	85.41	90.34	95.92	94.96	87.84	90.86	95.90	90.44	81.59	85.93	96.94	81.19	81.63	8.42	85.71
Species 'D'	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct	
Ammonia parkinsoniana	53.28	42.70	12.38	2.27	6.92	13.36	0.00	21.29	20.72	28.14	17.84	13.57	24.54	15.54	18.60	28.97	13.90	33.47	33.33	35.12	18.18	54.10	38.95	48.28	
Ammonia tepida		1.62							0.45					0.40			0.45			0.67	1.82		1.40		
Ammotium salsum																			0.39						
Asterigerina carnata															0.47										
Asterigerinata pulchella															0.00		0.45								
Bolivina lowmani								0.40		0.50	0.83		0.46				0.45		2.34			0.70	0.00		
Bolivina pseudoplicata																							0.38		
Bolivina sp. A																							0.00		
Bolivina spathulata																							0.38		
Bolivina striatula													0.46										0.38		
Buccella inusitata		1.08	0.48		0.63	0.92		0.40	1.35			0.78	1.39	0.80	0.47								0.38		
Buliminella elegantissima											0.41						0.45					0.35	0.38		
Buliminella sp. A																									
Casidulina globulosa																									

Species 'D'	SL124-25	SL124-26	SL124-1-oct	SL124-5-oct	SL124-6-oct	SL124-7-oct	SL124-8-oct	SL124-9-oct	SL124-10-oct	SL124-11-oct	SL124-12-oct	SL124-13-oct	SL124-14-oct	SL124-15-oct	SL124-16-oct	SL124-17-oct	SL124-18-oct	SL124-19-oct	SL124-20-oct	SL124-21-oct	SL124-23-oct	SL124-24-oct	SL124-25-oct	SL124-26-oct
<i>Casidulina</i> sp. A																								
<i>Cibicides fletcheri</i>																								
<i>Cibicides lobatulus</i>		0.54	2.38			3.23		0.80	0.45	1.51	2.07	0.78	2.31	3.19		1.59	2.24						0.35	
<i>Cibicides</i> sp. A																								
<i>Coryphostoma gerorgiana</i>																0.40								
<i>Discorbinella berteloti</i>												0.39					1.35			0.33	0.00	0.00	0.35	
<i>Elphidium excavatum</i>	44.53	45.95	60.95	51.14	66.67	58.06	0.00	60.24	50.45	36.68	65.15	65.12	61.57	61.75	59.07	48.81	62.33	34.27	28.24	49.83	10.91	40.98	23.16	34.48
<i>Elphidium galvestonense</i>			0.48		0.63									1.20				0.40	0.39					
<i>Elphidium gunteri</i>	0.73		0.48							0.50					0.47				0.39				0.70	0.77
<i>Elphidium macellum</i>																								
<i>Elphidium mexicanum</i>		0.54		2.27	0.63	0.92		1.61	2.70	3.02	2.49	2.33	2.31	0.80	1.40	1.59	0.90	0.40	0.78	2.34				1.15
<i>Elphidium</i> sp. A																								0.38
<i>Elphidium translucens</i>		1.08	0.48								0.41	1.55		1.20			0.90					0.35	0.38	
<i>Eponedes ropandus</i>			0.48		1.26																			
<i>Gavilinospos preageri</i>		1.62							0.45		0.41	1.55					0.45			0.33	0.00	0.00	1.40	2.30
<i>Glaberatela laurei</i>												0.78												
<i>Gutulina estralis</i>																								
<i>Gutulina glacialis</i>																0.40								
<i>Hanzawaia strattoni</i>	0.73		4.76	11.36	5.03	1.84		0.80			2.07	0.78	0.93	3.19	1.40	1.98	2.69		0.67			0.35		
<i>Hanzawia strattoni</i>																								
<i>Hanzena germanica</i>																								
Indeterminate agglutinated																					9.09			
Indeterminate rotaliid																								
<i>Nonionella atlantica</i>			1.43		0.63	0.92			0.90		0.41		0.46	1.99			0.90		0.33			0.35		
<i>Oolina melo</i>																								
<i>Proeponedes lateralis</i>			0.48																					
<i>Quinqueloculina boschiana</i>																0.40	0.45							

Species 'D'	SL124-25	SL124-26	SL124-1-oct	SL124-5-oct	SL124-6-oct	SL124-7-oct	SL124-8-oct	SL124-9-oct	SL124-10-oct	SL124-11-oct	SL124-12-oct	SL124-13-oct	SL124-14-oct	SL124-15-oct	SL124-16-oct	SL124-17-oct	SL124-18-oct	SL124-19-oct	SL124-20-oct	SL124-21-oct	SL124-23-oct	SL124-24-oct	SL124-25-oct	SL124-26-oct
<i>Quinqueloculina compta</i>												0.39		0.40			0.45							
<i>Quinqueloculina frigida</i>																								
<i>Quinqueloculina impressa</i>																							0.35	
<i>Quinqueloculina jugosa</i>		0.54			1.26	0.46																		
<i>Quinqueloculina lamarkiana</i>			0.95	20.45	2.52	1.84						0.39											0.35	
<i>Quinqueloculina poliana</i>																								
<i>Quinqueloculina seminula</i>			2.38	1.14	3.77	2.76			0.90			1.94	1.85	2.39										
<i>Quinqueloculina</i> sp. A																								
<i>Rosalina floridana</i>		1.62							0.45					0.40			0.45	0.40		0.33				0.38
<i>Textularia earlandi</i>																			0.39					0.38
<i>Tiphotrocha comprimata</i>																								
<i>Triferina angulosa</i>		0.54						0.40	0.45		0.83	1.16			0.93		0.90			0.33				0.38
<i>Triloculina</i> sp. A																								
<i>Tritatixis fusca</i>				1.14	0.63	0.46						0.39												
<i>Trochammina "squamata"</i>																								
<i>Trochammina inflata</i>																								
<i>Uvigerina subperegrina</i>																0.40								
<i>Valvuleneria</i> sp. A		0.54	0.48			0.46																		
<i>Wiesnerella auriculata</i>																								
Total	99.27	98.38	88.57	89.77	90.57	85.25	0.00	85.94	79.28	70.35	92.95	91.86	96.30	93.63	82.79	84.52	90.58	68.95	63.92	92.64	40.00	95.08	69.82	90.80

Table B4: Percentage data for the live foraminifera specimens in Sugarloaf Island used in calculating the cluster analysis found in figure 21.

Species 'L'	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
<i>Ammonia parkinsoniana</i>	27.27	22.22	70.00	50.00	100.00	50.00	100.00	75.00		71.43	61.54	57.14		66.67	100.00	60.00	80.00	70.59	59.46	46.15					70.11
<i>Ammonia tepida</i>								8.33			30.77	14.29					0.00	5.88	10.81						
<i>Ammotium salsum</i>				25.00																					
<i>Bolivina lowmani</i>	9.09																								
<i>Bolivina striatula</i>																				3.85					
<i>Elphidium excavatum</i>	18.18	11.11	10.00						100.00	14.29	7.69			33.33		20.00	20.00	5.88	2.70				25.00	1.15	
<i>Elphidium gunteri</i>																								28.74	
<i>Elphidium mexicanum</i>		33.33						16.67			28.57							5.88	8.11	34.62					
<i>Gavilinopsos preageri</i>																									
<i>Hanzawaia strattoni</i>																							25.00		
<i>Laryngosigma williamsoni</i>																									
<i>Nonionella atlantica</i>										14.29															
<i>Quinqueloculina impressa</i>																		11.76	18.92	11.54			25.00		
<i>Quinqueloculina jugosa</i>	9.09																								
<i>Quinqueloculina seminula</i>																20.00									
<i>Rosalina floridana</i>	9.09			25.00		16.67																			
<i>Textularia earlandi</i>																									
<i>Tritatixis fusca</i>	18.18	33.33	20.00			33.33																			
<i>Trochammina "squamata"</i>	9.09																						25.00		
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.00	0.00	100.00	100.00	0

Species 'L'	SL124-25	SL124-26	SL124-1-oct	SL124-5-oct	SL124-6-oct	SL124-7-oct	SL124-8-oct	SL124-9-oct	SL124-10-oct	SL124-11-oct	SL124-12-oct	SL124-13-oct	SL124-14-oct	SL124-15-oct	SL124-16-oct	SL124-17-oct	SL124-18-oct	SL124-19-oct	SL124-20-oct	SL124-21-oct	SL124-23-oct	SL124-24-oct	SL124-25-oct	SL124-26-oct
<i>Ammonia parkinsoniana</i>	100.00	100.00	88.89					100.00	97.73	98.31	81.25	90.91	100.00	100.00	93.33		93.33	98.61	78.02	68.42	66.67	100.00	95.35	87.50
<i>Ammonia tepida</i>																		1.39						
<i>Ammotium salsum</i>																								
<i>Bolivina lowmani</i>											6.25													4.17
<i>Bolivina striatula</i>																								
<i>Elphidium excavatum</i>										1.69	12.50	9.09			3.33	100.00	6.67		7.69	31.58	27.27		1.16	8.33
<i>Elphidium gunteri</i>																					6.06		1.16	
<i>Elphidium mexicanum</i>																			14.29					
<i>Gavilinospos preageri</i>																							1.16	
<i>Hanzawaia strattoni</i>																								
<i>Laryngosigma williamsoni</i>																								
<i>Nonionella atlantica</i>																								
<i>Quinqueloculina impressa</i>									2.27															
<i>Quinqueloculina jugosa</i>																								
<i>Quinqueloculina seminula</i>																								
<i>Rosalina floridana</i>				100.00																				
<i>Textularia earlandi</i>														3.33									1.16	
<i>Tritatixis fusca</i>			11.11			100.00																		
<i>Trochammina "squamata"</i>																								
Total	100.00	100.00	100.00	100.00	0.00	100.00	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table B6: Percentage data for the total modern dead and live foraminifera specimens in Sugarloaf Island used in calculating the cluster analysis found in figure 22.

Species	SL123-1	SL123-3	SL123-4	SL123-5	SL123-6	SL123-7	SL123-8	SL123-9	SL123-10	SL123-11	SL123-12	SL123-13	SL123-14	SL123-15	SL123-16	SL123-17	SL123-18	SL123-19	SL123-20	SL123-21	SL123-Bluff	SL124-2	SL124-22	SL124-23	SL124-24
<i>Ammonia parkinsoniana</i>	14.20	7.81	16.14	10.87	15.58	18.71	6.12	17.77	20.97	21.95	20.17	16.39	20.41	14.03	14.19	15.23	22.56	42.23	26.87	38.19	23.47	1.98	10.71	68.42	57.14
<i>Ammonia tepida</i>		1.56			0.50			2.03			4.29	1.68		0.72	1.35			7.17	5.97	3.02	4.08				
<i>Ammotium salsum</i>				0.54																					
<i>Asterigerina carnata</i>																									
<i>Asterigerinata pulchella</i>												0.42													
<i>Bolivina lowmani</i>	0.62																1.03	0.40							
<i>Bolivina pseudopicata</i>																									
<i>Bolivina</i> sp. A																					1.02				
<i>Bolivina spathulata</i>																									
<i>Bolivina striatula</i>												0.42								0.50					
<i>Buccella inusitata</i>	1.85			0.54	0.50	1.17		0.51	1.61	0.49	1.29	2.10	4.08	2.16		1.02	3.08		0.50				1.53		
<i>Buliminella elegantissima</i>									0.54																
<i>Buliminella</i> sp. A											0.43														
<i>Casidulina globulosa</i>			0.45																						
<i>Casidulina</i> sp. A																	0.51								
<i>Cibicides fletcheri</i>								1.02					1.02												
<i>Cibicides lobatulus</i>	0.62	1.56	0.90	1.63	1.01			1.02		1.95	2.15	2.52		1.80	2.03	0.51	1.54	0.40		1.01			0.51		
<i>Cibicides</i> sp. A						1.17																			
<i>Coryphostoma gerorgiana</i>																									
<i>Discorbinella berteloti</i>																									
<i>Elphidium excavatum</i>	28.40	63.02	70.85	38.59	59.30	55.56	79.59	51.27	67.20	56.59	50.21	49.58	65.31	60.43	67.57	66.50	60.00	42.23	52.74	45.23	59.18	72.28	42.86	3.16	28.57
<i>Elphidium galvestonense</i>	0.62			0.54			2.04	0.51			1.29			1.08		2.54	1.03	0.40	0.50	1.01	1.02	2.97	0.51		
<i>Elphidium gunteri</i>	1.85	1.04			0.50			1.52						1.08		0.51	1.03	0.80					3.06	27.37	
<i>Elphidium macellum</i>																							0.51		

Species	SL123-1	SL123-3	SL123-4	SL123-5	SL123-6	SL123-7	SL123-8	SL123-9	SL123-10	SL123-11	SL123-12	SL123-13	SL123-14	SL123-15	SL123-16	SL123-17	SL123-18	SL123-19	SL123-20	SL123-21	SL123-Bluff	SL124-2	SL124-22	SL124-23	SL124-24
<i>Elphidium mexicanum</i>	4.94	1.56	1.35	1.09		6.43	1.02	15.23	1.08	0.98	2.15	2.94	1.02	4.32	2.03	2.54	2.05	1.59	3.98	6.03	3.06		0.51		
<i>Elphidium</i> sp. A																									
<i>Elphidium translucens</i>	2.47	1.56	0.45					2.54	0.54			2.52	1.02	2.52				0.40	1.00	1.01					
<i>Eponedes ropandus</i>				1.09																			2.04		
<i>Gavilinopsos preageri</i>				1.09								0.42		2.16		0.00	1.54		0.50						
<i>Glaberatela laurei</i>																									
<i>Gutulina estralis</i>														0.36									0.51		
<i>Gutulina glacialis</i>																						0.99			
<i>Hanzawia strattoni</i>	6.17	2.08	3.14	3.80	3.52	4.09	1.02	1.02	2.69	2.44	3.00	4.20		1.08		0.51	2.56		1.00	0.50	2.04		7.14		
<i>Hanzena germanica</i>												0.84								0.50					
Indeterminate agglutinated																									
Indeterminate rotaliid						0.58							2.04		0.68										
<i>Laryngosigma williamsoni</i>																									
<i>Nonionella atlantica</i>	0.62	0.52		1.09	0.50	1.75	0.00	0.51	0.54	0.49	1.29	2.10		0.36		1.52					1.02		1.02		
<i>Oolina melo</i>														0.36											
<i>Proeponedes lateralis</i>																							1.53		
<i>Quinqueloculina bosciana</i>					0.50	1.17					0.43	1.26							0.50						
<i>Quinqueloculina compta</i>																	0.51								
<i>Quinqueloculina frigida</i>				0.54																					
<i>Quinqueloculina impressa</i>																		0.80	3.98	1.51			0.51		
<i>Quinqueloculina jugosa</i>	1.85	0.52			3.52							0.84					0.51				1.02		0.51		
<i>Quinqueloculina lamarkiana</i>		1.04		4.89	1.01							1.68				0.51							4.08		
<i>Quinqueloculina poliana</i>						0.58																			
<i>Quinqueloculina seminula</i>	1.85	0.52	1.35	5.98	3.52	0.58				3.90	0.43	0.84	1.02	1.80		0.51			0.50		1.02	0.99	4.59	1.05	
<i>Quinqueloculina</i> sp. A																							1.02		
<i>Rosalina floridana</i>	0.62		1.35	1.63	0.50	0.58	1.02	0.51	0.54	1.95	3.00	0.42		1.08	0.68	1.02			1.00			0.99			
<i>Textularia earlandi</i>																									
<i>Tiphotrocha comprimata</i>																		0.40							

Species	SLI23-1	SLI23-3	SLI23-4	SLI23-5	SLI23-6	SLI23-7	SLI23-8	SLI23-9	SLI23-10	SLI23-11	SLI23-12	SLI23-13	SLI23-14	SLI23-15	SLI23-16	SLI23-17	SLI23-18	SLI23-19	SLI23-20	SLI23-21	SLI23-Bluff	SLI24-2	SLI24-22	SLI24-23	SLI24-24
<i>Triferina angulosa</i>			0.90		0.50		1.02	0.51		0.98	0.43	2.10				0.51									
<i>Triloculina</i> sp. A											0.43														
<i>Tritatix fusca</i>	2.47	1.56	1.35	0.54		1.75													0.50	0.50					
<i>Trochammina "squamata"</i>	0.62																					0.99	0.51		
<i>Trochammina inflata</i>																		0.40							
<i>Uvigerina subperegrina</i>																									
<i>Valvuleneria</i> sp. A						1.17		1.02						0.72					0.50						
<i>Wiesnerella auriculata</i>																	0.51								
Total	69.75	84.38	98.21	74.46	90.95	95.32	91.84	96.95	95.70	91.71	90.99	93.28	95.92	96.04	88.51	93.40	98.46	97.21	100.00	98.99	96.94	81.19	83.67	100.00	85.71
Species	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct	
<i>Ammonia parkinsoniana</i>	54.01	43.24	16.19	2.27	6.92	13.36		35.34	40.09	57.29	23.24	17.44	25.93	19.12	31.63	28.97	20.18	62.10	61.18	39.46	58.18	59.02	67.72	56.32	
<i>Ammonia tepida</i>		1.62							0.45					0.40			0.45	0.40		0.67	1.82		1.40		
<i>Ammotium salsum</i>																			0.39						
<i>Asterigerina carnata</i>															0.47										
<i>Asterigerinata pulchella</i>																	0.45								
<i>Bolivina lowmani</i>								0.40		0.50	1.24		0.46				0.45			2.34		0.70	0.38		
<i>Bolivina pseudoplicata</i>																							0.38		
<i>Bolivina</i> sp. A																									
<i>Bolivina spathulata</i>																							0.38		
<i>Bolivina striatula</i>													0.46										0.38		
<i>Buccella inusitata</i>		1.08	0.48		0.63	0.92		0.40	1.35			0.78	1.39	0.80	0.47								0.38		
<i>Buliminella elegantissima</i>											0.41						0.45					0.35	0.38		
<i>Buliminella</i> sp. A																									
<i>Casidulina globulosa</i>																									

Species	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct
<i>Casidulina</i> sp. A																								
<i>Cibicides fletcheri</i>																								
<i>Cibicides lobatulus</i>		0.54	2.38			3.23		0.80	0.45	1.51	2.07	0.78	2.31	3.19		1.59	2.24						0.35	
<i>Cibicides</i> sp. A																								
<i>Coryphostoma gerorgiana</i>																0.40								
<i>Discorbinella berteloti</i>											0.39						1.35			0.33			0.35	
<i>Elphidium excavatum</i>	44.53	45.95	60.95	51.14	66.67	58.06		60.24	50.45	37.19	65.98	65.50	61.57	61.75	59.53	63.89	62.78	34.27	30.98	51.84	27.27	40.98	23.51	35.25
<i>Elphidium galvestonense</i>			0.48		0.63									1.20				0.40	0.39					
<i>Elphidium gunteri</i>	0.73		0.48							0.50					0.47				0.39		3.64		1.05	0.77
<i>Elphidium macellum</i>																								
<i>Elphidium mexicanum</i>		0.54		2.27	0.63	0.92		1.61	2.70	3.02	2.49	2.33	2.31	0.80	1.40	1.59	0.90	0.40	5.88	2.34			0.70	1.15
<i>Elphidium</i> sp. A																								0.38
<i>Elphidium translucens</i>		1.08	0.48								0.41	1.55		1.20			0.90						0.35	0.38
<i>Eponedes ropandus</i>			0.48		1.26																			
<i>Gavilinopsos preageri</i>		1.62							0.45		0.41	1.55					0.45			0.33			1.75	2.30
<i>Glaberatela laurei</i>												0.78												
<i>Gutulina estralis</i>																								
<i>Gutulina glacialis</i>																0.40								
<i>Hanzawia strattoni</i>	0.73		4.76	11.36	5.03	1.84		0.80			2.07	0.78	0.93	3.19	1.40	1.98	2.69			0.67			0.35	
<i>Hanzena germanica</i>																								
Indeterminate agglutinated																					9.09			
Indeterminate rotaliid																								
<i>Laryngosigma williamsoni</i>																								
<i>Nonionella atlantica</i>			1.43		0.63	0.92			0.90		0.41		0.46	1.99			0.90			0.33			0.35	
<i>Oolina melo</i>																								
<i>Proeponedes lateralis</i>			0.48																					
<i>Quinqueloculina bosciana</i>																0.40	0.45							

Species	SLI24-25	SLI24-26	SLI24-1-oct	SLI24-5-oct	SLI24-6-oct	SLI24-7-oct	SLI24-8-oct	SLI24-9-oct	SLI24-10-oct	SLI24-11-oct	SLI24-12-oct	SLI24-13-oct	SLI24-14-oct	SLI24-15-oct	SLI24-16-oct	SLI24-17-oct	SLI24-18-oct	SLI24-19-oct	SLI24-20-oct	SLI24-21-oct	SLI24-23-oct	SLI24-24-oct	SLI24-25-oct	SLI24-26-oct
<i>Quinqueloculina compta</i>												0.39		0.40			0.45							
<i>Quinqueloculina frigida</i>																								
<i>Quinqueloculina impressa</i>									0.45														0.35	
<i>Quinqueloculina jugosa</i>		0.54			1.26	0.46																		
<i>Quinqueloculina lamarkiana</i>			0.95	20.45	2.52	1.84						0.39											0.35	
<i>Quinqueloculina poliana</i>																								
<i>Quinqueloculina seminula</i>			2.38	1.14	3.77	2.76			0.90			1.94	1.85	2.39			0.90							
<i>Quinqueloculina</i> sp. A																								
<i>Rosalina floridana</i>		1.62		1.14					0.45					0.40			0.45	0.40		0.33				0.38
<i>Textularia earlandi</i>															0.47				0.39				0.35	0.38
<i>Tiphotrecha comprimata</i>																								
<i>Triferina angulosa</i>		0.54						0.40	0.45		0.83	1.16			0.93		0.90			0.33				0.38
<i>Triloculina</i> sp. A																								
<i>Tritaxis fusca</i>			0.48	1.14	0.63	0.92						0.39												
<i>Trochammina "squamata"</i>																								
<i>Trochammina inflata</i>																								
<i>Uvigerina subperegina</i>																0.40								
<i>Valvuleneria</i> sp. A		0.54	0.48			0.46																		
<i>Wiesnerella auriculata</i>																								
Total	100.00	98.92	92.86	90.91	90.57	85.71	0.00	100.00	99.10	100.00	99.59	96.12	97.69	97.21	96.74	99.60	97.31	97.98	99.61	99.00	100.00	100.00	100.00	100.00