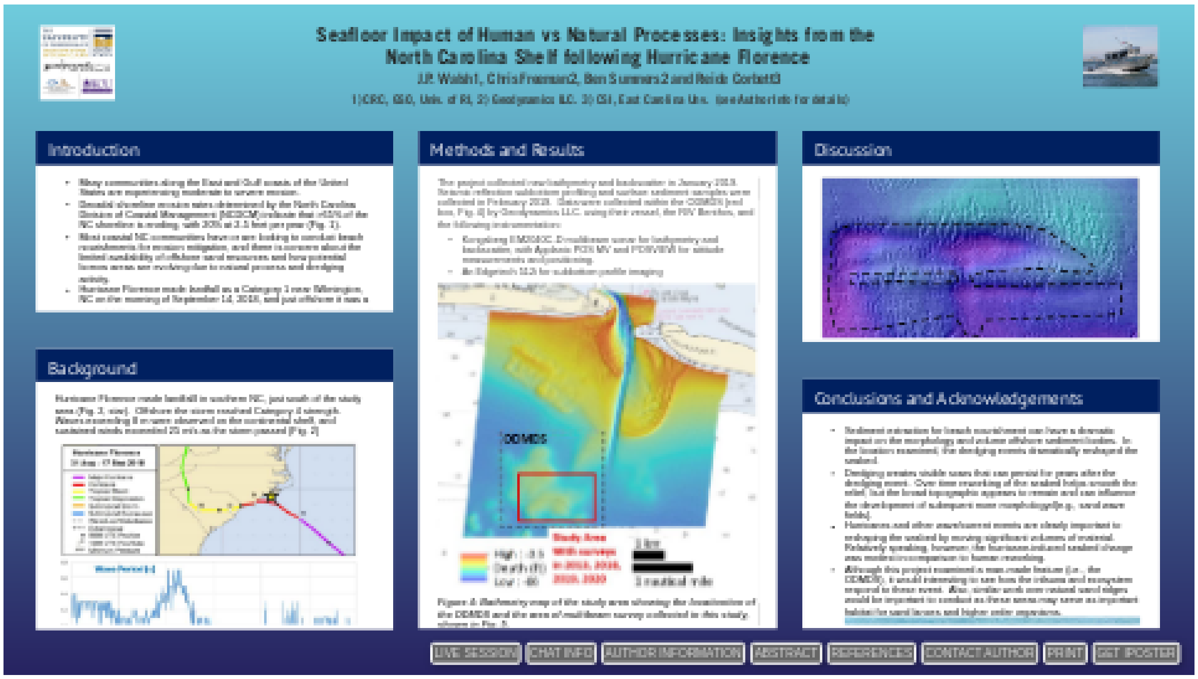
Seafloor Impact of Human vs Natural Processes: Insights from the North Carolina Shelf following Hurricane Florence



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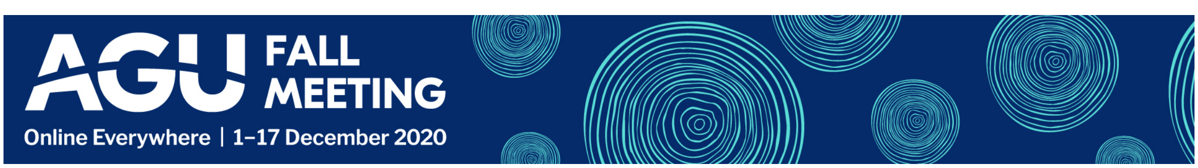

INTRODUCTION

- Many communities along the East and Gulf coasts of the United States are experiencing moderate to severe erosion.
- Decadal shoreline erosion rates determined by the North Carolina Division of Coastal Management (NCDCM) indicate that >65% of the NC shoreline is eroding, with 20% at 2-5 feet per year (Fig. 1).
- Most coastal NC communities have or are looking to conduct beach nourishments for erosion mitigation, and there is concern about the limited availability of offshore sand resources and how potential borrow areas are evolving due to natural process and dredging activity.
- Hurricane Florence made landfall as a Category 1 near Wilmington, NC on the morning of September 14, 2018, and just offshore it was a powerful Category 4 (Fig. 2). Many communities in southern NC and northern SC experienced significant erosion, including Bogue Banks (Fig. 1, yellow box).
- **The objective of this study was to examine changes in an offshore borrow area in response to natural (i.e., Hurricane Florence, 2018) and dredging activity (in 2013 and 2020).**

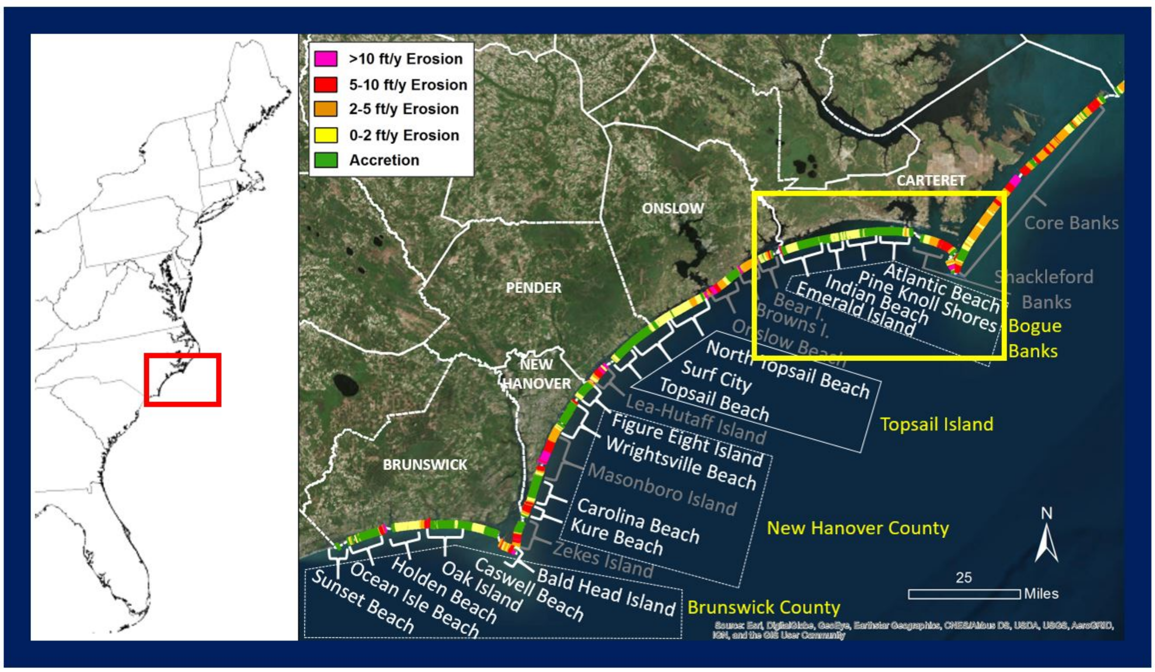

Figure: 1 Map of long-term erosion rates along southeastern North Carolina, USA. Red box indicates map location. Along the area shown (and most of the U.S. East Coast) chronic long-term erosion is a widespread problem. Many communities are conducting beach nourishment projects to mitigate the potential threats of erosion. Bogue Banks (yellow box and location of Fig. 2) is a barrier island system where sand placement has transpired, and immediately offshore of Atlantic Beach is the site of research for this project.

BACKGROUND

Hurricane Florence made landfall in southern NC, just south of the study area (Fig. 2, star). Offshore the storm reached Category 4 strength. Waves exceeding 8 m were observed on the continental shelf, and sustained winds exceeded 25 m/s as the storm passed (Fig. 2)

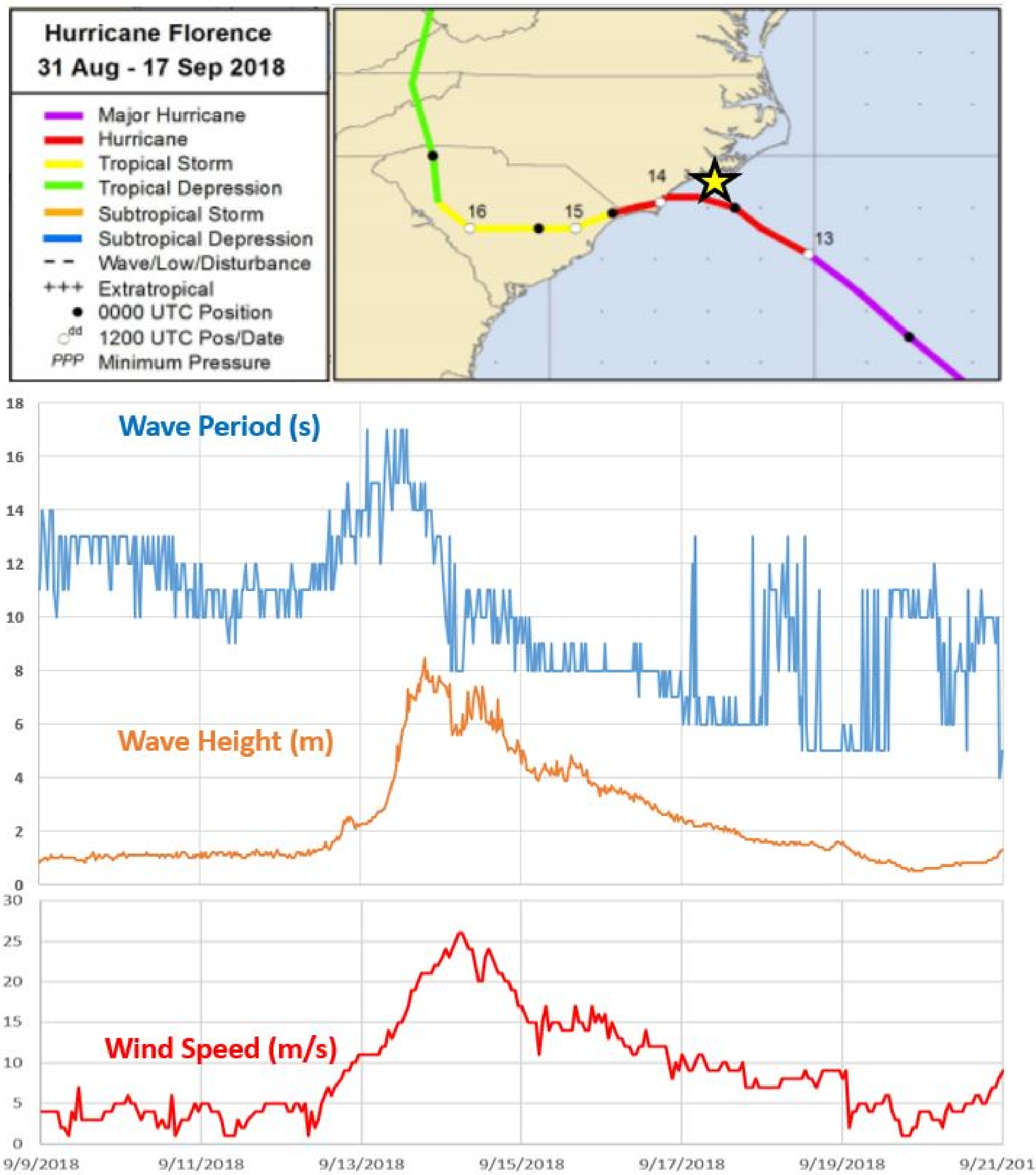

Figure 2: Track of (top) and conditions during Hurricane Florence. Note long-period (>14s) waves with heights of >8 m along with currents would have generated bed stresses suitable for significant sediment transport as observed during past hurricanes (Wren and Leonard, 2005)

Carteret County, where Bogue Banks is located in NC, has been proactively preparing its coast for hurricanes by investing in nature-based infrastructure (e.g., dunes). Its Shore Protection Office in partnership with private, state and federal entities has created a long-term plan for shoreline management. The area completed a significant nourishment in 2013 (~1 million cubic yards), following Hurricane Irene. This major nourishment, along with another following Florence, used sediment dredged from the Ocean Dredged Material Disposal Site (ODMDS) borrow area (Fig. 3).

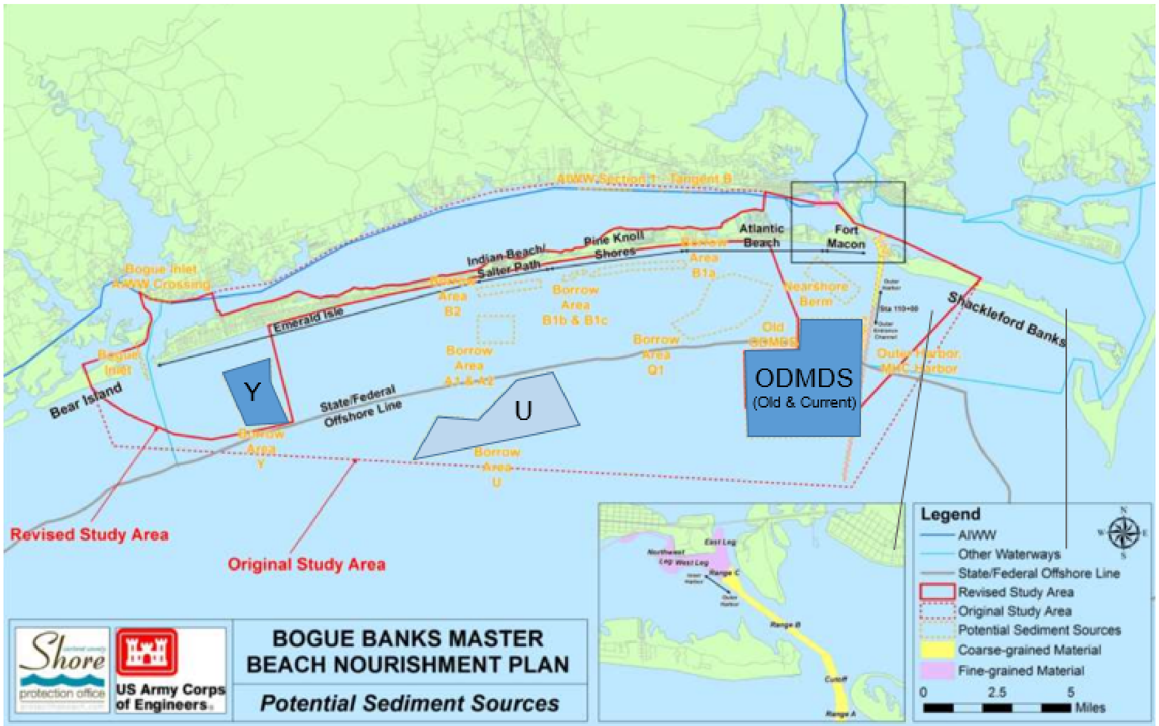

Figure 3: Map from the Boge Banks Master Beach Nourishment Plan (BBBMNP, 2017). This study examined seafloor dynamics in the ODMDS. Red box shows the location of Fig. 4.

METHODS AND RESULTS

The project collected new bathymetry and backscatter in January 2019. Seismic reflection subbottom profiling and surface sediment samples were collected in February 2019. Data were collected within the ODMDS (red box, Fig. 4) by Geodynamics LLC. using their vessel, the R/V Benthos, and the following instrumentation:

- Kongsberg EM2040C-D multibeam sonar for bathymetry and backscatter, with Applanix POS MV and POSVIEW for attitude measurements and positioning.
- An Edgetech 512i for subbottom profile imaging

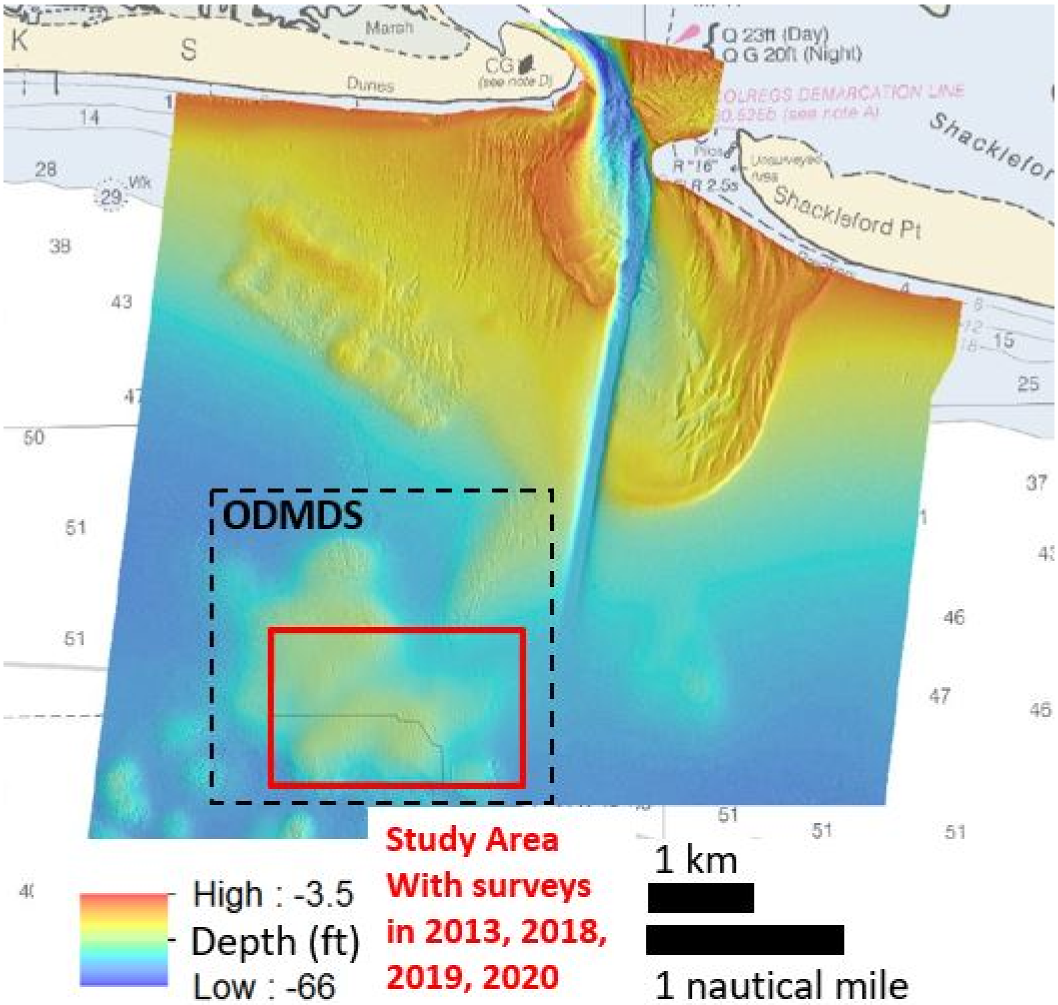

Figure 4: Bathmetry map of the study area showing the location of the ODMDS and the area of multibeam survey collected in this study, shown in Fig. 5.

Multibeam was processed with CARIS HIPS/SIPS, and backscatter surfaces were generated in Fledermaus FGMT software. Seismic data were examined and interpreted using Chesapeake Scientific SonarWiz, and the sediment grain-size distributions were measured with a Malvern Mastersizer 3000 laser diffraction grainsize. Where gravel was present, sediments were presieved at 2 mm, and distributions were adjusted accordingly.

These data were added to the collection of existing information at the study site. Also, another bathymetry and backscatter dataset was collected in spring 2020 following dredging for a Post-Hurricane Florence beach nourishment project.

Exciting Results

Shaded bathymetry provides a wonderful visualization of the seafloor after Hurricane Florence. The gross morphology has a variable geometry with the gross positive relief related to deposition of the ODMDS and the prominent linear depression created by dredging in 2013. Superimposed on shallow portions of the deposit are NNW-SSE oriented ridges, presumably created by Hurricane Florence.

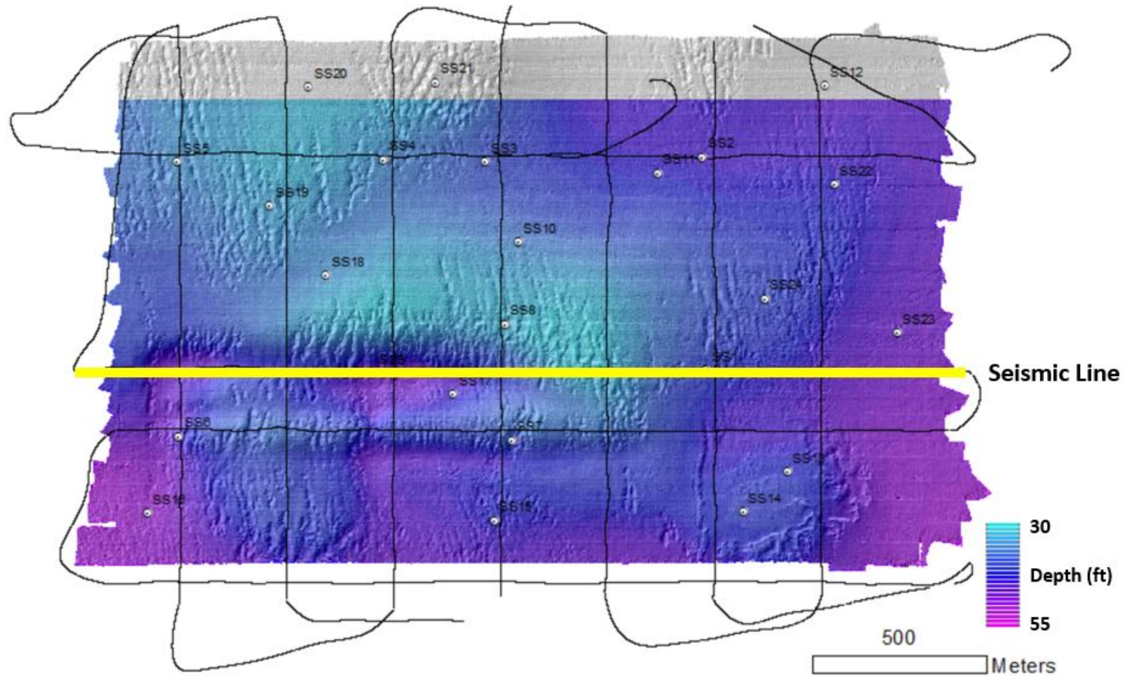

Figure 5: Post-Hurricane Florence shaded multibeam bathymetry. Locations of seismic lines and sediment grab samples are shown with the location of Figure 6 noted by the yellow line. Grain-size data from sediment samples are presented in Fig. 7. Bathymetry data from other surveys are shown in Fig. 8 along with an outline of the area dredged in 2013.

Seismic-reflection profiles show the ODMDS deposit overlying transgressive and older deposits. (Fig. 4)

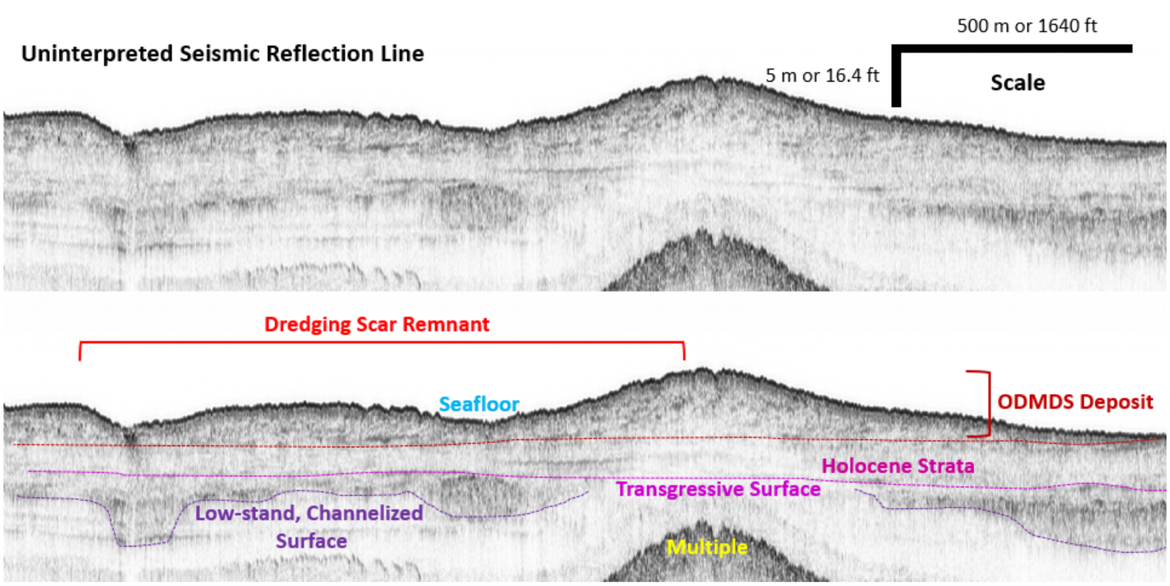

Figure 6: Uninterpreted (top) and interpreted (bottom) E-W-oriented seismic reflection line. Note, the ODMDS deposit overlies horizontally bedded Holocene strata.

Surface samples show the sediments across the area are dominantly fine-to-medium sands, <500 microns in size (Fig. 7). This well-sorted sand was dredged from Beaufort Inlet, making it an excellent source for beach nourishment. This project is examining this area to see how it responds to dredging and storm reworking.

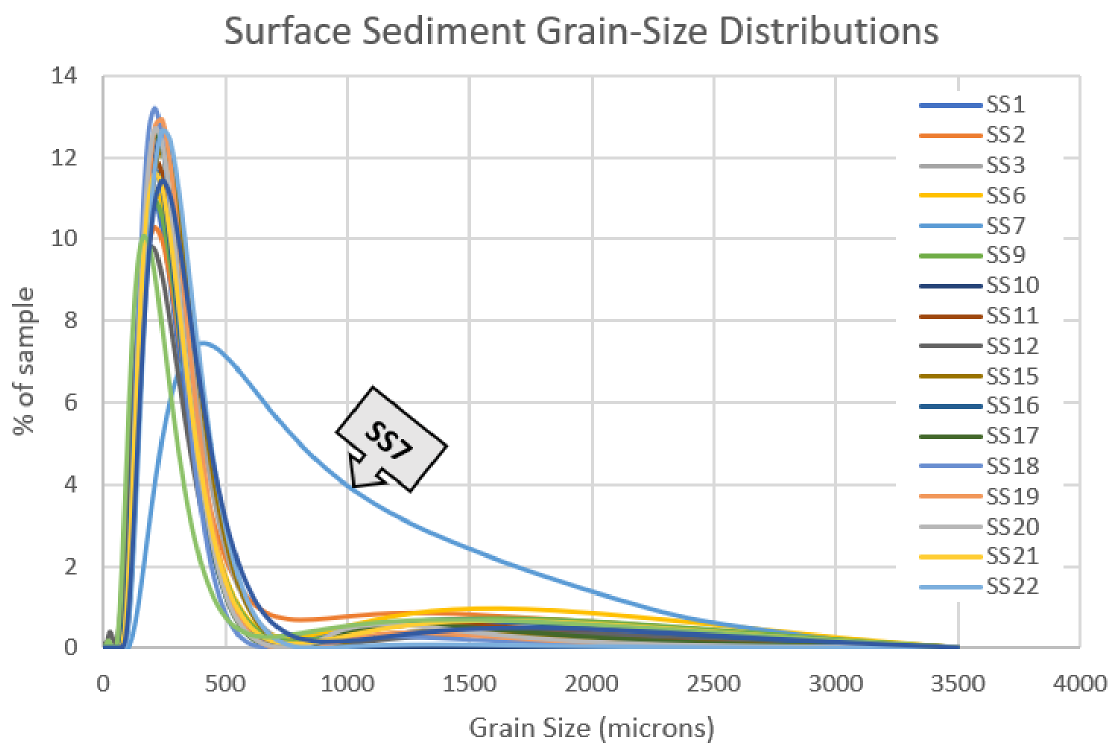

Figure 7: Grain-size distribution of the sand-component of the surface samples. Note, gravel only represented a few percent of most samples. Data show samples (except SS7) are similarly well-sorted sand.

This research is informed by time-series multibeam data which are summarized in Table 1, and the collection of data are visible in Figure 8 (an animated gif).

Table 1: Bathymetric datasets collected and associated observations.

Year	Associated Event	Qualitative Description	Elevation Change Relative to Previous	Slopes
2013	Post-dredging	Pronounced E-W hopper-dredge tracks across ~1 km2	>15 ft` (5 m)	10-25° in dredge
2018	Pre-Hurricane Florence	Broad E-W dredge depressions, >3 m deep, >1 km wide, Shallow: N-S sand waves, ~0.15m H, ~15 m λ	Up to 3 ft (1 m) in dredged areas	Mostly <2.5° & 2-5° around dredge area
2019	Post-Hurricane Florence	Broad E-W dredge depressions >1km wide, Shallow: NNW-SSE sand waves, ~0.25m H, ~30 m λ	<1 ft (<0.33 m)	Mostly <2.5°; & 2-5° around dredge area
2020	Post-dredging	Pronounced, complicated dredge scars, >1km wide, with islands of non-dredged areas	Up to 5 ft (1.5 m) in dredge areas	2.5-10° common

DISCUSSION

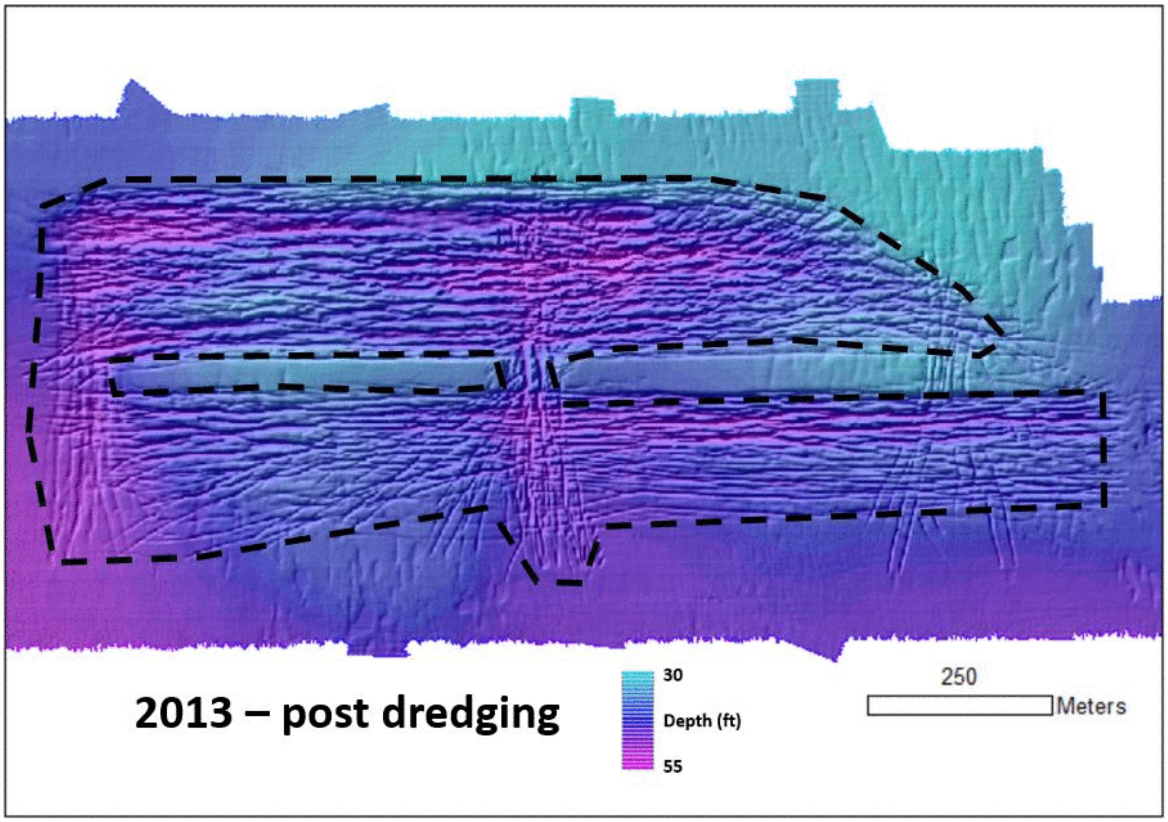

Figure 8: An animated gif (wait to see all four images) of bathymetry from the four surveys. Location is shown in Fig. 4. To help visualize the changes, an outline (dotted line) of the area dredged in 2013 is superimposed on all four datasets. In the 2013 and 2020 bathymetries, dredging tracks are conspicuous. An image of a hopper dredge is shown in the Conclusions.

Bathymetric data reveal pronounced changes between all years, with the most dramatic changes evident after dredging events in 2013 and 2020. After Hurricane Florence, well-developed but discontinuous NNE-SSE oriented sand waves are visible, especially around the perimeter of the 2013 dredging scar (Fig. 8, i.e., near the dashed line). A summary of bathymetric differences are noted in Table 1 and are visible in Figure 9.

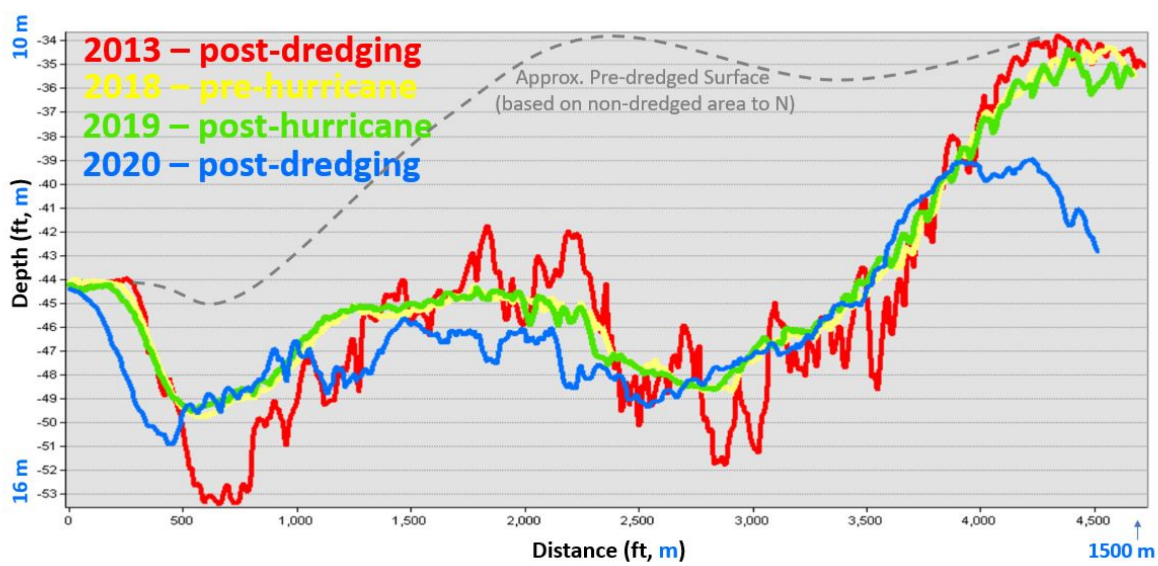

Figure 9: Topographic profiles showing change over time, including an approximation of the pre-dredging topography in 2013. Data are from the location indicated by the yellow line in Figure 5 (i.e., where the seismic-reflection profile was collected). Over time the elevation across the area shown is progressively reduced due to dredging removal.

Mapping of slopes across the bathymetry sheds like on the variability of the seafloor topography. Following the dredging in 2013, a prominent mixture of slopes is visible. Figures 10 highlights the slope changes over time. Steepest slopes are observed following dredging.

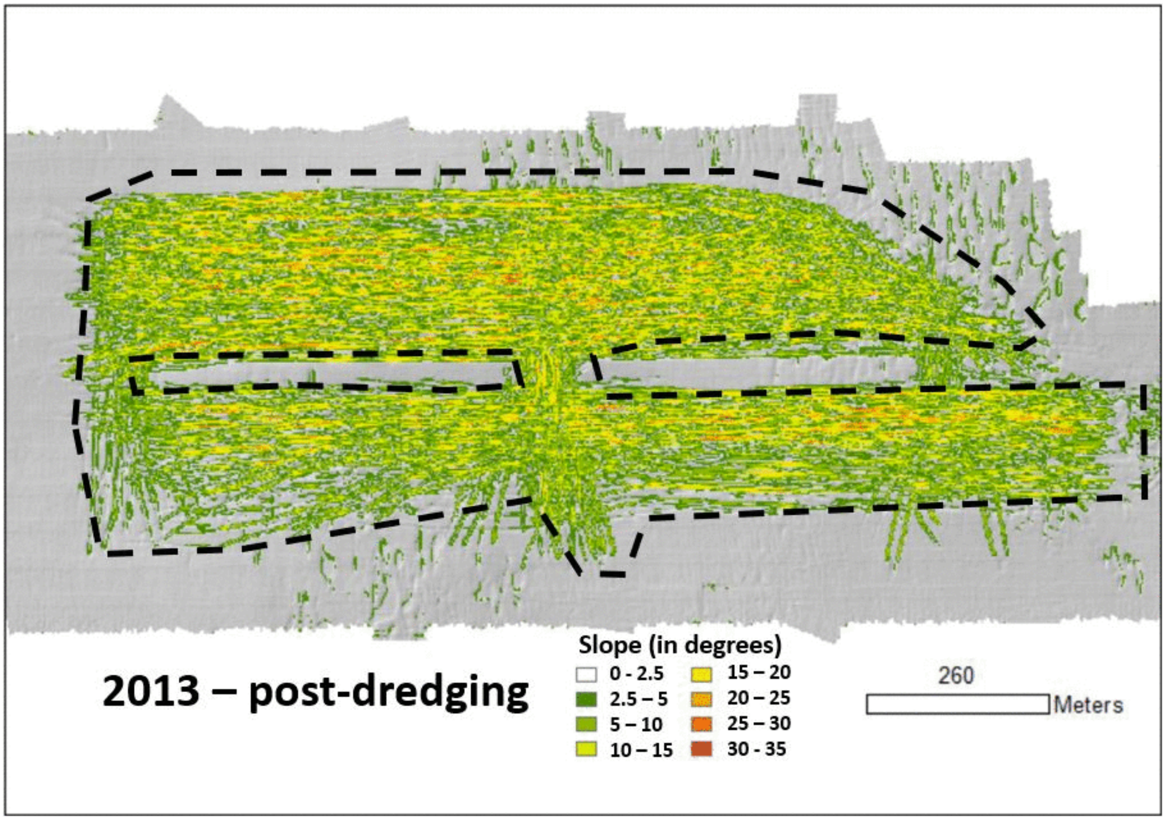

Figure 10: Slope variations determined from the four bathymetric datasets. The dashed line denotes the approximate boundary of dredging in 2013 (see Fig. 8).

The change in the seafloor due to Hurricane Florence is modest in comparison to that induced by dredging in 2013 and 2020. Histograms of elevation changes for two differences clearly demonstrate how erosion and deposition following the dredging (on left, Fig. 11) was considerable vs. the measured change from pre- to post-Hurricane Florence (on right, Fig. 11).

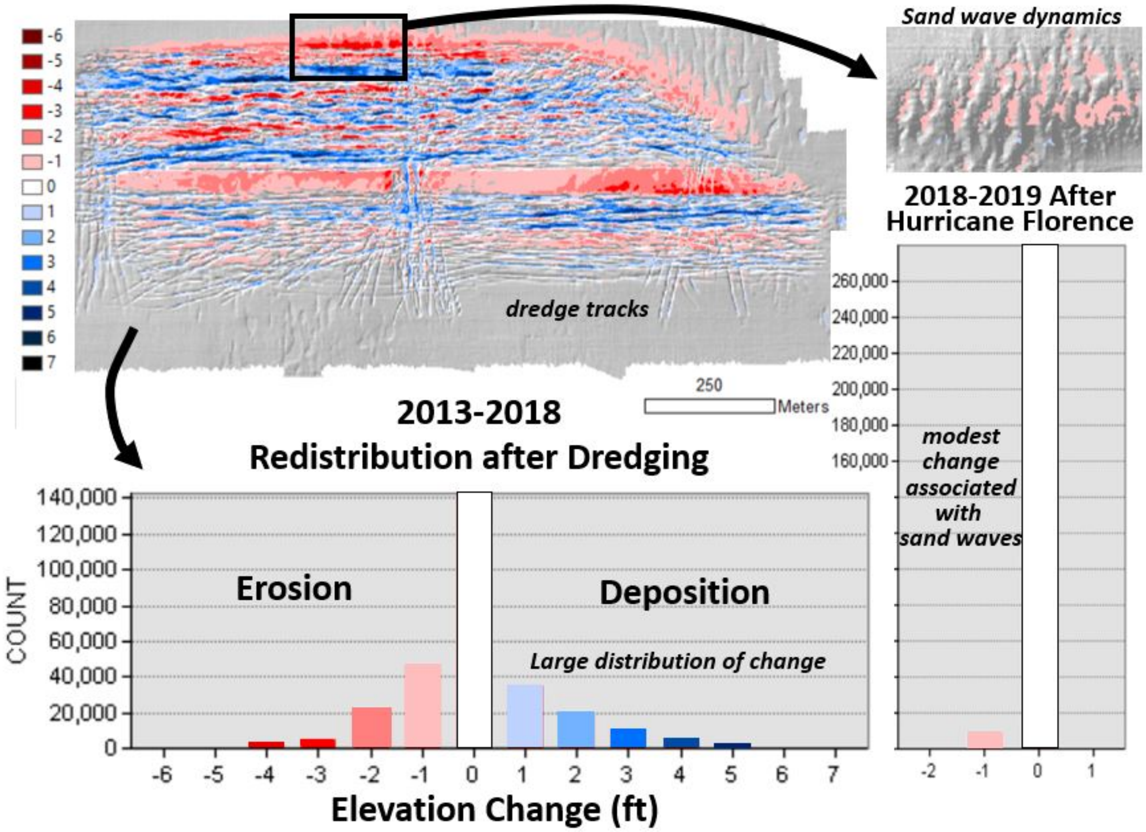

Figure 11: Erosion and deposition data for the periods indicated. On left is a map (top) and histogram (bottom) of erosion and deposition for the 5-year period following dredging in 2013. Note the great range (but balance) in the distribution, reflecting reworking of the destabilized seabed surface. On the right, similar data are shown, with the map of a subregion following Florence, showing erosion in the sand wave troughs. But the overall distribution of change for the same area has very limited reworking.

CONCLUSIONS AND ACKNOWLEDGEMENTS

- Sediment extraction for beach nourishment can have a dramatic impact on the morphology and volume of offshore sediment bodies. In the location examined, the dredging events (by a hopper dredge, e.g., pictured below) notably reshaped the seabed.
- Dredging creates visible scars that can persist for years after the dredging event. Over time reworking of the seabed helps smooth the relief, but the broad topographic appears to remain and can influence the development of subsequent more morphology (e.g., sand wave fields).
- Hurricanes and other wave/current events are clearly important to reshaping the seabed by moving significant volumes of material. Relatively speaking, however, the hurricane-induced seabed change was modest in comparison to human reworking.
- Although this project examined a man-made feature (i.e., the ODMDS), it would interesting to see how the infauna and ecosystem respond to these events. Also, similar work over natural sand ridges would be important to conduct as these areas may serve as important habitat for higher-order organisms.

Acknowledgements

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Image of a hopper dredge, the type used for dredging of the study area. Note, the two suction arms leave noticeable features on the seabed (e.g., Fig. 8) but these visible tracks are reworked and erased over time.
Source: https://confluence.qps.nl/qinsy/latest/en/trailing-suction-hopper-dredger-tshd-object-definitions-54878709.html (https://confluence.qps.nl/qinsy/latest/en/trailing-suction-hopper-dredger-tshd-object-definitions-54878709.html)

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ABSTRACT

Many communities along the East and Gulf coasts of the United States are experiencing moderate to severe erosion. Decadal shoreline erosion rates determined by the North Carolina Division of Coastal Management indicate that >65% of the NC shoreline is eroding, with 20% losing shore at ~1 m per year. Chronic long-term erosion and episodic rapid impacts from storms have encouraged most coastal NC communities to conduct beach nourishments for mitigation. One concern is that there is limited knowledge of how offshore sand shoals – often sources for nourishments – are evolving in response to storm conditions and dredging activity. In September 2018, Hurricane Florence impacted southern NC and northern SC, and many communities experienced enhanced erosion. Future offshore sand removal for beach nourishment is inevitable here and elsewhere along the East Coast. A borrow area on the continental shelf seaward of Bogue Inlet (NC) offers an opportunity to see how the seabed is changing as a result of anthropogenic and oceanographic processes.

Hurricane Florence made landfall as a Category 1 near Wilmington, NC on the morning of September 14, 2018. Prior to making landfall the storm was a powerful Category 2 hurricane, down from Category 4 status days prior. Hurricane-force winds were experienced over a large region, yielding powerful storm surge and waves over 8 m near the study area. Given the water depths of the ODMDS, seabed reworking was anticipated. The project collected geophysical data and sediment samples over a portion of the ODMDS offshore of Bogue Banks, NC in February 2019. Multibeam bathymetry, backscatter and seismic reflection data were obtained along with 24 sediment samples. These data add to previously collected data over the same area in 2013 and 2018. Grain-size analysis has been completed on all collected samples.

Preliminary analysis of the post-hurricane data in comparison to earlier results indicate that the seabed has been reshaped since the last survey in March 2018, likely in response to Hurricane Florence. The broad dome-shape of the ODMDS remains, however, there is conspicuous morphological change. In shallower areas large sand waves (crests oriented roughly N-S, wavelength 20-30 m) differ from earlier mapping. Despite notable reworking, the anthropic signature of dredging in 2013 remains on the seascape.

REFERENCES

BBBMNP (Bogue Banks Beach Master Nourishment Plan). 2017. Information available from http://www.carteretcountync.gov/313/Preservation-Plan.

Wren, P.A. and Leonard, L.A, 2005. Sediment transport on the mid-continental shelf in Onslow Bay, North Carolina during Hurricane Isabel. Estuarine, Coastal, and Shelf Science 63: 43-56.