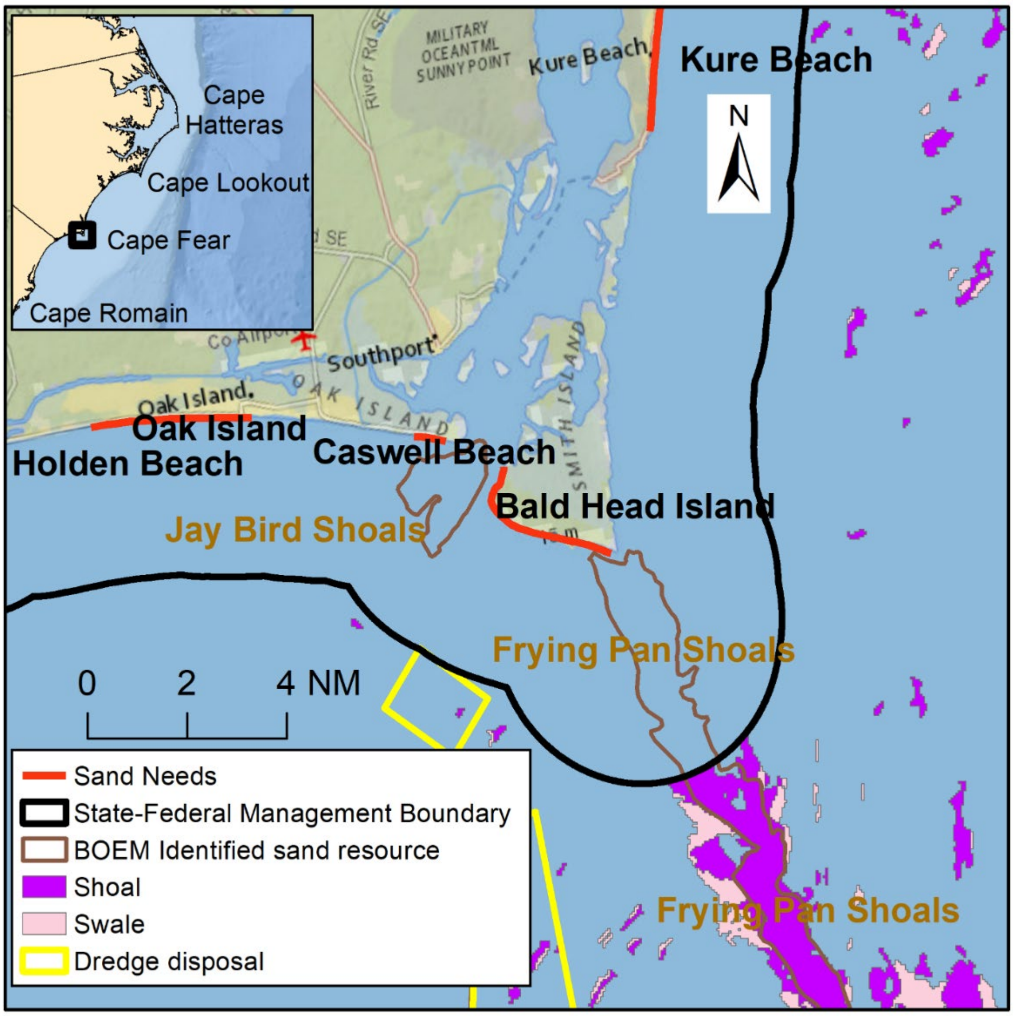
OCS Study
BOEM 2021-028

Assessment of Frying Pan Shoals as a Potential Sand Source in the Cape Fear Region of North Carolina



U.S. Department of the Interior
Bureau of Ocean Energy Management
Sterling, VA

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Assessment of Frying Pan Shoals as a Potential Sand Source in the Cape Fear Region of North Carolina

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DISCLAIMER

Study concept, oversight, and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, DC, under Contract Number 140D0419F0461. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the US Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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CITATION

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ABOUT THE COVER

Overview of sand shoals and towns of interest near Frying Pan Shoals. The black line represents the border of state and federally managed waters. Classified shoals and swales (pink and purple colors) derived from Pickens et al. (2021b) are shown in offshore federal waters. BOEM identified sand resource data provide information for federal and state-managed waters. The red line indicates sand needs identified by the US Army Corps of Engineers (Taylor Engineering Inc. 2020).

ACKNOWLEDGMENTS

We thank the staff and scientists of the BOEM Marine Minerals Program for their insights throughout the process of interviews, workshops, and literature synthesis. We thank the many local-, state-, and federal government participants in this process as well as the expertise provided by academic participants. Valuable information, input, and feedback were provided by these participants during the course of the assessment process.

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List of Abbreviations and Acronyms

ACT Network	The Atlantic Cooperative Telemetry Network
ARNI	Aquatic Resource of National Importance
BOEM	Bureau of Ocean Energy Management
CPUE	catch per unit effort
cm s^{-1}	centimeter(s) per second
EFH	Essential Fish Habitat
EIS	environmental impact statement
FACT Network	Florida Atlantic Coast Telemetry Network
FPS	Frying Pan Shoals
ft	foot/feet
HAPC	Habitat Area of Particular Concern
HMS	highly migratory species
K&W	Kearns & West
km	kilometer(s)
km hr^{-1}	kilometer(s) per hour
lb	pound(s)
m	meter(s)
m^3	cubic meter(s)
MCY	million cubic yard(s)
mi	mile(s)
mm	millimeter(s)
NMFS	National Marine Fisheries Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
OCS	outer continental shelf
ppt	part(s) per thousand
s^{-1}	per second
TSHD	trailing suction hopper dredge
UNCW	University of North Carolina Wilmington
USACE	United States Army Corps of Engineers
VBHI	Village of Bald Head Island
yd	yard(s)

Preface

BOEM, through the Department of the Interior's Collaborative Action and Dispute Resolution office, contracted with Kearns & West to convene technical experts and stakeholders for interviews and workshops, as well as to produce a report synthesizing the state-of-knowledge and priority research gaps of Frying Pan Shoals (FPS), a potential sand source in the Cape Fear Region of North Carolina. Kearns & West is a collaboration, stakeholder engagement, and process design firm that assisted with the planning, coordination, and facilitation of a series of situation assessment interviews followed by a technical expert workshop and a stakeholder workshop that took place virtually on October 13 & 16, 2020, and December 10, 2020, respectively. Kearns & West contracted CSS-Inc. to help provide a synthesis of findings from these events, and to provide a synthesis of the state-of-knowledge in the context of FPS' geological, oceanographic, and biological conditions. CSS-Inc. is a safety, health, and scientific support service provider. This report is an effort to take stock of what is known and unknown, from a scientific perspective, about FPS in the context of the potential for sand dredging in the Cape Fear Region of North Carolina. The Bureau of Ocean Energy Management (BOEM) intends this document to articulate known information about FPS and similar cape-associated sand shoal systems. This report, and the interviews and workshops conducted, were designed to seek information from technical experts and stakeholders to identify or fill data gaps at FPS in advance of possible future BOEM lease requests and to help formulate a science/research strategy.

1 Introduction

1.1 Sand Availability and the Need for Sand in the Cape Fear Region

The coastal communities of the Cape Fear Region of North Carolina have experienced rapid population growth, increased economic growth via tourism, and increased land values. Investments in beach nourishment projects in the Cape Fear Region from 2000 to 2019 have exceeded $137 million and brought > 20 million yd^3 (> 18 million m^3) of sand to beaches, including the beaches of Bald Head Island, Caswell Beach, Oak Island, Holden Beach, and Kure Beach (**Table 1**) (PSDS 2020). These projects are typically constructed to reduce risk of damage to infrastructure, restore eroded beaches, and provide improved recreation benefits. Erosion continues to be problematic, and the demand for long-term, beach-compatible sand resources to support future nourishment needs is increasing. A study of Brunswick County beaches showed 52% of shorelines were eroding; erosion rates were up to -3.2 ft $year^{-1}$ (-0.98 m $year^{-1}$) except for areas of higher erosion near inlets (Overton et al. 1999). The North Carolina Division of Coastal Management (2020) has compared ocean-side erosion rates from the 1940s to 2016 with the following results (**Figure 1**):

- Bald Head Island had lengthy shorelines that were eroding with an average of -5.1 ft $year^{-1}$ (-1.56 m $year^{-1}$) where erosion occurred.
- Caswell Beach and Kure Beach have largely been eroding with rates averaging -1.9 ft $year^{-1}$ (-0.58 m $year^{-1}$) where erosion occurred.
- Oak Island had erosion rates averaging -0.83 ft $year^{-1}$ (-0.25 m $year^{-1}$) where erosion occurred.

Table 1. History of beach nourishment projects in the Cape Fear Region since 2000

Beach	Number of Projects	Years of Renourishment (2000–2019)	Total Volume of Sand (yd^3)	Total Estimated Nominal Cost
Bald Head Island	9	2001, 2005, 2006, 2007, 2010, 2012, 2013, 2015, 2019	10.3 million	$68 million
Caswell Beach	2	2001, 2009	1.2 million	$13 million
Holden Beach	17	2002, 2003, 2004, 2006, 2008, 2009, 2010, 2011, 2012, 2014, 2017	3.3 million	$20.8 million
Oak Island	2	2001, 2015	2.6 million	$28 million
Kure Beach	6	2001, 2004, 2007, 2010, 2013, 2016	3.2 million	$28 million

Data source: Western Carolina University (PSDS 2020), http://beachnourishment.wcu.edu/

In 2020, the United States Army Corps of Engineers (USACE) South Atlantic Division completed an analysis of sand availability and beach renourishment needs in the southeast region (Taylor Engineering Inc. 2020). Using data on historic nourishment placement volumes and stakeholder inputs on future needs, the study showed New Hanover and Brunswick Counties of North Carolina will have a net sediment deficit over the next 50 years. This estimate includes the use of Regional Sediment Management best practices, defined as a "system approach [to manage] the effective use of sediments in coastal, estuarine, and inland environments." (USACE 2020).

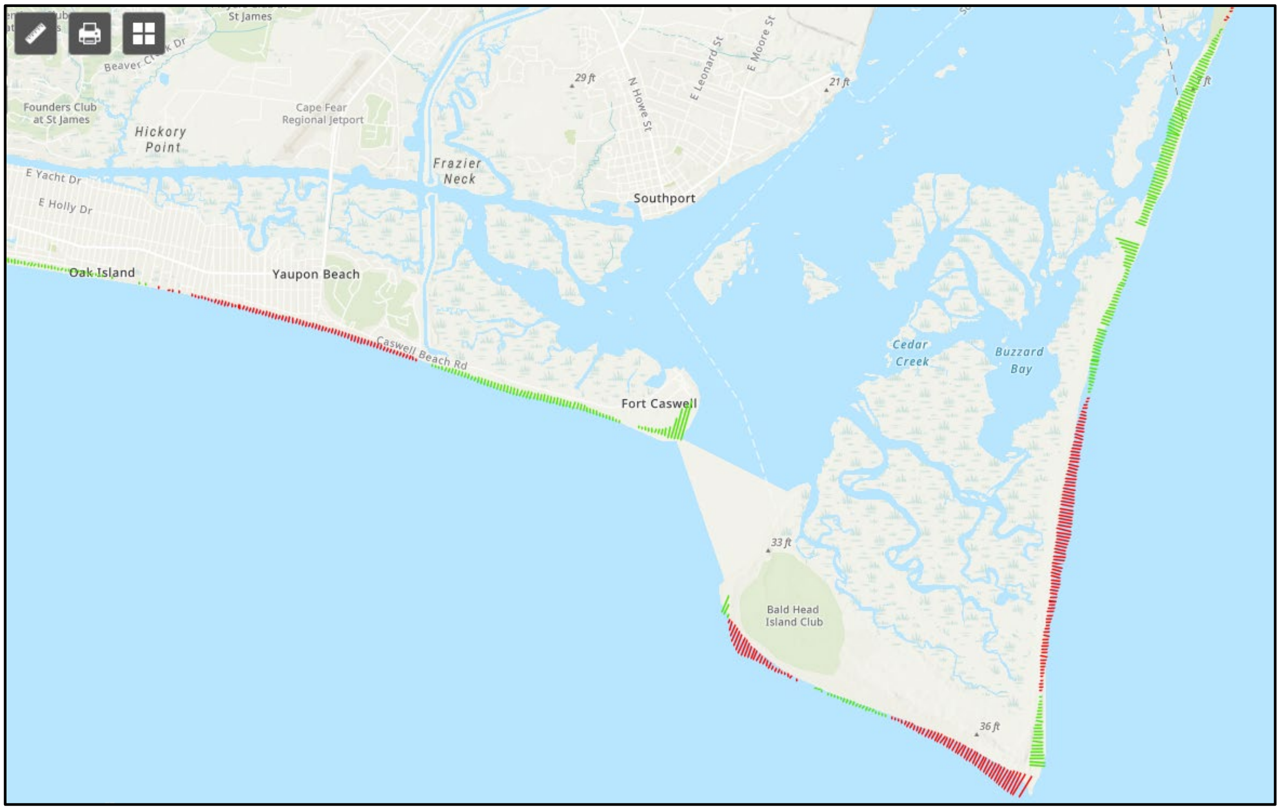

Figure 1. Long-term shoreline erosion rate estimates in the vicinity of FPS.
Data and map by the North Carolina Division of Coastal Management (2020). Red transects represent eroding shoreline, and green transects represent accreting shorelines from the period spanning the 1940s to 2016.

Historically, beach-compatible sand resources have been beneficially placed on adjacent beaches through various navigation-related dredging projects in the Cape Fear Region. However, the current demand for sand exceeds the available volume and frequency of navigation dredging events, and navigation dredging is generally not considered a long-term solution. Therefore, additional offshore sand resources would be needed to meet the demand for sand.

Based on recent sand search surveys conducted offshore of Brunswick County beaches, alternative long-term sand resource options are severely limited, with the exception of Frying Pan Shoals (FPS). Both state and federally managed sand resources located at FPS are under consideration for local municipalities to support long-term beach nourishment needs (**Figure 2**).

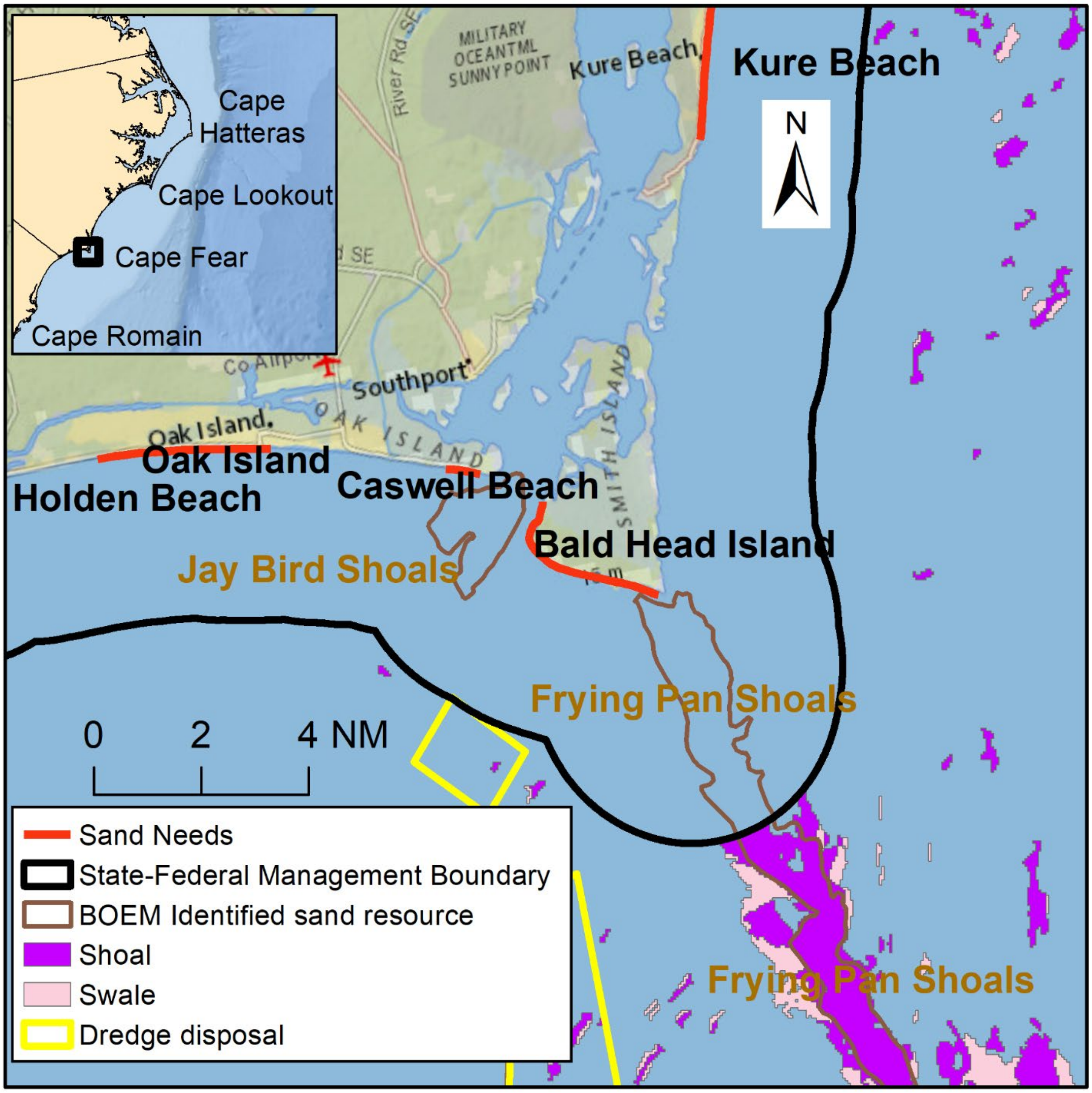

Figure 2. Overview of sand shoals and towns of interest near FPS.
The black line represents the border of state and federally managed waters.
Data sources: Modeling from Pickens et al. (2021b) show shoals and swales (pink and purple colors) in federal waters. BOEM identified sand resources were mapped from various geological and geophysical data (https://mmis.doi.gov/ BOEMMMIS/). The red line indicates sand needs identified by the USACE South Atlantic Division Sand Availability and Needs Determination report (Taylor Engineering Inc. 2020).

1.2 Introduction to Sand Shoals and Frying Pan Shoals

Sand shoals are composed of unconsolidated sediments formed into topographic highs, and they are often preferred for dredging because of their high volume of sand. Rutecki et al. (2014) defines sand shoals as:

> "A shoal is a natural, underwater ridge, bank, or bar consisting of, or covered by, sand or other unconsolidated material, resulting in shallower water depths than surrounding areas."

As sand shoals are part of a broader system, the term shoal complex refers to "...two or more shoals (and includes adjacent morphologies, such as troughs separating shoals) that are interconnected by past and/or present sedimentary and hydrodynamic processes" (Rutecki et al. 2014). In particular, large shoal complexes associated with cape landforms (herein, cape-associated shoals) have the potential to affect the geology, oceanography, and ecology of the marine environment. FPS is a cape-associated shoal complex located southeast of Bald Head Island, North Carolina, and it extends seaward from the cape (**Figures 2 and 3**). FPS is located northeast of waters designated as Wind Planning Areas (**Figure 3**). FPS is currently designated by the National Marine Fisheries Service (NMFS) as an Essential Fish Habitat (EFH) and a Habitat Area of Particular Concern (HAPC), and dredging is considered a potential threat to EFH and HAPCs. NMFS has expressed concern that long-term and repeated dredging operations could impact the habitat value that supports several important commercial and recreational fisheries.

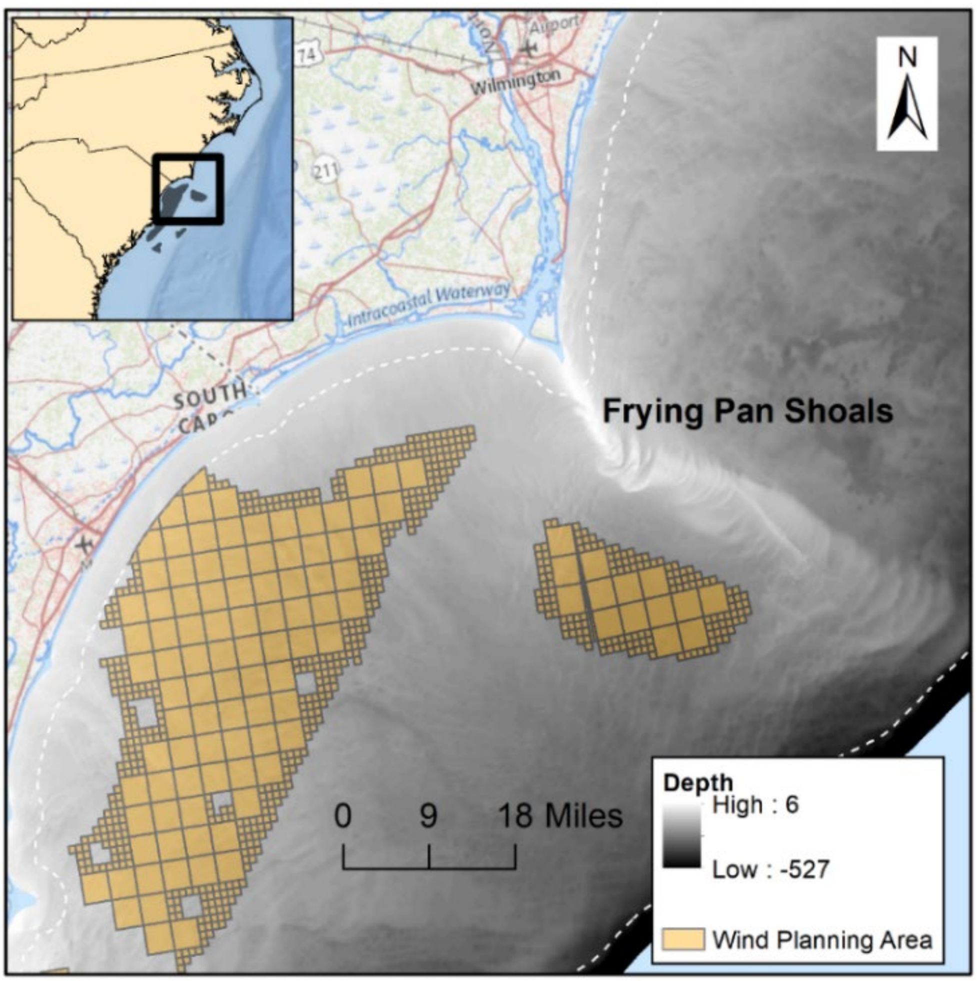

Figure 3. The Cape Fear Region with BOEM Wind Planning Areas and water depth.

1.3 Objectives of the Report

The objectives of this report are to:

A) Share the methodology and processes that have taken place to assess FPS as a potential sand source. This includes interviews, a technical expert workshop, a stakeholder workshop, and a literature synthesis specific to FPS.

B) Introduce sand dredging actions and summarize potential effects of dredging to the marine environment. This includes a particular emphasis on fish and their associated habitat.

C) Highlight the collective knowledge of geology, oceanography, and biology of FPS. Specifically, a focus was placed on topics that were noted as concerns by interviewees regarding the potential impact of sand dredging on species and their habitats in offshore, federally managed waters.

D) Integrate the interviews, literature synthesis, and input gained from technical expert and stakeholder workshops into the identification of high priority knowledge gaps and scientific research priorities.

1.4 Structure of the Report

The first sections have introduced sand availability, the need for sand in the Cape Fear Region, and FPS. In **Section 2**, we detail the methodology for assessing FPS as a potential sand source. The methodology included a series of interviews, a technical expert workshop, a stakeholder workshop, and a literature synthesis. **Section 3** provides background on sand dredging actions and potential effects in the marine environment; the concerns of interviewees regarding dredging effects and its potential impacts are also included.

The literature synthesis is divided into sections on oceanographic conditions (**Section 4**), geological conditions (**Section 5**), and biological conditions (**Section 6**). Each section contains a brief summary of the input provided by interviewees during the assessment process. Then, this report provides the scientific literature on each topic, with a specific focus on FPS or similar shoal systems. The focus of the literature synthesis is on topics that were deemed to be of high importance during the interviews. These were topics of concern or knowledge that was considered integral for decision making given the potential for sand dredging of FPS. Citations are provided to assist with further exploration or in-depth investigations, as needed. At the conclusion of each of the sections on oceanographic, geological, and biological conditions, we state the identified knowledge gaps and research priorities. These scientific research priorities were identified based on the accumulation of information gained from the interviews, expert technical workshop, stakeholder workshop, and the literature synthesis. During the technical expert workshop, presentations were made by technical experts and an overview of the draft literature synthesis was provided. Then, participants were given the opportunity to discuss what the priority research topics should be to better inform the assessment of FPS as a potential sand source. Kearns & West, CSS-Inc., and BOEM staff then reviewed this information in light of the available literature and summarized these research priorities within each topic area.

2 Methods of Assessment of FPS as a Potential Sand Source

To assess FPS as a potential sand source, this study utilized a six-step process (**Figure 4**). This technical report is the final product of this process, and we developed the report iteratively through a process that enabled input and feedback from stakeholders and from technical experts in the fields of marine geology, oceanography, and marine ecology. This document is aimed at presenting a science and research strategy to address needs and concerns related to potential sand dredging at FPS. The following paragraphs summarize how this process was undertaken to develop this report.

First, interviews were conducted with 18 technical experts and 6 stakeholders (see list in **Appendix A**). These interviews were confidential, informal, and semi-structured. A list of interviewees were developed in consultation with BOEM staff. Of the technical experts, the goal was to represent a mix of specializations in the fields of fisheries, fish ecology, benthic habitats, marine geomorphology, coastal morphodynamics, sediment transport, and oceanography. Technical experts were from academic institutions and federal and state agencies. Stakeholders included consultants on beach renourishment projects, local government officials, a dredge operator, and a regulatory agency. All interviewees participated with an assurance from Kearns & West that specific comments would not be attributed to individual interviewees. The interview questions posed to the technical expert and stakeholder interviewees are attached in **Appendix A** (Text A1 and A2). Kearns & West and CSS-Inc. developed these questions in consultation with BOEM staff and shared the questions with interviewees in advance of interviews. The interviews were conducted by a combination of Kearns & West and CSS-Inc. staff.

Second, we developed draft literature synthesis based on the interviews conducted. This literature synthesis focused on the information derived from the interviews, including the identified primary topics relevant to assessing the habitat value and functioning of FPS, concerns regarding the potential effect of sand dredging, and the identified knowledge gaps and research priorities that were initially identified as important. The literature synthesis helped inform the agenda for the subsequent technical expert and stakeholder workshops and informed participants on the current state-of-knowledge regarding FPS.

The third and fourth steps in the process were organizing a technical expert workshop that occurred in a virtual environment October 13 and 16, 2020, and a stakeholder workshop on December 10, 2020. The agenda, attendee lists, and workshop summaries are available in Appendix B (Text B1 and B2). Attendees were encouraged to read the draft literature synthesis and provide feedback on it. The major goal of these workshops, particularly the technical expert workshop, was to identify applicable knowledge gaps in regards to FPS as a potential sand source and to identify scientific research priorities.

A fifth step was added to interview people with fishing experience in the region. Two people were interviewed to provide important perspective on this topic (see interview question template in Appendix A, Text A3) based on feedback received from workshop participants.

Finally, the sixth step of the process was to use the information, input, and feedback gained from the two workshops and fisher interviews to update the literature synthesis and formalize scientific research priorities regarding FPS as a potential sand source. These research priorities are identified in sections under oceanographic conditions (**Section 4**), geological conditions (**Section 5**), and biological conditions **(Section 6**).

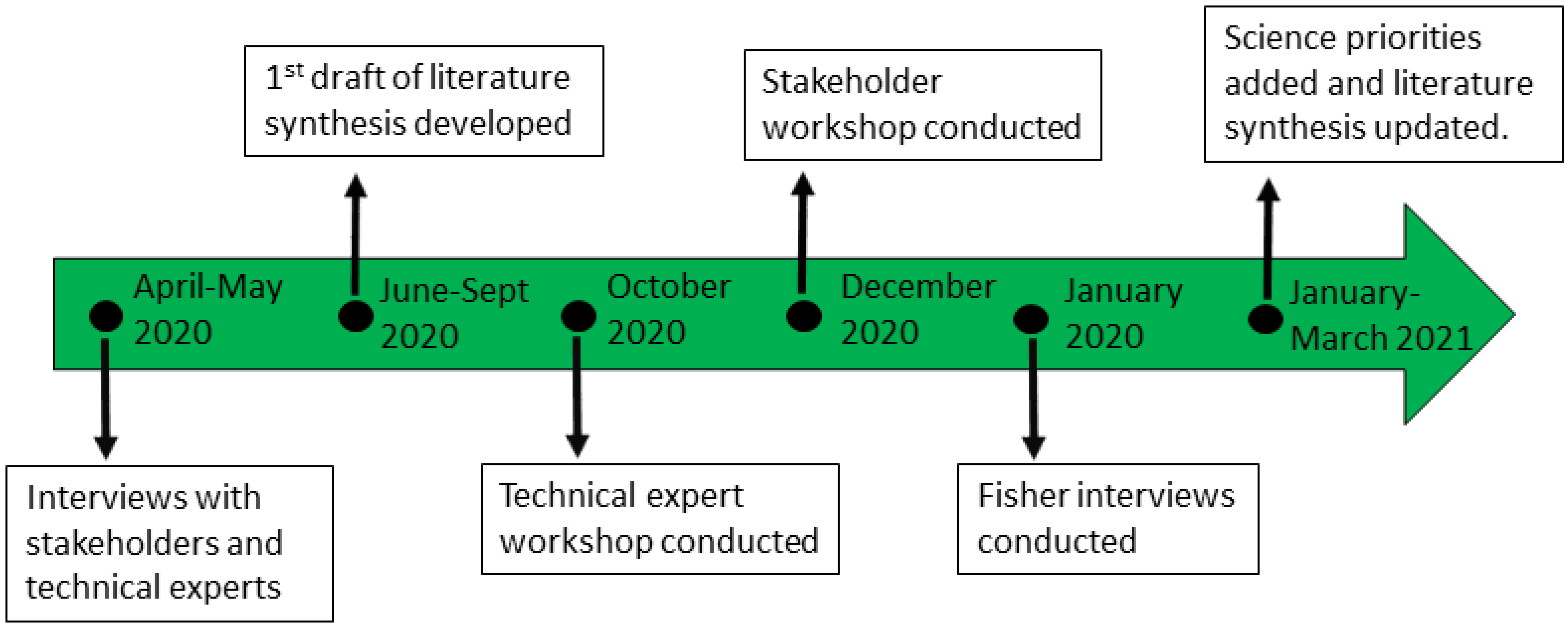

Figure 4. Timeline of the process of assessing FPS as a sand resource for the Cape Fear Region of North Carolina.

3 Sand Dredging Actions and Potential Impacts

3.1 Sand Dredging Actions

The most likely method of extracting marine sand within offshore federal waters at FPS is with a trailing suction hopper dredge (TSHD) (**Figure 5**), though a cutterhead dredge may also be considered. As such, the focus here is on TSHDs, but many of these potential effects are relevant to both dredging techniques. The TSHD vessel works by moving at 1.5–3 knots while an onboard dredge pump creates a suction that is transmitted through 1–3 pipes leading to each pipe's draghead, which are 1.5–4 m in width and lie on the seafloor (Michel et al. 2013). Sand is suctioned through the trailer arm pipe and into the hopper located in the hull of the ship. The dredge then moves to a stationary in-water pump-out station to pump sand to shore via pipelines.

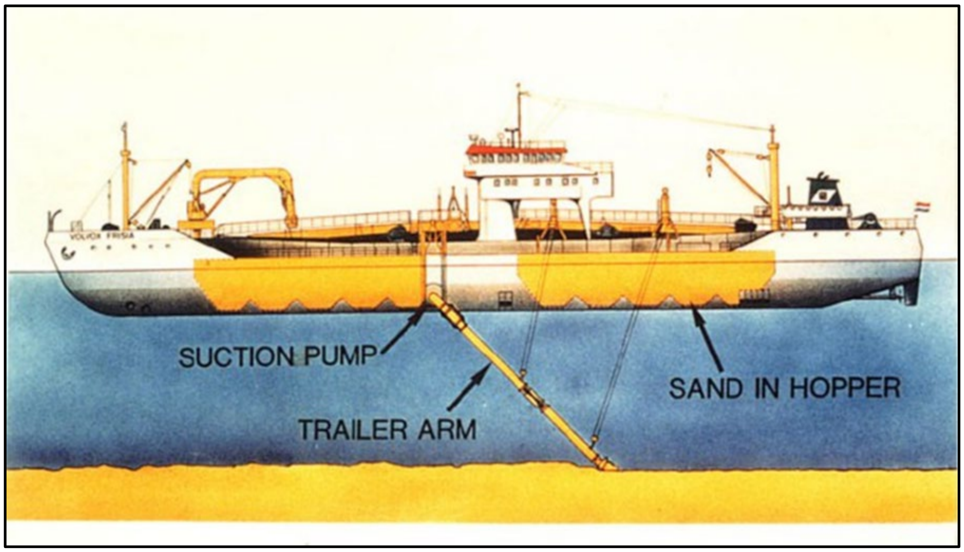

Figure 5. Main components of a trailing suction hopper dredge.
Additionally, the draghead is attached to the bottom of the trailer arm and is where the hydraulic suction is generated.
Source: Adapted from **https://oceanandairtechnology.wordpress.com/2013/06/11/trailing-suction-hopper-dredger/**

A visualization of the TSHD[1] demonstrates the equipment and a reasonable approximation of associated dredging actions; specific techniques differ in the USA. A hydraulic cutterhead dredge works by agitating sediments as the cutterhead rotates. To allow the cutterhead to swing back and forth, anchors, spuds, or a spud pole are used to moor the vessel. A cutterhead may pump sand directly to shore from the dredge site via pipelines. A visualization of the cutterhead dredge[2] demonstrates the equipment and a reasonable approximation of associated dredging actions; specific techniques differ in the USA. For both dredges, additional boats are used to support operations, conduct monitoring, and move anchors for cutterhead dredging. Further details of offshore dredging vessels and their operation are reviewed elsewhere (CSA International Inc et al. 2010; Michel et al. 2013).

[1] https://www.youtube.com/watch?app=desktop&v=nzMOtKHhgsc
[2] https://www.youtube.com/watch?v=PvwUitZewvw

3.2 Interview Responses Concerning Sand Dredging Effects

During the interviews, most concerns regarding sand dredging effects were about the disruption of migratory routes of fish. These concerns included seasonal fish movements along latitudinal gradients, inshore-offshore fish movements, movements from the ocean to estuarine waters for spawning, larvae transport to the estuary, movements of juveniles from estuarine waters to the ocean, potential disruptions caused by turbidity plumes and underwater sounds, and, to a lesser extent, disruptions to food resources.

3.3 Potential Impacts of Sand Dredging

The short-term effects of dredging include entrainment, human-made sounds, loss of prey or alteration of food webs, suspended and resuspended sediments, sedimentation of the seafloor, and, in some circumstances, the release of contaminants (Kim et al. 2008; Suedel et al. 2008; Wenger et al. 2017). Given the uncertainty surrounding the effects of dredging, seasonal restrictions on dredging operations are sometimes implemented. Of the dredging operations conducted by the USACE from 1987 to 1996, time window restrictions for dredging to address biological concerns were implemented in 85% of Atlantic operations (Dickerson et al. 1998). Seasonal restrictions on dredging are most likely to be implemented for protected species; however, diverse species have been a basis for restrictions. Fish species used as a basis for seasonal dredging restrictions include American shad, Atlantic tomcod, blue crab, Gulf sturgeon, shortnose sturgeon, striped bass, winter flounder, and shrimp species (Reine and Clarke 1998). Unfortunately, the lack of available data may result in inefficient restrictions on dredging activity, which can drive up costs, increase transportation distances, and delay projects (Dickerson et al. 1998).

From a review of the effects of sand dredging on fish, Pickens et al. (2020) highlight the following:

- Fish are most vulnerable to dredging effects during egg or larvae stages, spawning periods, or during migration, when compared to other life stages. Demersal species have been suggested to be more vulnerable than pelagic, though evidence is lacking.
- Entrainment of benthic fish and invertebrates occurs locally during dredging. A few studies have examined entrainments rates of fish in estuaries, but rates in marine ecosystems are lacking.
- Turbidity occurs during and shortly after dredging activity, but resuspension of sediments at the borrow area has reoccurred 1.5 years post-dredging. Studies have regularly found turbidity to influence a 0.62-mi (3-km) radius around dredging, though concentrations are not high enough to directly cause fish mortality.
- Sedimentation may threaten hardbottom and reef fish habitats because of burial and mortality of live bottom species.
- Underwater sounds during dredging are not severe enough to cause fish mortality, but sounds may persist above ambient conditions for to 0.25 to 1.7 mi (400 m to 2.7 km).

  Avoidance responses (including response distance) of fish to underwater sounds and turbidity are unknown. Fish behavioral responses will determine habitat loss, disruptions to migration, and other impacts.
- Substrate removal by dredging may result in bathymetric depressions or more homogeneous, flattened topography within the footprint of dredging.

4 Oceanographic Conditions

4.1 Interview Responses on Oceanographic Conditions

Sand shoals are recognized as unique, shallow water features in the marine environment. Interviewees frequently recognized that upwelling and eddies are a major source of energy and productivity in cape-associated shoal systems, including FPS. Waves and currents near shoals result in well-mixed waters with high levels of dissolved oxygen. The high topographic complexity and shallow water nature of shoals facilitates this water movement, and there is concern that sand dredging over extended periods could change this oceanographic system and reduce productivity. Respondents often identified the link between currents and sediment transport as being important.

Interviewees recognized that cross-shelf water movements likely leads to temperature change, cold water incursions, and cross-shelf temperature gradients. Fish are likely to respond to seasonal changes. For example, small overwintering fish in nearshore habitats may be forced offshore when cold water incursion occurs. Temperature will also affect latitudinal migration of fish. Salinity is likely an important factor to consider because of the proximity of the Cape Fear River and nearby estuarine waters.

4.2 Currents, Waves, and Productivity

Coarse measures of wind, currents, and waves for the FPS region are as follows (**Figure 6**):

- National Oceanic and Atmospheric Administration (NOAA) predictions of tidal currents at Wrightsville Beach in 2020 range -1.2 to 5.9 ft MLLW (Mean Lower Low Water) (-0.37 to -1.80 m) with tidal heights typically being 3 to 4 ft (0.91 to 1.22 m) (NOAA 2020).
- Weber and Blanton (1980) show the seasonality of winds as originating from the northwest in the winter (November–February) and from the southwest in summer (June–July). The mean annual wind speed and direction also show this pattern (**Figure 6**) (NOAA Office for Coastal Management 2020).
- Significant wave height, period, and duration show waves primarily originate from the northeast, east, and north-northeast.
- Predominate ocean currents originate from the west.

Sand dredging studies have examined whether there is a threshold where sand removal from a shoal might result in deflation or the disappearance of a feature because the wave pattern is reduced in magnitude or if depth is increased to a point where sand deposition is minimal (Hayes and Nairn 2004). Simulations have been conducted elsewhere to determine potential effects of sand extraction on wave heights and bottom currents (Byrnes et al. 2004a; Byrnes et al. 2004b; Maa et al. 2004; Stone et al. 2009). For example, Byrnes et al. (2004b) simulated various dredging sand volumes and showed that dredging in the mid-Atlantic is expected to increase wave heights by 0.20–0.50 m in the lee of the shoal and decrease wave heights by a maximum of -0.4 m adjacent to the shoal. Changes became minimal when waves approached the shoreline (Byrnes et al. 2004b). In contrast, Maa et al. (2004) simulated removal of 31.4 million yd^3 (28.7 m^3) of sand shoals and found wave height increased by a factor of two and may contribute to increased shoreline erosion.

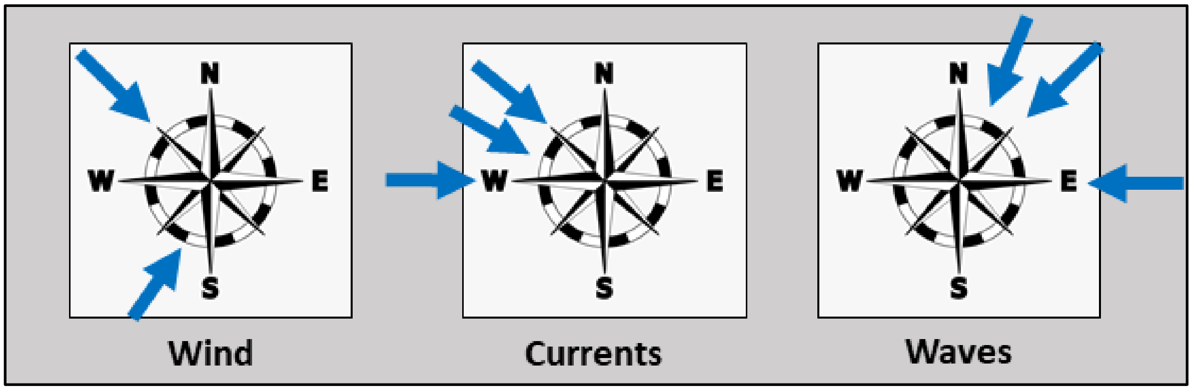

Figure 6. The dominant direction and velocity of wind, ocean currents, and waves in the vicinity of FPS.
Data are based on frequency and duration of these forces on an annual basis in the vicinity of FPS. Data source: Ocean Reports (NOAA Office for Coastal Management 2020) at https://coast.noaa.gov/digitalcoast/tools/ort.html.

Interviewees frequently recognized that upwelling and eddies are a major source of energy and productivity in cuspate foreland systems, including FPS. However, the biological productivity that might result from such oceanographic characteristics has not been explicitly studied at cape-associated shoals. The combination of tidal currents, wind and waves, and bottom currents interact with sand shoals at Cape Lookout Shoals to form two rotating eddies that help determine sediment transport (McNinch and Luettich 2000). The details of these currents and the resulting sediment transport are covered in **Section 5** below.

4.3 Water Temperature and Salinity Regime

Atkinson et al. (1983) describes the breadth of oceanographic climatology of the South Atlantic Bight, and their synthesis is summarized as follows:

- Shallow shelf waters of the South Atlantic Bight respond quickly to atmospheric conditions and river discharge.
- Deeper waters are moderated by the deep ocean and respond to the Gulf Stream.
- At moderate depths 22–44 yd (20–40 m), wind forcing plays a role in temperature fluctuations.
- Generally, shelf temperatures reach a maximum in August and September when temperatures are high at all depths.
- The strongest cross-shelf temperature gradients occur in winter (November–January).

As an example of cross-shelf temperature gradients, Freshwater et al. (2016) monitored winter bottom temperatures at varying depths in Onslow Bay. They found winter temperatures were progressively higher at greater depths, and this also resulted in lower temperature ranges. For example, depths of 18–20 m had a mean temperature of approximately 14°C and range of 13.5°C, whereas depths of 38.5–42 m had a mean temperature of > 18°C with range of 8.5°C (Freshwater et al. 2016).

The Gulf Stream can intrude upon shelf waters by surface water intrusion, interlayering, or a bottom water intrusion (Atkinson 1977). Surface and bottom water intrusions are most frequent in the summer months, are influenced by wind stress, interact with salinity, and are more frequent at the extreme northern and southern waters of the South Atlantic Bight (Castelao 2011).

Salinity in the South Atlantic Bight is typically lowest in April and May, when runoff is at its annual peak (Atkinson et al. 1983). Xia et al. (2007) modeled the Cape Fear River plume using simulations. They investigated the distribution of salinities based on the effect of river discharge, wind, and tidal effects. Predicted salinities ranged 20 to 36 ppt, and the following patterns emerged:

- Normal river discharge without wind effects shows a low salinity plume moving west of the Cape Fear River near the shoreline.
- Common southwest winds simulated at 5.5 yd s^{-1} (5 m s^{-1}) drive the salinity to levels ranging approximately 24 to 36 ppt in the vicinity of FPS.
- The effect of a moderate southwest wind 5.5 yd s^{-1} (5 m s^{-1}) was highly sensitive to river discharge, as the response to flood conditions showed a great expansion of low salinity waters. In fact, the simulation to river flood conditions coincided well with the pattern of finer grained sediments.
- Common southwest winds simulated at a high 22 yd s^{-1} (20 m s^{-1}) restrict the low salinity plume to the mouth of the Cape Fear River.

4.4 Oceanography Knowledge Gaps and Research Priorities

From the literature review and workshops, one major knowledge gap and research priority was identified regarding oceanography of the FPS region:

A) Where, when, and how frequently does the Cape Fear River plume occur on or near FPS?

5 Geological Conditions

Cuspate forelands are large shoreline promontories created by the convergence of barrier islands or mainland beach ridges at an approximately right angle (McNinch and Wells 1999). These features often have an underwater sand shoal that projects from the convergence point outward into the sea (Shepard and Wanless 1971). These cape-associated shoals are found worldwide, and these shoals occupy as much as 30% of the shoreface of North Carolina (defined as the area between the -10 m isobath and shoreline) (McNinch and Wells 1999). FPS, Cape Lookout, and Cape Hatteras are all examples of cuspate forelands. Although, FPS has been less studied than Cape Lookout or Cape Hatteras, we can still draw inferences from the other North Carolina sand shoals.

5.1 Interview Responses on Geological Conditions

The topic of sediment grain size was initiated by most interviewees. As a first step, the distribution of beach-suitable sediment grain sizes will determine the potential areas for sand dredging. There is considerable uncertainty among interviewees about our collective knowledge on sediment grain sizes, and it is likely that the information is fragmented among various entities. The USACE has conducted surveys in limited parts of FPS, though the information has not been formally shared with the public. This information will answer the question of, "How and where on FPS do you get sand?" The answer to this question will also help determine biological impacts; sediment grain size and presence of shell may affect fish habitat use. The thickness and volume of sand were secondary topics.

Sediment transport was commonly mentioned as a concern, as the rates of shoal accretion and erosion were identified as important measures to consider. Important questions are, "Are the shoals growing? "How stable is the shoal [regarding movement]?" and "What sediment grain sizes will infill?" The process of sediment transport seaward from the eroding beaches, and therefore, shoreline erosion was a concern.

Recovery of shoals was mentioned, but interviewees often had to be asked specifically about recovery to obtain feedback on the topic. Several respondents noted that the dynamic sand habitats are associated with early successional benthos, which are likely to recover quickly if sediment grain size remains the same. Monitoring of bathymetry, post-mining depths, and sediment grain size was suggested.

5.2 Sediment Grain Size

At a coarse level, Conley et al. (2017) used an interpolation of usSEABED data, along with supplemental data points, to map sediment grain sizes of the South Atlantic continental shelf. They used a simplified version of Wentworth (1922) to classify sediment grain size. These data show FPS, and the area directly east of FPS, primarily consists of medium sand (0.25–0.5 mm) as well as coarse and very coarse sand (0.5–2 mm). Immediately to the west of FPS, there are primarily fine and very fine sands (0.063–0.25 mm) (**Figure 7**). In this dataset, a pattern can be observed that very fine and fine sands are generally distributed southwest of cape-associated shoals in the South Atlantic. Medium and coarser sediment grain sizes are often found east/northeast of cape-associated shoals. This pattern may have implications for infilling sediments if sand dredging were to occur.

The USACE Wilmington District and Land Management Group, Inc. (2014) reported that geotechnical evaluations of sediments at FPS were conducted by Catlin (2010). In Catlin's study of FPS, Vibracore samples showed sediment grain size ranged from 1.47 (phi) to 2.83 (phi) with a weighted mean of 2.53 (phi). There was a mean silt content of 3.2% and a mean percentage by weight shell content of 1.5%. Based on these measures, FPS sands in the southwest flank are generally compatible with native beach material (Catlin 2010). Although the stratigraphy of FPS has not been scientifically studied, Cape Lookout Shoals are composed of unconsolidated sediments with a maximum thickness of 20 m (McNinch and Wells 1999). Olsen Associates Inc. (2016) conducted vibracore sampling at a potential borrow location on FPS. They found sediment grain size, shell, and percent carbonate content increased when approaching the top of the shoal. Samples in relatively deeper waters along the western flank of the shoal showed a decreasing sediment grain size. Sand thickness recorded included 10 and 13 ft (3 and 4 m) in specific locations with intermittent layers of sand and 5–10% fine sediments present. Further details are available in Olsen Associates Inc. (2016).

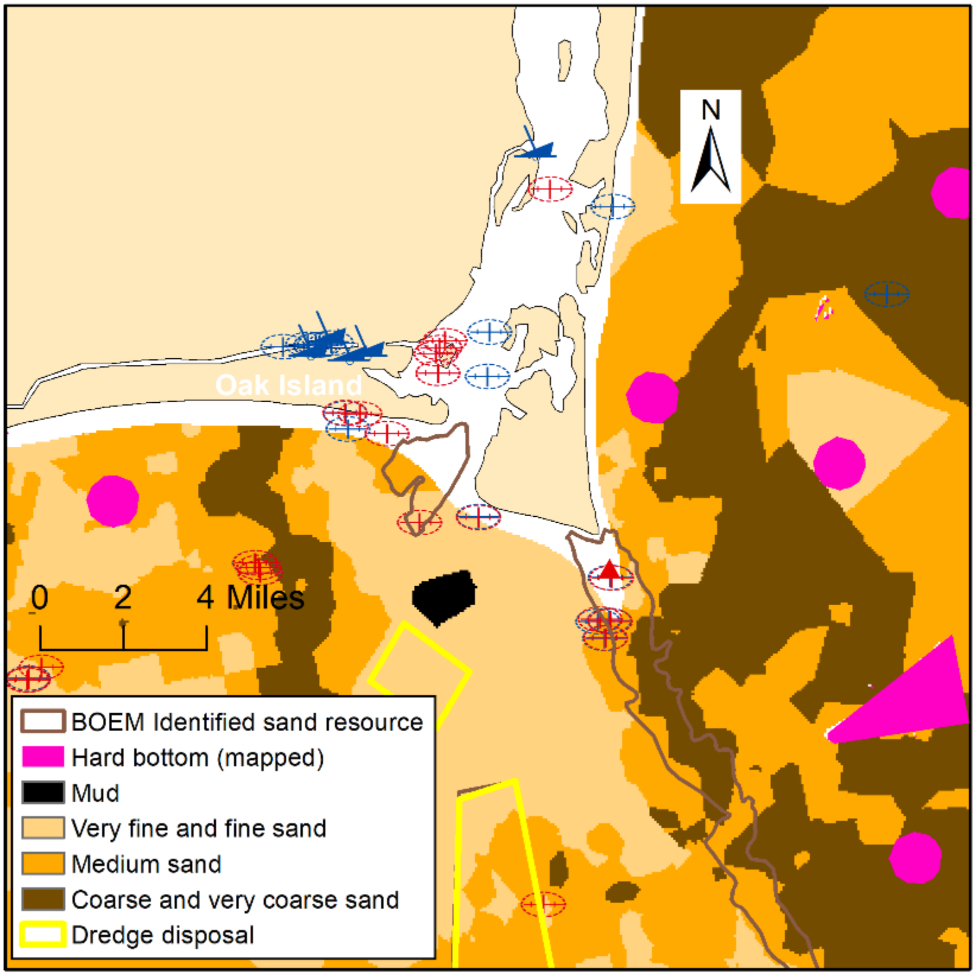

Figure 7. Mapped hardbottom, sediment grain sizes, and shipwrecks in the vicinity of FPS. Hardbottom and sediment grain size data were derived from The Nature Conservancy's South Atlantic Marine Bight Assessment (Conley et al. 2017). Hardbottom is shown with a 0.62-mi (1-km) buffer around each point. Shipwrecks are represented by red and blue open circles with crosses. Shipwreck data are from NOAA Office of Coast Survey's Public Wrecks and Obstructions database, https://nauticalcharts.noaa.gov/data/wrecks-and-obstructions.html

5.3 Physical Processes of Sediment Transport and Accretion

The physical processes of sediment transport, and the subsequent accretion of sediments, are critical to the sustainability of FPS. Research on these mechanisms have not been conducted at FPS. Instead, we focus on the geologic processes described for Cape Lookout Shoals, which has a similar geomorphology and has been the subject of extensive study. A thorough review of these studies is presented by McNinch (2009), and a synopsis is presented here.

McNinch and Luettich (2000) used near-bottom current meters located at the east and west margin of Cape Lookout Shoals, at the shoal crest, and near its seaward terminal location. They identified the residual flow, which is defined as the tidally averaged flow that can be influenced by topography, density gradients, wind, and the discharge of freshwater (Duran-Matute and Gerkema 2015). The residual flow had two major components: 1) water movement towards the cape-associated shoal at a speed of 0.83–1.5 inches s^{-1} (2.1–3.7 cm s^{-1}), and 2) water movement along the axis of the shoal crest outward to the outer continental shelf at 1.5–2.3 inches s^{-1} (3.7–5.9 cm s^{-1}) (McNinch and Luettich 2000). The first component is influenced apparently by two counter-rotating eddies at the margins of Cape Lookout Shoals that unite near the shoal crest. Such eddies are a product of tidal vorticity created by spatial changes in water depth (i.e., topography) and tidal amplitude as water flow bends around the headland (Pattiaratchi and Collins 1987). The tidal component explained 75% of the total semi-diurnal energy (McNinch and Luettich 2000). The second component of water flow was from the headland to the sea along the shoal crest, which has previously been documented where two eddies are united (Dyer 1991). At Cape Lookout Shoals, particle tracking confirmed the major seaward movement of water along the shoal crest to the outer continental shelf (McNinch and Luettich 2000).

The primary sediment source for Cape Lookout Shoals is derived from longshore transport of materials from the north (McNinch and Wells 1999). Longshore current velocity, and thus the delivery of sediments to the cuspate foreland headland, is driven chiefly by wave direction and intensity, particularly during nor'easters (Park and Wells 2005). The shoal causes the refraction of waves and blocks wave action on the leeward side of the shoals (McNinch 2009). A model of sediment transport at Cape Lookout Shoals provides evidence that the energy needed to move 80–90% of sand-sized sediments is provided by wave action (McNinch and Luettich 2000). Given the sediment movement, accretion on the shoal is distributed by the residual currents at the shoal (**Figure 8**). By these mechanisms, an estimated 400–700 million m^3 of sediments can delivered from the headland to the shoal each year (McNinch and Luettich 2000). McNinch and Wells (1999) also provide evidence that the shoal is a sediment sink and remains active throughout its length.

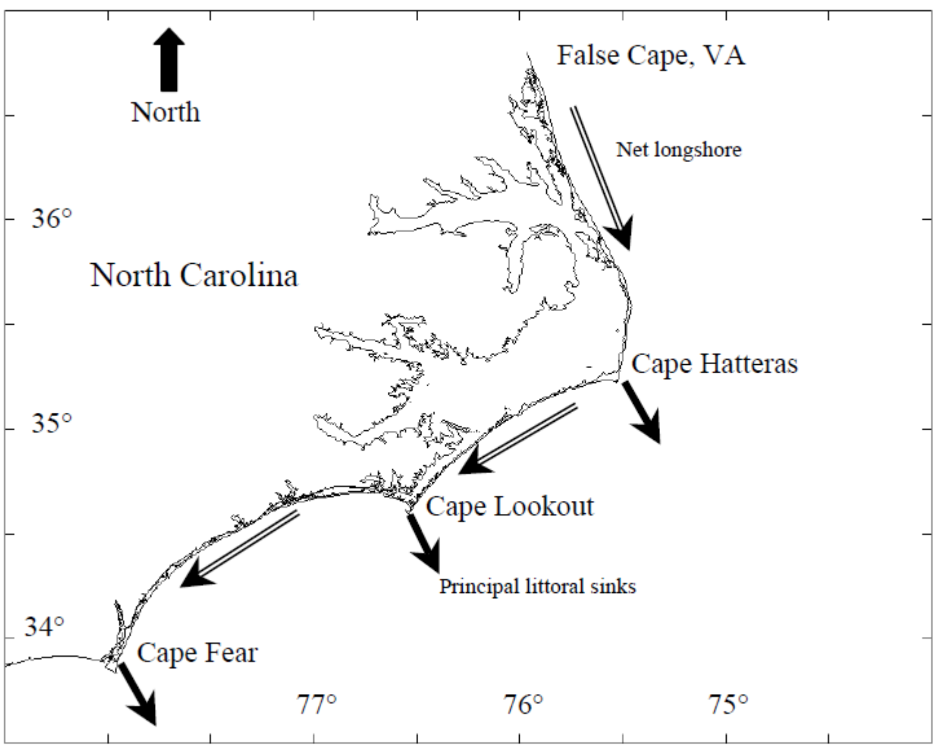

Figure 8. Map depicting principal littoral cells and long-term sediment sinks offshore of North Carolina.
Figure from McNinch et al. (1999) based on Inman and Dolan (1989)

Based on work with Cape Lookout Shoals, McNinch (2009) made following inferences about FPS:

- The primary sediment source of FPS is likely sand within the littoral cells of the updrift beaches, Wrightsville-Carolina-Kure Beach.
- The volume of sediment delivered to FPS is likely comparable to the magnitude of the southern longshore drift.
- The most active region of sediment recharge within FPS is likely near the cape point, particularly along the crest of the shoal, where it extends seaward from the subaerial cape point and the shore-parallel sandbar that merges into FPS from the updrift beach.
- Sediment along the flanks of FPS likely migrates crestward during swell conditions and seaward when it reaches the crest.
- The crest of the shoal is likely planed-off during storms, when waves are steep and breaking across the shoal, and sediment is transported to the flanks.
- Sediment dredged from the northwest flank of FPS will likely recharge episodically by sediment transported from the crest during storms, particularly extratropical nor'easters.

5.4 Geological Knowledge Gaps and Research Priorities

From the literature review and workshops, major knowledge gaps and research priorities were identified regarding the geology of FPS (no order of importance is implied):

A) An improved understanding of sediment transport mechanisms from shore to shoal is needed. This would meet the need to estimate recharge rates and would help inform ideal borrow location and design. Olsen Associates Inc. (2012) did develop a model of nearshore sediment transport near Bald Head Island and the Cape Fear River, but models are needed over the broader area and should further investigate seasonal events, including variability in river discharge, waves, wind, and tides.

B) What is the post-dredging sediment recharge and infilling rates specific to FPS? These data could act as validation for priority A above.

C) How much sand is required for nourishment in the long term? More specifically, what is the area and volume projected to be dredged?

D) Would dredging require an access channel? The answer to this question will help determine the area affected and the potential effect on biological communities.

E) Where is sand dredging likely to occur within FPS? This may affect biological concerns and research priorities.

6 Biological Conditions

6.1 Interview Responses on Biological Conditions

There was widespread belief among interviewees that sand shoal habitats are extremely productive habitats. In particular, forage fish (i.e., bait fish, pelagic prey) were frequently mentioned in a variety of contexts. High productivity and biomass were also commonly mentioned in relation to phytoplankton, zooplankton, demersal zooplankton, shrimp, blue crab, coastal migratory pelagic fish, and sharks. Concurrently, the reason for high productivity on shoal habitats is poorly known. Seasonality was also consistently mentioned in regard to productivity, as winter and spring were suggested to be less productive. Benthic invertebrate fauna were an uncommon topic of concern, as sand habitats are thought to support early successional species that recover from disturbance quickly.

Common themes arose concerning the habitat use of fish at FPS, and the following sections represent those themes. At the beginning of each section, we briefly summarize specific interviewee concerns.

6.2 Interviews with Fishers

Two interviews were conducted with representative fisherman of the Cape Fear Region of North Carolina. The first interviewee provided general information on fisheries concerns, but the individual did not have direct knowledge of fisheries specific to FPS or its immediate vicinity. The second individual was a charter boat captain with > 15 years of knowledge specifically regarding FPS as a recreational fishing resource. This individual also spends about 10% of the year doing commercial fishing and had a limited knowledge of commercial fisheries. Commercial fisheries mainly harvest in warm seasons ranging March–October. The following paragraphs summarize the local knowledge and observational information provided based on years of fishing experience in the region.

These fishers had minor concerns with short-term effects of sand dredging and did not have long-term concerns. Because of the infilling of numerous historical inlets, there is a strong preference to remove sediments from inlets and let inlets stay open. Inlets were suggested to help flush out river pollutants. (We note that inlet management is a specific issue that also affects navigation of charter boats in the Cape Fear Region.) Generally, dredging farther offshore was considered better than near the shore. Water quality was suggested to be better east of the cape (e.g., Wrightsville Beach) rather than near the Cape Fear River, and a channel that facilitates the movement of poor-quality water offshore was suggested as potentially good for nearshore fisheries.

Fish distributions are considered to be driven by water quality, runoff after hurricanes, visibility, water temperature, currents, and interactions with the Gulf Stream. Forage fish abundance is thought to be particularly influenced by water quality, and some fish species have been observed to move offshore because of poor water quality inshore. If dredging were conducted, winter is the preferred season. One interviewee suggested that in summer glass minnow [likely silverside (*Menidia* spp.) or anchovy (family Engraulidae)] accumulate in cleaner water, and he believed that dredging could affect them. This is important because glass minnow are thought to attract Spanish mackerel and flounder. In winter, the water generally has less visibility, and dredging would be less likely to affect species.

Forage fish are thought to drive the ecology of the shoal, and the shallow waters of FPS are associated with masses of these small fish. Forage fish are most abundant in the winter (November–December), though this is not true for all species. In addition to glass minnow, juvenile porgies, American shad (November–January), croaker, and spot are very abundant. In recent years, an extremely high biomass of forage fish, especially croaker, has been found near the offshore end of the shoal. Forage fish are suspected to be moving farther offshore because of currents and water quality. Forage fish travel through swales and use large ridges of 10–20 ft (3–6 m) in relief.

Sharks are abundant and consistently caught during the summer months, and they start appearing in early May. Shark species noted include blacktip shark, spinner shark, spiny dogfish, bonnethead sharks, Atlantic sharpnose shark, and blacknose shark. A fisher described FPS as the "Land of Giants," because the clean water and abundance of forage fish result in the prevalence of many sharks > 100 lb.

Mackerel and cobia are thought to be abundant on FPS. King and Spanish mackerel arrive in early May and stay until September. Fishers catch 99% female king mackerel that are in a spawning stage. The mackerel stay on rocks or ledges and spawn there, but feed 1–2 times a day in surrounding areas. Bigger individuals go into deeper waters, but also move to shallow waters to feed on forage fish. One fisher noted that North Carolina waters may be one of largest spawning areas for king mackerel on the east coast.

Shrimp fishers rarely get > 5 miles (8 km) offshore, though some are thought to go 5–7 mi (8–11 km) offshore. Shrimp are caught on muddy bottoms, usually within 3 miles (4.8 km) of the beach. No shrimp are found on top of sandbars. Brown shrimp migrate south in autumn. White shrimp are available September through January, and occasionally through March. Some commercial shrimpers harvest in July. The fishers did not have experience with blue crab at FPS.

6.3 Forage Fish and Fish/Invertebrate Pathways Linking the Estuary and Ocean

Interviewees had concerns about spawning, larvae transport, and fish movements linking estuarine and ocean habitats near FPS. There was emphasis on the importance of the shrimp and potentially the blue crab fisheries. Other species, or groups of species, of concern included juvenile reef fish that use estuaries (e.g., black sea bass), red drum, striped bass, spotted seatrout, flounder species, and coastal migratory pelagics. Forage fish such as croaker, menhaden, spot, pinfish, juvenile herring, and sea mullet were mentioned in this context and were perceived as the main reason that FPS is very biologically productive. Juvenile flatfish (e.g., southern flounder) migratory movements in the fall and flatfish spawning in the winter were recognized as important considerations.

Wickliffe et al. (2019) summarized the life history, habitat use, and seasonality of select fish and invertebrate species that use coastal inlets in North Carolina. Their summaries include penaeid shrimp, gag grouper, summer flounder, American shad, river herring, blue crab, summer flounder, and red drum (**Figures 9 and 10**). Reiterating the emphasis on blue crab, new Blue Crab Spawning Sanctuaries have now been designated by the North Carolina Division of Marine Fisheries at the Cape Fear River, Masonboro, and Carolina Beach inlets.

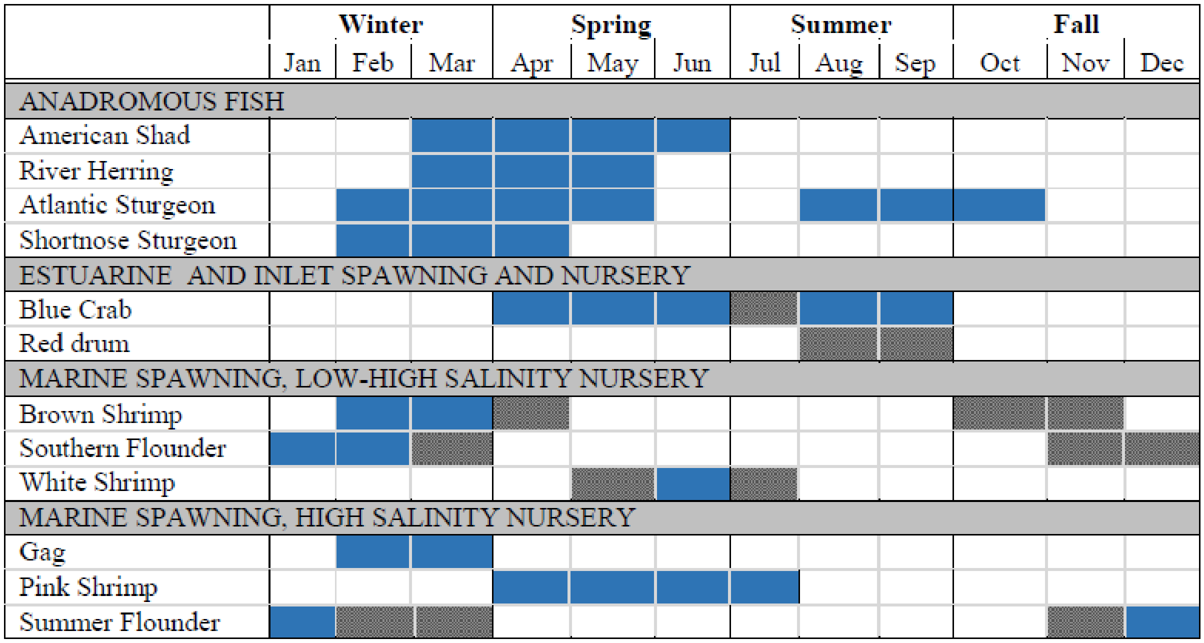

Figure 9. Spawning seasons for select coastal fish and invertebrate species occurring in North Carolina coastal waters.
Species include those with broadcast planktonic or semi-demersal eggs. Blue indicates peak spawning season, and the gray areas indicate spawning occurrence. Figure from Wickliffe et al. (2019) and adapted from NCDEQ (2016).

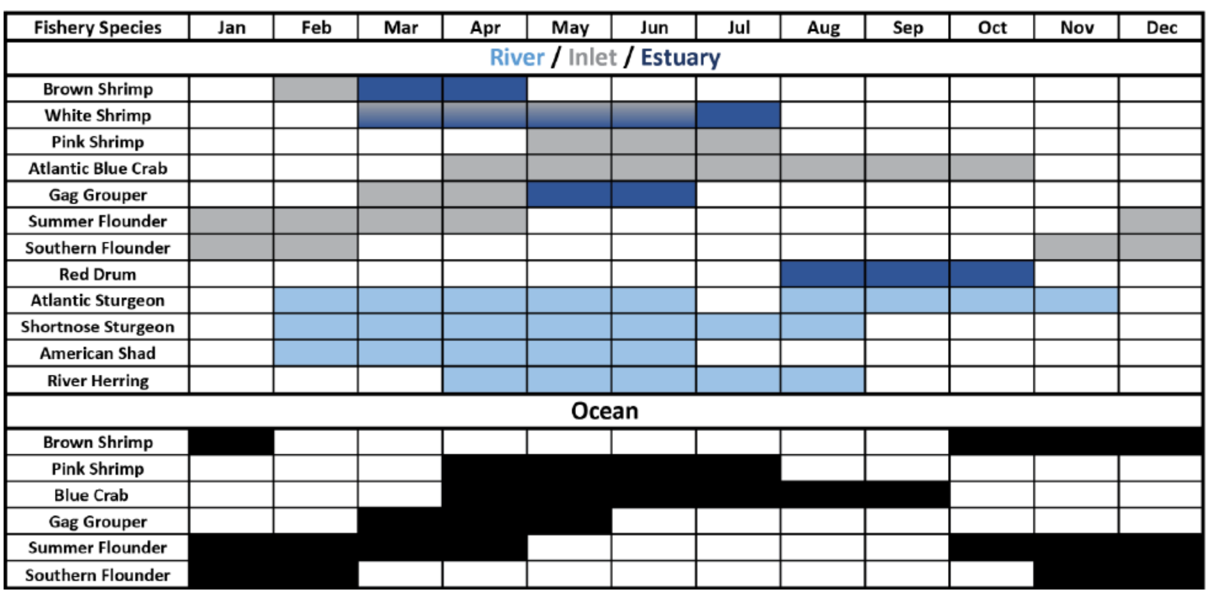

Figure 10. Summary of the most sensitive life stages (eggs, larvae, and early juveniles) for select fish species and their distribution throughout the year.
Boxes represent abundant eggs and/or larvae present in a given area. Light blue = River habitat; Gray = Inlet habitat; Dark blue = Estuarine habitat; Black= ocean. Figure from Wickliffe et al. (2019) and adapted from NCDEQ (2016).

In North Carolina, brown shrimp and white shrimp (also known as green tails) are among the most harvested species by weight (NCDEQ 2016). Few studies of these shrimp species have been conducted in the offshore waters of North Carolina. Pickens et al. (2021a) found the distribution of penaeid shrimps in the Gulf of Mexico marine environment were most influenced by oceanographic conditions, followed by area of nearby coastal wetlands and bottom water temperature. More specifically, brown shrimp catch per unit effort (CPUE) was higher where the mixed layer depth was deeper, particularly where a deep mixed layer depth combined with a high area of nearby wetlands (Pickens et al. 2021a). White shrimp CPUE was highest with a salinity of < 31 ppt, where chlorophyll-*a* concentration was high, within 6.2 miles (10 km) of the shoreline and at depths of 10–30 m. Both brown and white shrimp CPUE had positive relationships with bottom temperature and area of nearby wetlands; white shrimp CPUE was greater where the area of nearby estuary was greatest. Although geomorphology was a minor influence, some shoals were clearly more important than others based on the oceanographic characteristics and nearby estuarine habitats. Pickens and Taylor (2020) did not directly study forage fish, however, sharks that primarily feed on forage fish species (e.g., croaker, menhaden) were a focus. A commonality among these shark species was a positive association with chlorophyll-*a*, salinities of < 31 ppt and a greater area of nearby wetlands and estuaries (Pickens and Taylor 2020). These characteristics are likely to support forage fish in the Cape Fear Region.

In regard to larvae transport, Delft3D hydrodynamic simulations were conducted in the Cape Fear Region to better understand the effect of tidal currents on the transport of larvae into the estuary (USACE Wilmington District and Land Management Group Inc 2014). Drogues were then placed in the waters near Bald Head Island to track potential pathways (**Figure 11**). The findings were interpreted in the context of examining the potential impact of hard structures, but the drogue pathways show that larvae are expected to flow from the western part of Bald Head Island into the estuary.

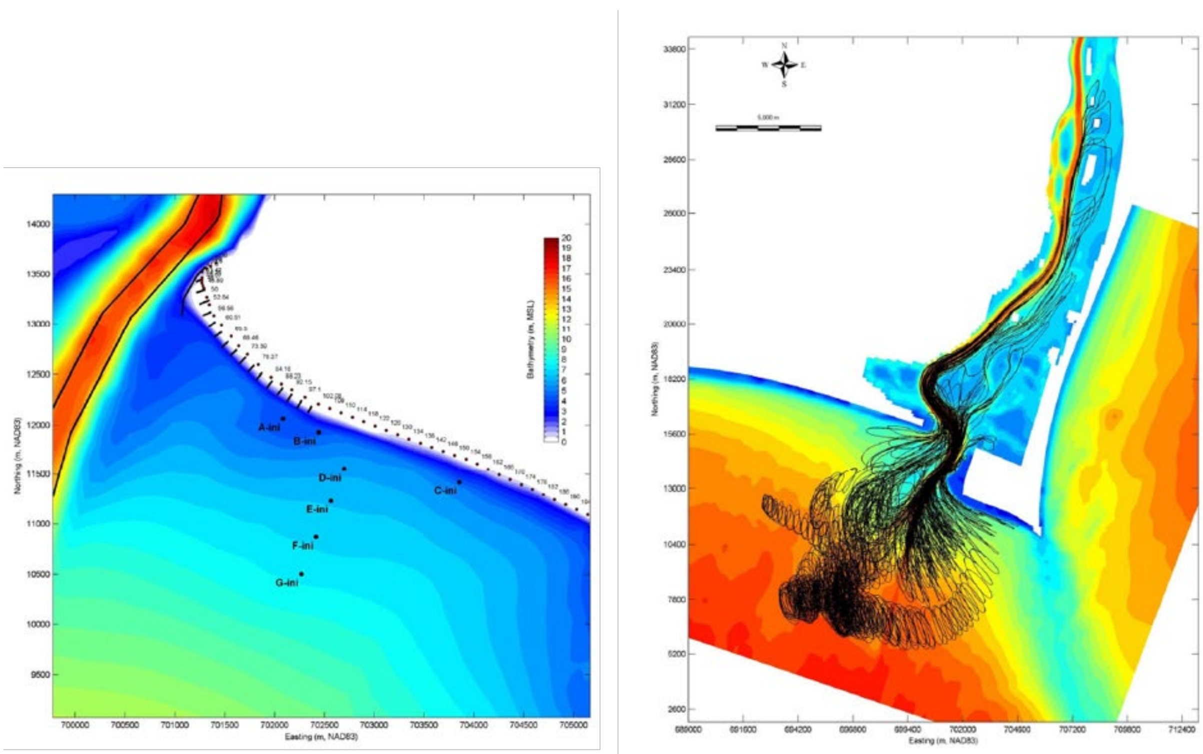

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Figure 11. Initial sites for deployment of drogues for tracking (left) and all drogue tracks simulating larvae transport into the estuary (right).
Figures from USACE Wilmington District and Land Management Group Inc. (2014).

Markovsky (2004) examined the distribution and abundance of larval fishes and decapods in the Cape Fear River discharge plume (described in the oceanography section) and at ocean sites west of FPS. Although annual differences were substantial due to rainfall, he found salinity was lower in the plume compared to the ocean. Markovsky (2004) found larvae abundances were approximately 2.5 times greater in the plume compared to the ocean, and larvae in the plume were most abundant near the bottom. During several timeframes, the plume had a much more diverse assemblage of ichthyoplankton compared to the ocean or estuary. Fish ichthyoplankton that appeared much more abundant in the plume compared to ocean or estuary habitats included anchovies, goby (Gobiidae), Atlantic croaker, spot, pinfish, and southern kingfish. These may be generalized as forage fish species. Over the two years of study, plume surveys recorded 856 individuals, whereas the ocean had 590 and the estuary had 206. The plume showed substantial variability, particularly in 2003 when salinity was lower (corresponding with more rainfall) and greater ichthyoplankton differences were found. In this year, the plume had 475 individuals compared to 73 in the ocean and 123 in the estuary.

6.4 Atlantic Sturgeon and Diadromous Fish

Atlantic sturgeon was listed as a federally endangered species in 2012 with the recognition of five distinct population segments, including the Carolinas population. In North Carolina, Atlantic sturgeon critical habitat is found in the following rivers: Cape Fear, Northeast Cape Fear, Roanoke, Tar-Pamlico, Waccamaw, and Neuse (Federal Register 2017). Wickliffe et al. (2019) provides an in-depth examination of the natural history of the species (**Figure 12**). Atlantic sturgeon primarily forage on benthic species (Johnson et al. 1997), which makes them potentially vulnerable to the loss of substrate and its associated invertebrates. In the context of sand dredging, we summarize Atlantic sturgeon ecology in relation to spawning, movement pathways, aggregations, and marine habitat use.

Spawning, Movement Pathways, and Aggregations

Movement pathways to and from spawning sites in the Cape Fear River are largely unknown and were a concern of interviewees. Spawning-related movements to estuarine corridors and farther upstream begin in February and March in South Carolina (Collins et al. 2000). Although Atlantic sturgeon are historically well-known to spawn in the spring along the Atlantic Coast, recent evidence shows fall spawning occurs in northeast North Carolina (Smith et al. 2015) and in South Carolina (Collins et al. 2000). Fall spawning occurs September 1 to November 30 (Wickliffe et al. 2019). Atlantic sturgeon have been documented aggregating in marine waters in the vicinity of the mouth of large rivers during the spring and fall spawning seasons (Breece et al. 2016; Dunton et al. 2015; Dunton et al. 2010). In the mid-Atlantic, Atlantic sturgeon spent long periods of time at the mouth of Delaware Bay spanning May to October, presumably because of cooler water temperatures and possibly due to upwelling conditions (Breece et al. 2018). The location and timing of potential aggregations of Atlantic sturgeon offshore of the Cape Fear River is unknown.

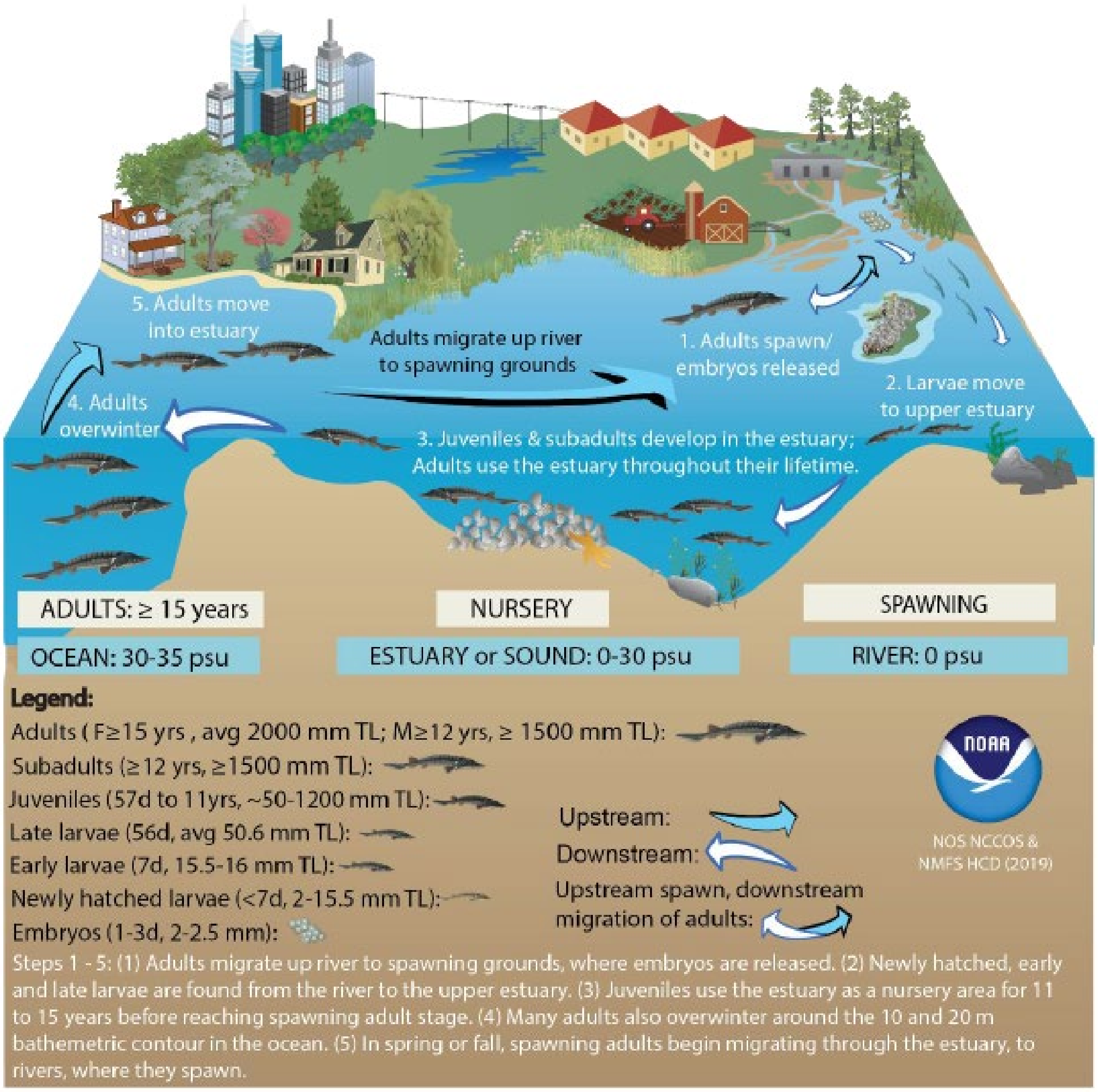

Figure 12. Life cycle of Atlantic sturgeon.
Figure from Wickliffe et al. (2019).

In North Carolina, Moser and Ross (1995) tagged 100 juvenile Atlantic sturgeon in the Cape Fear River and Brunswick River. They reported that four Atlantic sturgeon were recaptured by commercial fishers located at Carolina Beach, Kure Beach, and Fort Fisher. One of these fish came within 100 m of a hydraulic pipeline dredge. For a previous Bald Head Island assessment (USACE Wilmington District and Land Management Group Inc 2014), the North Carolina Division of Marine Fisheries summarized information on Atlantic sturgeon in the Cape Fear River. Movements of fish were tracked by acoustic stations, including 80 Atlantic sturgeon and 2 shortnose sturgeon that were implanted with acoustic transmitters. The findings indicate that mature and sub-adult Atlantic sturgeon start entering the Cape Fear River in February with a peak in March and April (**Figure 13**), and they exit the river by the end of May. Sub-adult Atlantic sturgeon spend the summer above the saltwater interface north of Wilmington and start to emigrate to the ocean beginning in September with a peak in November. Little is known about their habitat use after this time.

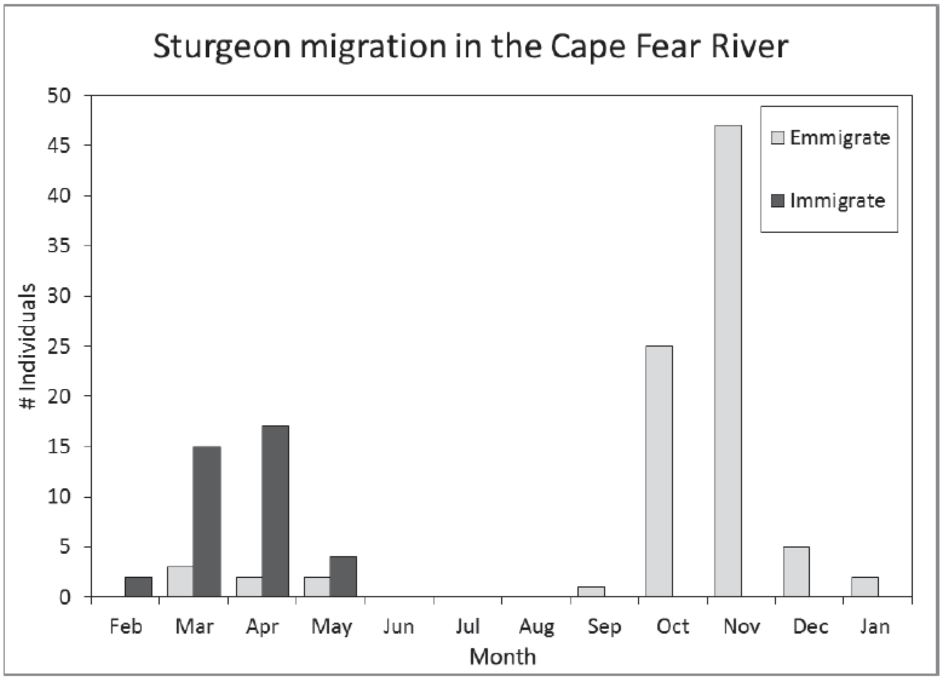

Figure 13. Number of individual, acoustically tagged Atlantic sturgeon entering or leaving the Cape Fear River April 2011 to January 2014.
Figure from USACE Wilmington District and Land Management Group Inc. (2014).

Marine Habitat Use

Interviewees suggested Atlantic sturgeon marine habitat use in the late fall and winter were a concern. During winter, Atlantic sturgeon from various geographies share marine habitats (Erickson et al. 2011). Knowledge of Atlantic sturgeon distributions in marine habitats is limited (Ingram et al. 2019), particularly in the Carolinas. Information from other geographies suggest that Atlantic sturgeon primarily use waters of < 50 m in depth during this time (Dunton et al. 2010; Ingram et al. 2019; Stein et al. 2004). Similarly, Atlantic sturgeon were often observed at depths of < 20 m during migration periods (Dunton et al. 2015). In the mid-Atlantic, Rothermel et al. (2020) found Atlantic sturgeon were closer to shore in spring and summer when temperatures were relatively warmer there, but they were detected farther offshore in winter when those waters were comparatively warmer (Rothermel et al. 2020).

Other diadromous fish of commercial or recreational fisheries importance in North Carolina and the Cape Fear River include alewife, blueback herring, American shad, hickory shad, and striped bass. Greene et al. (2009) provides an in-depth analysis of habitat associations of each of these diadromous species for the Atlantic Coast. The seasonality of spawning and related movements is detailed by Wickliffe et al. (2019) (**Figures 9 and 10**). Anadromous species such as American shad, river herring, and striped bass utilize the cape shoals as staging areas for migration along the coast (NCDEQ 2016). Shortnose sturgeon is an endangered species but is rare in the Cape Fear River (Moser and Ross 1995); the species also uses inshore waters rather than the federally managed waters of interest here.

6.5 Coastal Migratory Pelagics

Coastal migratory pelagic fish in the Cape Fear Region include Spanish mackerel, king mackerel, cobia, and bluefish. These fishes are among the most data-poor species, as their traits of being highly mobile and seasonal lead to poor representation in reef fish or groundfish monitoring programs (Iafrate et al. 2019; Pickens and Taylor 2020). The data-poor status of these species is particularly true in waters near North Carolina, where their habitat selection and seasonality are poorly documented. Interviewees suggested aggregations of these fishes occur in winter (late November to April), and biomass of juvenile coastal migratory pelagic fish is also expected to be high during this time. One concern regarding potential dredging is the disruption of spring and fall migration. King and Spanish mackerels feed on forage fish, seasonally congregating on shoals and reefs (NCDEQ 2016). NMFS has designated the cape shoals of North Carolina as HAPC, specifically for coastal migratory pelagics (NCDEQ 2016; SAFMC 2009).

In a comparative study at Cape Canaveral, Iafrate et al. (2019) used acoustic transmitters to detect fishes, including coastal migratory pelagic species. They found the following:

- Cobia were widespread on the cape-associated shoal, occurring at 56 of 62 acoustic receivers. In a comparative study, detections of individual cobia numbered 13 at a dredge site, 22 at a control site, and 35 at offshore reefs.
- Detections of individual Spanish mackerel were 10 at a dredge site, 7 at a control site, and 1 at offshore reefs. Spanish and king mackerel were extremely ephemeral during the study.
- Only 5 king mackerel were detected, with 4 being detected at offshore reefs.

Spanish mackerel is a piscivore that commonly uses depths of 10–35 m (Froese and Pauly 2018). Schmidt et al. (1993) showed the Spanish mackerel spawning season ranges primarily May–August in the South Atlantic. Ichthyoplankton samples also show larvae in depths spanning 11–29 m (Collins and Stender 1987). Larvae and juvenile Spanish mackerel have been captured in the nearshore of North Carolina from May–October (Peters and Schmidt 1997), and the species likely winters in south Florida.

King mackerel is a piscivore that uses depths of 5–140 m (Froese and Pauly 2018) and winters near south Florida (Sutter et al. 1991). In the South Atlantic, serial spawning occurs from April through early October, with a peak in September (Collins and Stender 1987; Finucane et al. 1986). King mackerel larvae were found to be more abundant at depth ranges of 21–200 m compared to more shallow waters (only 2 of 175 surveys in depths ≤ 20 m had larvae). The abundance of king mackerel in North Carolina waters is greatest in the spring (April peak) and fall (November peak) as the species migrates through the region (Trent et al. 1987).

Atlantic cobia are now managed by the Atlantic States Marine Fisheries Commission (as of 2019). Beginning in April of each year, cobia move to inshore waters to spawn in bay and estuaries of North Carolina (Shaffer and Nakamura 1989). Spawning primarily spans May–August in North Carolina (NCDEQ 2016). From data on tagged individuals, Crear et al. (2020) found cobia use temperatures of 22.5–29.5°C during warm months, depths of 0–20 m during the summer, and depths of 0–40 m during the spring and fall. The habitat suitability models developed by Crear et al. (2020) show high suitability near FPS in the fall but not the spring. With climate change scenarios, North Carolina is expected to have large decreases in suitable habitat for cobia, particularly in the next 20–60 years.

Atlantic bluefish offshore of North Carolina primarily spawn in the spring but may also spawn in the fall as fish migrate southward (Wuenschel et al. 2012). Sampling in Onslow Bay, North Carolina, shows that spring-spawned young-of-year bluefish begin appearing in April, remain along the coast in summer, and are followed by a pulse of more young-of-year that have likely migrated south from the mid-Atlantic (Wuenschel et al. 2012). These fish primarily use waters of < 20 m in depth and occur September–December. Morley et al. (2007) found 95.5% of young-of-year bluefish were caught within one mile (1.6 km) of shore (sampled to 5 miles or 8 km). These bluefish were common September–December and April–July. Variability appeared to be driven by water temperature, as bluefish appeared during times of warmer temperatures (Morley et al. 2007).

6.6 Reef Fish and Hardbottom Habitat

Interviewees recognized the high value of hardbottom outcroppings as habitat for reef fish, and they recognized the value of shipwrecks from a biological and cultural perspective. Among interviewees and other experts, there was substantial uncertainty about the relevance of hardbottom habitats to potential FPS dredging because 1) it was unknown whether hardbottom is close enough to FPS to be a concern, and 2) no surveys of juvenile reef fish have been conducted on cape-associated shoals in North Carolina. The distribution of known hardbottom and shipwrecks near FPS have been mapped (**Figure 7**), although hardbottom locations only represent approximate centroids of known hardbottom. NCDEQ (2016) provides more detailed locations of these habitats. Hardbottom was also identified near the seaward limit of the former federal navigation channel approximately 5 mi offshore (USACE Wilmington District and Land Management Group Inc 2014). In a remote sensing study of a potential borrow area on FPS, Olsen Associates Inc. (2016) found localized, unidentified magnetic anomalies were present on FPS and may represent small vessel remains. They suggested avoidance of two clusters of these detections.

Natural hardbottom, or "live bottom," provides substrate for the colonization of sessile invertebrates such as sponges, hard corals, soft corals, and algae (SAFMC 1998, 2008). As a result of this structural complexity, a tremendous diversity of adult and juvenile reef fish use these habitats for shelter, foraging, and spawning. Man-made structures, such as shipwrecks, also serve as similar habitat for reef fish (NCDEQ 2016). The North Carolina Coastal Habitat Protection Plan (NCDEQ 2016) provides a comprehensive list of fish that use hardbottom and highlights the high economic value of these fish. The South Atlantic Fishery Management Council manages reef fish as part of the Snapper-Grouper Complex, which includes 59 species. Hardbottom in nearshore waters are thought to be valuable for snapper-grouper because it acts as stopping points for fish emigrating offshore (Lindeman and Snyder 1999; NCDEQ 2016). If hardbottom were to be found in close vicinity to a potential dredging location, then burial from sedimentation (Lindeman and Snyder 1999) and loss of nearby soft-bottom foraging areas would be a concern. For adult reef fish, Bacheler et al. (2016) found the distribution of hardbottom fish were primarily structured by depth, latitude, and the percent of hardbottom substrate. Pickens and Taylor (2020) tested habitat associations of adult red snapper and black sea bass on hardbottom habitats in the South Atlantic. Black sea bass had a broad distribution, whereas red snapper were more limited. Red snapper were associated with westward currents, distance to the Gulf Stream, and nearby wetlands, and were frequently in depths of 25–35 m. Studies of reef fish at large cape-associated shoals are rare. In a study encompassing adult reef fish at Cape Canaveral Shoals in Florida, only one individual of the snapper-grouper complex was caught in 978 longline surveys (Iafrate et al. 2019).

Notably, no surveys of juvenile reef fish have occurred at FPS or other North Carolina cape-associated shoals. Numerous reef fish species, such as red snapper, use sand substrates as juveniles and then undergo an ontogenetic shift to waters with natural or artificial reefs. For example, Pickens and Taylor (2020) found juvenile red snapper were positively influenced by sand shoals and topography, although the effect was minor compared to oceanographic influences. In Florida, as much as 80% of hardbottom fish visually sampled represented early life stages (Lindeman and Snyder 1999). Walsh et al. (2006) studied reef fish habitat use of unconsolidated sediment substrates by conducting trawl surveys offshore of Georgia. They classified 121 of 181 fish species as being a juvenile life stage, and they suggest that unconsolidated sediments of the continental shelf are important for early life stages of reef-associated species.

6.7 Sharks

Interviewees suggested coastal sharks are a dominant component of the predator community on sand shoal complexes. This has been confirmed at Cape Canaveral Shoals (FL), as 90% of predators surveyed by longline were sharks (Iafrate et al. 2019). Anecdotes of interviewees suggested the productivity of forage fish are likely to be the reason for this phenomenon. Concerns with coastal sharks were mixed, with some interviewees suggesting seasonal migratory movements to be most important in the Cape Fear Region, while others expressed concern about movements to and from pupping areas in the estuary. For both movement types, seasonality is expected to play a large role in habitat use and abundance of sharks on FPS. As a migration route, interviewees suggested FPS is likely to be a stopover habitat that has predictable resources for sharks and has the structural complexity preferred by some species (e.g., sand tiger shark, spiny dogfish).

Studies conducted in the shallow waters offshore of North Carolina (Thorpe et al. 2004) and South Carolina (Ulrich et al. 2007) investigated waters of 3–15 m depths, and Atlantic sharpnose, blacknose, blacktip, bonnethead, finetooth, sandbar, and spinner shark were common. Pickens and Taylor (2020) developed predictive models for blacknose, sandbar, and tiger shark in the South Atlantic. They found the following (**Figure 14**):

- Blacknose shark had a positive relationship with chlorophyll, area of nearby estuaries, and east-west current velocities. Spatial modeling showed these associations translated to an affinity towards coastal inlets.
- Sandbar shark had their highest probability of occurrence in water depths of 42–50 m, and they were more common in areas with higher bottom temperatures in the autumn, particularly with waters > 24.5°C.
- Tiger shark were associated with a greater amount of nearby wetlands and with greater water depths; peak occurrence correlated with depths of 25–50 m.

No research in the South Atlantic has linked the distribution of sharks to their prey. In the Gulf of Mexico, Pickens and Taylor (2020) studied spinner and blacktip sharks, which are menhaden and forage fish specialists. These sharks were associated with the amount of nearby wetlands and estuaries, chlorophyll, and lower salinity waters, which are all indicative of their prey's habitat. Blacktip shark and Atlantic sharpnose in the Gulf of Mexico were associated with croaker abundance, and sharpnose shark was associated with nearby wetlands and shrimp distribution.

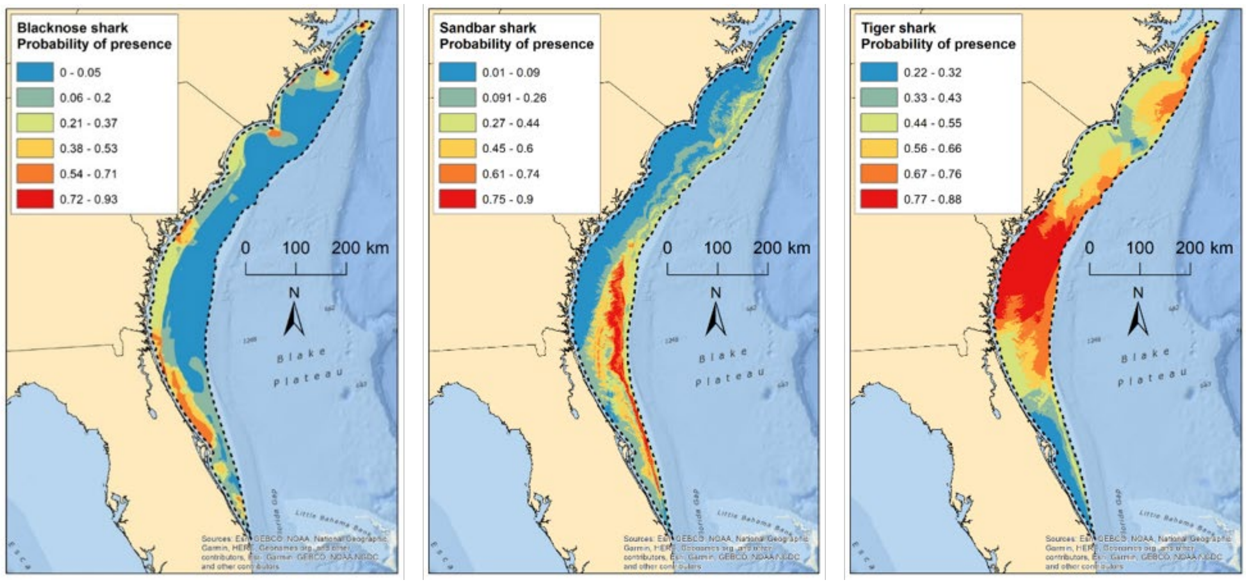

Figure 14. Predictive models of probability of occurrence for three shark species
Blacknose shark (left), sandbar shark (middle), and tiger shark (right). Figures from Pickens and Taylor (2020).

At Cape Canaveral Shoals, Iafrate et al. (2019) found the following:

- With longline surveys, the most common sharks captured were Atlantic sharpnose (1,436 captures), blacknose (488), blacktip (277), finetooth (157), nurse (52), bonnethead (40), spinner (34, mostly young-of-year), and sandbar shark (22).
- In a comparison of a dredge site and control site, Atlantic sharpnose sharks were more common at a control site, finetooth shark were more common at the dredge site, and blacknose and blacktip shark detections were similar at both sites.
- Finetooth and blacknose sharks spent much of their time in depths of < 5 m, with deeper locations used in the winter. All available depths were used.
- Atlantic sharpnose used comparatively deeper waters on the shoals (16–22 yd) (15–20 m).

Specifics of latitudinal migrations and inshore-offshore shark migrations are species-specific, unknown for many species, and difficult to generalize. There is a reasonable consensus that migration timing and movements are directly linked to water temperature (Haulsee et al. 2018; Kessel et al. 2014), and several species are restricted during winter to waters south of Cape Hatteras, North Carolina (Pickens et al. 2020). Interviewees stated that the spring migration in North Carolina spans April to mid-June as sharks move northward and fall migration peaks October–November when sharks migrate southward. Wintering species, such as spiny dogfish, reside offshore of North Carolina from December–March (Bangley 2012). Below we provide case studies of pelagic, wintering, and migratory shark studies. Specific details of habitat associations of species are provided by Pickens et al. (2020). Data gaps include species-specific habitat use at, or near FPS, and the importance of cape-associated shoals compared to other available habitats.

Pelagic Sharks

Research on pelagic sharks is largely lacking. In a study of pelagic sharks that included tiger, blue, shortfin mako, and great hammerhead shark, Queiroz et al. (2016) found they were distributed along the Atlantic Coast during March–August, but during September–February they were more limited to waters near Florida and deep offshore waters. Hotspots of use were predictable based on temperature and fronts of temperature or productivity gradients (Queiroz et al. 2016).

Wintering Locations and Migration

North Carolina is a wintering area for sharks and a common migratory stopover, although data specific to FPS are lacking. Evidence is provided by:

- Conrath and Musick (2008) tracked sandbar sharks offshore of Virginia during the summer, and all seven individuals wintered offshore of North Carolina. The authors suggest that central North Carolina could be an important wintering area for sharks because of its proximity to the warm Gulf Stream.
- Kneebone et al. (2014) tracked sand tiger sharks in the northeastern US and found 27 sand tiger sharks (43% of individuals studied) were detected transiting near Cape Hatteras, North Carolina, during migration, and 20% had residency there. This is likely due to Cape Hatteras being a temperature break point with warmer waters, and possibly, because a steep depth gradient exists there and may funnel shallow water species along the cape-associated shoals. The value of habitat farther south, such as FPS, remains unknown.
- A sand tiger shark study in Delaware Bay showed all seven tagged males migrated south to the vicinity of Cape Hatteras, North Carolina, whereas females moved outward to the edge of the continental shelf (Teter et al. 2015). Again, waters near North Carolina were thought to be important to wintering sharks because of relatively high temperatures of the Gulf Stream.
- In the mid-Atlantic, sand tiger sharks were found to migrate northward along a narrow, nearshore band of shallow water in the spring (Haulsee et al. 2015). They further suggest that sand tigers may use the shoreline and sand shoals as landmarks for their migration in the fall (Haulsee et al. 2015).

Pupping and Nursery Waters

Published studies on shark species using the Cape Fear River estuary as a nursery are lacking. Castro (1993) investigated estuaries of South Carolina during the spring and summer (March to late September) for evidence of gravid females, females carrying embryos, neonate, and young-of-year sharks. Most species were observed in very shallow waters (< 10 m in depth). Common species using the estuaries as nurseries include:

- Blacknose shark
- Blacktip shark
- Spinner shark
- Sandbar shark
- Finetooth shark
- Dusky shark
- Atlantic sharpnose shark
- Scalloped hammerhead
- Smooth dogfish

6.8 Sea Turtles, Marine Mammals, and Seabirds

Sea turtles, marine mammals, and seabirds were not a major focus of this review, but several of these species will need to be addressed in any potential FPS sand dredging project. Therefore, we provide a brief overview here based on a previous environmental impact statement (USACE Wilmington District and Land Management Group Inc 2014).

- Marine mammals that might use waters in the vicinity of FPS are North Atlantic right whale and humpback whale. Humpback whales migrate through the region December–April. Right whales, an endangered species, occasionally winter offshore of North Carolina, and right whale breeding has been observed offshore of Wrightsville Beach, North Carolina.

- State-listed birds that forage in the ocean near FPS include least tern, common tern, and brown pelican. These bird species prey on forage fish, but little is known about foraging-related movements of these birds or their habitat use in the region. Addressing impacts to forage fish would indirectly affect these birds.
- Sea turtle species in the vicinity of FPS are loggerhead, Kemp's Ridley, leatherback, green, and Hawksbill (less common) sea turtles. Hopper dredges are known to lethally entrain sea turtles, and further details regarding this issue are provided by Dickerson et al. (2004). Certain dredging conditions and borrow area designs may increase the risk of sea turtle entrainment and may be mitigated.

6.9 Biological Knowledge Gaps and Research Priorities

With a basis in the literature synthesis and workshops, major knowledge gaps and research priorities were identified regarding the biology of FPS (no order of importance is implied):

A) What drives the high productivity of shoal systems? In particular, shoals are thought to be extremely productive for phytoplankton, forage fish, shrimp, and sharks. What species are particularly abundant? How does productivity vary among seasons? How might biological productivity be affected by dredging?

B) What areas on, or near, FPS are important for estuary-ocean connectivity for larvae and anadromous fish? Are these pathways narrow or broad?

C) How does FPS act as a pathway and habitat during seasonal migration for fish such as mackerel, cobia, and sharks?

D) How does fine-scale fish and shrimp habitat use vary within the FPS complex (e.g., on the shoal vs. edge of shoal vs. lee of shoal)?

E) What is the best environmental window for dredging? There needs to be clearly identified species of interest for this offshore environment. As an example, a synthesis of environmental windows has been developed for the nearshore environment with a focus on inlets, fish, and invertebrate spawning seasons (Wickliffe et al. 2019). For FPS, the recommendation is to investigate fish and invertebrate spawning, abundance, and biomass across seasons. In particular, information is needed on seasonal latitudinal migrations of coastal migratory pelagics (Spanish mackerel, king mackerel, cobia) and sharks. As in Wickliffe et al. (2019), estuarine-ocean linkages with spawning and various life stages should also be considered.

Biological Research Methodologies

Cutting-edge biological research methodologies were a prominent topic discussed during interviews and both workshops. The FPS area, similar to other shoal complexes, is well known to be challenging for the navigation needed for research because of extremely shallow waters and the potential dangers involved with even mild storms. This means that standard biological techniques—such as trawls, bottom or vertical longline, traps, stomach content analysis, and plankton tows—may benefit from supplemental data collected remotely. For example, accelerometer fish tags can track species behavior and habitat use. Stable isotopes can be useful for trophic studies, and satellite remote sensing can quantify oceanographic metrics.

A commonality that was frequently expressed by interviewees, technical experts, agency personnel, and even stakeholders was the potential benefits of an underwater acoustic telemetry array. Of the research priorities identified above, B through E would all benefit from such a receiver array. For example, in Cape Canaveral, Iafrate et al. (2019) built upon an existing telemetry array to answer questions related to the seasonality of species habitat use, fish habitat selection within the shoal complex, and the direct effects of dredging and movements of fish outside the shoal complex. The FACT Network (originated as the Florida Atlantic Coast Telemetry Network, https://secoora.org/fact/) (Bangley et al. 2020; Young et al. 2020) and ACT Network (The Atlantic Cooperative Telemetry Network, https://www.theactnetwork.com) include organizations and individuals acting in cooperation to support fish acoustic arrays. The majority of ACT arrays are in the northeast and Mid-Atlantic, with a few in North Carolina, whereas FACT arrays are primarily in Florida and have only a limited number of receivers available in North Carolina. The MATOS (Mid-Atlantic Acoustic Telemetry Observation Systems, https://matos.asascience.com/home/acousticTelemetry) may also be useful for potential FPS studies. Notably, data are considered to be owned as intellectual property by the transmitter owner, and these networks are designed to facilitate those collaborative relationships for research purposes. Although new acoustic receivers would be expected to identify fish from other tagging studies, field research would be needed to tag species of interest. The use of automated wave gliders may also supplement fish data from fixed telemetry receiving stations (Iafrate et al. 2019).

Because of the difficulty of accessing extremely shallow waters, active acoustic surveys were recognized as a potentially important tool for research on shoals. Sidescan sonar, multibeam sonar, splitbeam echosounders, fish finders, and other remote sensing instruments have the capability of collecting data over a broad area while being positioned at a discrete location. Sonar data have been used to quantify fish schools, biomass, and abundance of coral reef fish (Bollinger and Kline 2017; Campanella and Taylor 2016), pelagic fish (Vatnehol et al. 2018), tuna (Melvin 2016), and forage fish (Lankowicz et al. 2020; Misund and Coetzee 2000; Stockwell et al. 2013). Acoustic data is ideally collected alongside complementary data collection techniques to help interpret acoustic data in terms of biomass, abundance, and species composition (Trenkel et al. 2011). As shoals are expected to be productive for forage fish, coastal migratory pelagics, and sharks, these techniques could play a valuable role in an assessment of shoal habitats.

Expert Consultation

During the technical and stakeholder workshops, staff from NMFS and the North Carolina Division of Marine Fisheries suggested that they would be willing to provide input and technical guidance on characteristics of any new infrastructure developed as part of a new fish telemetry array (e.g., location of array receivers, identifying species of interest for tagging). Researchers involved with the Cape Canaveral research study (Iafrate et al. 2019) also offered advice and consultation if an array is developed at FPS.

7 Potential Mitigation Measures for Dredging at FPS

Mitigation methods have not been developed specifically for FPS; however, we summarize measures that have been previously proposed in the literature to promote biological recovery and reduce impacts to shoal integrity. This suite of mitigation measures should be considered "tools in the toolbox" for implementation where appropriate to reduce risk from specific dredging related impacts. Other mitigation measures not included in detail here are ship strike avoidance and mitigation for entrainment. For marine mammals, the greatest risk from dredging activities are related to ship strike, which can be mitigated with observers and slow down procedures.

Mitigation methods related to dredging action and fisheries identified by Tomlinson et al. (2007), Diaz et al. (2004), and Slacum Jr et al. (2010) include the following:

- Put in place spatial zoning to protect areas important to fish or areas that are sensitive to disturbance.
- Develop navigation routes that minimize conflict with fishing.
- Select a dredging technique and timing of dredging to minimize potential negative effects. These may be seasonal exclusions or using knowledge of tidal stages or ocean currents. Dredging sand during the winter could minimize adverse ecological effects by avoiding periods of peak recruitment of species.
- To reduce direct injury to fish, sand could be dredged at night, when some species migrate vertically into the water column.
- Shoals could be mined in a rotation, or be partially dredged, to allow shoal-associated fauna assemblages to recover between dredging events; this should be done with consideration of recovery rates of shoals. Limit the distance between dredged and undredged shoals to facilitate recolonization of biota.
- Shoals with less relief could be targeted for mining instead of steeper shoals when the option is available.
- Avoid dredging when demersal finfish are using the inner continental shelf as a nursery ground.
- Prevent on-board screening, or minimize material passing through spillways, when outside the dredging area to reduce the area of sediment plumes.
- Modify dredging depth and design to reduce changes to hydrodynamics and sediment transport.

Mitigation measures identified or implied by Dibajnia and Nairn (2011), CSA International Inc. (CSA International Inc et al. 2010) to protect the geomorphic integrity of shoals include:

- Avoid dredging shoals in waters > 30 m in depth because it has been shown that a decrease in shoal height occurs beyond this depth, and a shoal may not recover to its pre-dredging height.
- Prioritize locations for shoal dredging to minimize physical impacts. Dredging of the leading edge of a shoal often leads to a net long-term deposition and faster infilling rates, followed by the crest and the trailing edge.
- Use innovative dredging methodologies such as a “striped” dredging pattern that appears to support a more timely and uniform recovery.
- Extract sand from a deposition center, leading edge, or down drift margin of a shoal to avoid interrupting natural shoal migration and potentially reduce the time required for site refilling. Avoid dredging in erosional areas that are sources for down drift deposition because these areas may be slow to refill after dredging.
- Utilize shallow dredging over large areas rather than excavating small, but deep, pits.
- Dredge on shoal crests and higher areas of the leading edge rather than lower areas of the shoals because of greater exposure to wave-generated turbulence and greater sediment mobility, which potentially results in more rapid sediment reworking and site infilling, and likely would induce the benthic community to recover more rapidly.

8 Literature Cited

Atkinson, L. P. 1977. Modes of Gulf Stream intrusion into the South Atlantic Bight shelf waters. Geophysical Research Letters, 4(12), 583-586.

Atkinson, L. P., Lee, T. N., Blanton, J. O., & Chandler, W. S. 1983. Climatology of the southeastern United States continental shelf waters. Journal of Geophysical Research: Oceans, 88(C8), 4705-4718.

Bacheler, N. M., Schobernd, Z. H., Berrane, D. J., Schobernd, C. M., Mitchell, W. A., Teer, B. Z., . . . Glasgow, D. M. 2016. Spatial distribution of reef fish species along the southeast US Atlantic coast inferred from underwater video survey data. PloS One, 11(9), e0162653.

Bangley, C. W. 2012. Food and feeding habits of the spiny dogfish *Squalus acanthias* overwintering off the coast of North Carolina and the effects on the marine community. M.S. Thesis. East Carolina University.

Bangley, C. W., Whoriskey, F. G., Young, J. M., & Ogburn, M. B. 2020. Networked animal telemetry in the northwest Atlantic and Caribbean Waters. Marine and Coastal Fisheries, 12(5), 339-347.

Bollinger, M. A., & Kline, R. J. 2017. Validating sidescan sonar as a fish survey tool over artificial reefs. Journal of Coastal Research, 33(6), 1397-1407. doi:10.2112/jcoastres-d-16-00174.1

Breece, M. W., Fox, D. A., Dunton, K. J., Frisk, M. G., Jordaan, A., & Oliver, M. J. 2016. Dynamic seascapes predict the marine occurrence of an endangered species: Atlantic Sturgeon *Acipenser oxyrinchus oxyrinchus*. Methods in Ecology and Evolution, 7(6), 725-733.

Breece, M. W., Fox, D. A., & Oliver, M. J. 2018. Environmental drivers of adult Atlantic sturgeon movement and residency in the Delaware Bay. Marine and Coastal Fisheries, 10(2), 269-280. doi:10.1002/mcf2.10025

Byrnes, M. R., Hammer, R. M., Thibaut, T. D., & Snyder, D. B. 2004a. Effects of sand mining on physical processes and biological communities offshore New Jersey, U.S.A. Journal of Coastal Research, 201, 25-43. doi:10.2112/1551-5036(2004)20[25:eosmop]2.0.co;2

Byrnes, M. R., Hammer, R. M., Thibaut, T. D., & Snyder, D. B. 2004b. Physical and biological effects of sand mining offshore Alabama, USA. Journal of Coastal Research, 20(1), 6-24.

Campanella, F., & Taylor, J. C. 2016. Investigating acoustic diversity of fish aggregations in coral reef ecosystems from multifrequency fishery sonar surveys. Fisheries Research, 181, 63-76. doi:10.1016/j.fishres.2016.03.027

Castelao, R. 2011. Intrusions of Gulf Stream waters onto the South Atlantic Bight shelf. Journal of Geophysical Research: Oceans, 116(C10). doi:10.1029/2011jc007178

Castro, J. I. 1993. The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern coast of the United States. Environmental Biology of Fishes, 38(1-3), 37-48.

Catlin [Catlin Engineers and Scientists]. 2010. Brunswick County beaches renourishment study, Frying Pan Shoal soil testing and compatibility analysis and geotechnical report. Catlin Project No. 209-

049. Appendix to integrated general reevaluation report and environmental impact statement for Brunswick County Beach, North Carolina.

Collins, M. R., Smith, T. I., Post, W. C., & Pashuk, O. 2000. Habitat utilization and biological characteristics of adult Atlantic sturgeon in two South Carolina rivers. Transactions of the American Fisheries Society*,* 129(4), 982-988.

Collins, M. R., & Stender, B. W. 1987. Larval king mackerel (*Scomberomorus-Cavalla*), Spanish mackerel (*Scomberomorus-Maculatus*), and bluefish (*Pomatomus-Saltatrix*) off the southeast coast of the United-States, 1973-1980. Bulletin of Marine Science*,* 41(3), 822-834.

Conley, M. F., Anderson, M. G., Steinberg, N., & Barnett, A. 2017. The South Atlantic Bight marine assessment: species, habitats and ecosystems. The Nature Conservancy, Eastern Conservation Science.

Conrath, C. L., & Musick, J. A. 2008. Investigations into depth and temperature habitat utilization and overwintering grounds of juvenile sandbar sharks, *Carcharhinus plumbeus*: the importance of near shore North Carolina waters. Environmental Biology of Fishes*,* 82(2), 123-131. doi:10.1007/s10641-007-9263-0

Crear, D. P., Watkins, B. E., Saba, V. S., Graves, J. E., Jensen, D. R., Hobday, A. J., & Weng, K. C. 2020. Contemporary and future distributions of cobia, *Rachycentron canadum*. Diversity and Distributions. 26(8) 1002-1015

CSA International Inc, Applied Coastal Research and Engineering, Inc., Barry A. Vittor & Associates, Inc., C.F. Bean, L.L.C., and Florida Institute of Technology. 2010. Analysis of potential biological and physical impacts of dredging on offshore ridge and shoal features. Herndon (VA): Prepared for the U.S. Department of the Interior, Minerals Management Service, Leasing Division, Marine Minerals Branch. OCS Study MMS 2010-010. 160 pp.

Diaz, R., Cutter Jr, G., & Hobbs Iii, C. 2004. Potential impacts of sand mining offshore of Maryland and Delaware: Part 2—biological considerations. Journal of Coastal Research, 20(1): 61-69.

Dibajnia, M., & Nairn, R. B. 2011. Investigation of dredging guidelines to maintain and protect the geomorphic integrity of offshore ridge and shoal regimes. Herndon (VA): U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, OCS Study MMS 2011-025. 150 + appendices

Dickerson, D., Wolters, M., Theriot, C., & Slay, C. (2004). Dredging impacts on sea turtles in the Southeastern USA: a historical review of protection. Paper presented at the Proceedings of World Dredging Congress XVII, Dredging in a Sensitive Environment.

Dickerson DD, Reine KJ, Clarke DG. 1998. Economic impacts of environmental windows associated with dredging operations. DOER Technical Notes Collection (TN DOER-E3), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/dots/doer*

Dunton, K. J., Jordaan, A., Conover, D. O., McKown, K. A., Bonacci, L. A., & Frisk, M. G. 2015. Marine distribution and habitat use of Atlantic sturgeon in New York lead to fisheries interactions and bycatch. Marine and Coastal Fisheries*,* 7(1), 18-32. doi:10.1080/19425120.2014.986348

Dunton, K. J., Jordaan, A., McKown, K. A., Conover, D. O., & Frisk, M. G. 2010. Abundance and distribution of Atlantic sturgeon (*Acipenser oxyrinchus*) within the Northwest Atlantic Ocean, determined from five fishery-independent surveys. Fishery Bulletin*,* 108(4), 450-465.

Duran-Matute, M., & Gerkema, T. 2015. Calculating residual flows through a multiple-inlet system: the conundrum of the tidal period. Ocean Dynamics*,* 65(11), 1461-1475.

Dyer, K. R. 1991. *Coastal and Estuarine Circulation*. New York: Wiley-Interscience.

Erickson, D. L., Kahnle, A., Millard, M. J., Mora, E. A., Bryja, M., Higgs, A., . . . Pikitch, E. K. 2011. Use of pop-up satellite archival tags to identify oceanic-migratory patterns for adult Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchell, 1815. Journal of Applied Ichthyology*,* 27(2), 356-365. doi:10.1111/j.1439-0426.2011.01690.x

Federal Register. 2017. Endangered and threatened species; Designation of critical habitat for the endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic Distinct 131 population segments of Atlantic Sturgeon and the threatened Gulf of Maine distinct population segment of Atlantic Sturgeon. Federal Register 82 FR 39160.

Finucane, J. H., Collins, L. A., Brusher, H. A., & Saloman, C. H. 1986. Reproductive-biology of king mackerel, *Scomberomorus-Cavalla*, from the southeastern United-States. Fishery Bulletin*,* 84(4), 841-850.

Freshwater, D. W., Whitfield, P. E., Buckel, C. A., Munoz, R. C., & Degan, B. P. 2016. Epibenthic community assessments indicate high spatial and temporal variability among continental shelf hard bottom sites in a marine transition zone. Regional Studies in Marine Science*,* 5, 41-50. doi:10.1016/j.rsma.2016.01.005

Froese, R., & Pauly, D. (2018). FishBase World Wide Web electronic publication, Version (10/2018). Accessed 10 December 2018. Retrieved from https://www.fishbase.de/

Greene, K. E., Zimmerman, J. L., Laney, R. W., & Thomas-Blate, J. C. 2009. Atlantic coast diadromous fish habitat: a review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series*,* 464, 276.

Haulsee, D. E., Breece, M. W., Brown, L. M., Wetherbee, B. M., Fox, D. A., & Oliver, M. J. 2018. Spatial ecology of *Carcharias taurus* in the northwestern Mid-Atlantic coastal ocean. Marine Ecology Progress Series*,* 597, 191-206. doi:10.3354/meps12592

Haulsee, D. E., Breece, M. W., Miller, D. C., Wetherbee, B. M., Fox, D. A., & Oliver, M. J. 2015. Habitat selection of a coastal shark species estimated from an autonomous underwater vehicle. Marine Ecology Progress Series*,* 528, 277-288.

Hayes, M. O., & Nairn, R. B. 2004. Natural maintenance of sand ridges and linear shoals on the US Gulf and Atlantic continental shelves and the potential impacts of dredging. Journal of Coastal Research, 20(1): 138-148.

Iafrate, J., Watwood SL, Reyier EA, Ahr BJ, Scheidt DM, Holloway-Adkins KG, . . . E., S. 2019. Behavior, seasonality, and habitat preferences of mobile fishes and sea turtles within a large sand shoal complex: insights from traditional sampling and emerging technologies. Sterling (VA): U.S. Dept. of the Interior, Bureau of Ocean Energy Management, pp. 183

Ingram, E. C., Cerrato, R. M., Dunton, K. J., & Frisk, M. G. 2019. Endangered Atlantic sturgeon in the NewYork Wind Energy Area: implications of future development in an offshore wind energy site. Scientific Reports, 9, 13. doi:10.1038/s41598-019-48818-6

Inman, D.L. & Dolan R. 1989. The Outer Banks of North Carolina: Budget of sediment and inlet dynamics along a migrating barrier system. Journal of Coastal Research, 5, 193-237.

Johnson, J. H., Dropkin, D. S., Warkentine, B. E., Rachlin, J. W., & Andrews, W. D. 1997. Food habits of Atlantic sturgeon off the central New Jersey coast. Transactions of the American Fisheries Society, 126(1), 166-170. doi:10.1577/1548-8659(1997)126<0166:fhoaso>2.3.co;2

Kessel, S., Chapman, D., Franks, B., Gedamke, T., Gruber, S., Newman, J., . . . Perkins, R. G. 2014. Predictable temperature-regulated residency, movement and migration in a large, highly mobile marine predator (*Negaprion brevirostris*). Marine Ecology Progress Series, 514, 175-190.

Kim, T. G., Grigalunas, T. A., & Han, K.-N. 2008. The economic costs to fisheries because of marine sand mining in Ongjin Korea: concepts, methods, and illustrative results. Ecological Economics, 65(3), 498-507. doi:10.1016/j.ecolecon.2007.07.016

Kneebone, J., Chisholm, J., & Skomal, G. 2014. Movement patterns of juvenile sand tigers (*Carcharias taurus*) along the east coast of the USA. Marine Biology, 161(5), 1149-1163.

Lankowicz, K. M., Bi, H. S., Liang, D., & Fan, C. L. 2020. Sonar imaging surveys fill data gaps in forage fish populations in shallow estuarine tributaries. Fisheries Research, 226, 11. doi:10.1016/j.fishres.2020.105520

Lindeman, K. C., & Snyder, D. B. 1999. Nearshore hardbottom fishes of southeast Florida and effects of habitat burial caused by dredging. Fishery Bulletin, 97(3), 508-525.

Maa, J. P. Y., Hobbs, C. H., Kim, S. C., & Wei, E. 2004. Potential impacts of sand mining offshore of Maryland and Delaware: Part I - Impacts on physical oceanographic processes. Journal of Coastal Research, 20(1), 44-60. doi:10.2112/1551-5036(2004)20[44:piosmo]2.0.co;2

Markovsky, W. C. (2004). *The Role of the Cape Fear River Discharge Plume in Fisheries Production: Aggregation and Trophic Enhancement.* M.S. Thesis. University of North Carolina at Wilmington.

McNinch, J. (2009). *Literature review of cuspate rorelands, implications to dredging Frying Pan Shoals. Prepared for USACE, unpublished. 64 pp.*

McNinch, J. E., & Luettich, R. A. 2000. Physical processes around a cuspate foreland: implications to the evolution and long-term maintenance of a cape-associated shoal. Continental Shelf Research, 20(17), 2367-2389. doi:10.1016/s0278-4343(00)00061-3

McNinch, J. E., & Wells, J. T. 1999. Sedimentary processes and depositional history of a cape-associated shoal, Cape Lookout, North Carolina. Marine Geology, 158(1-4), 233-252.

McNinch, J. E., Wells, J. T., & Snyder, S. W. (1999). *The long-term contribution of pre-Holocene sands to transgressing barrier islands.* Paper presented at the Proceedings of Coastal Sediments, 4th International Symposium on Coasting Engineering and Science of Coastal Sediment Processes, New York.

Melvin, G. D. 2016. Observations of in situ Atlantic bluefin tuna (*Thunnus thynnus*) with 500-kHz multibeam sonar. ICES Journal of Marine Science, 73(8), 1975-1986. doi:10.1093/icesjms/fsw077

Michel, J., Bejarano, A. C., Peterson, C. H., & Voss, C. 2013. Review of biological and biophysical impacts from dredging and handling of offshore sand. Herndon (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management, OCS Study BOEM 2013-0119. pp. 258

Misund, O. A., & Coetzee, J. 2000. Recording fish schools by multi-beam sonar: potential for validating and supplementing echo integration recordings of schooling fish. Fisheries Research, 47(2-3), 149-159. doi:10.1016/s0165-7836(00)00166-1

Morley, J. W., Buckel, J. A., & Lankford Jr, T. E. 2007. Winter energy storage dynamics and cohort structure of young-of-the-year bluefish *Pomatomus saltatrix* off North Carolina. Marine Ecology Progress Series, 334, 273-286.

Moser, M. L., & Ross, S. W. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society, 124(2), 225-234.

NCDEQ. 2016. North Carolina Coastal Habitat Protection Plan. Morehead City (NC): North Carolina Division of Marine Fisheries. pp. 475

NOAA. (2020). Tides & Currents. https://tidesandcurrents.noaa.gov/noaatideannual.html?id=8658163. Retrieved from https://tidesandcurrents.noaa.gov/noaatideannual.html?id=8658163

NOAA Office for Coastal Management. (2020). OceanReports. https://coast.noaa.gov/digitalcoast/tools/ort.html.

North Carolina Division of Coastal Management. (2020). Oceanfront construction setback and erosion rates. Department of Environmental Quality https://deq.nc.gov/about/divisions/coastal-management/coastal-management-oceanfront-shorelines/oceanfront-construction-setback-erosion-rate. https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=f5e463a929ed430095e0a17ff803e156

Olsen Associates Inc. 2012. Calibration of a Deft3D model for Bald Head Island and the Cape Fear River Entrance. Prepared for the Village of Bald Head Island. (internal report)

Olsen Associates Inc. 2016. Frying Pan Shoals sand search investigation. (internal report)

Overton, M., Grenier Jr, R., Judge, E., & Fisher, J. 1999. Identification and analysis of coastal erosion hazard areas: Dare and Brunswick Counties, North Carolina. Journal of Coastal Research, 28: 69-84.

Park, J. Y., & Wells, J. T. 2005. Longshore transport at Cape Lookout, North Carolina: Shoal evolution and the regional sediment budget. Journal of Coastal Research, 21(1), 1-17. doi:10.2112/02051.1

Pattiaratchi, C., & Collins, M. 1987. Mechanisms for linear sandbank formation and maintenance in relation to dynamical oceanographic observations. Progress in Oceanography, 19(2), 117-176.

Peters, J. S., & Schmidt, D. J. 1997. Daily age and growth of larval and early juvenile Spanish mackerel, *Scomberomorus maculatus* from the South Atlantic Bight. Fishery Bulletin, 95(3), 530-539.

Pickens, B., & Taylor, J. (2020). Volume 3: Predicting the Distribution of Select Fish Species of the Gulf of Mexico, South Atlantic, and Greater Atlantic. In Pickens BA & Taylor JC (Eds.), *Regional Essential Fish Habitat geospatial assessment and framework for offshore sand features* (pp. 67). Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2020-002 and NOAA NCCOS Technical Memorandum 270. https://doi.org/10.25923/akzd-8556

Pickens, B., Taylor, J., & Hansen, D. (2020). Volume 1: Fish habitat associations and the potential effects of dredging on the Atlantic and Gulf of Mexico Outer Continental Shelf, literature synthesis and gap analysis. In Pickens BA & Taylor JC (Eds.), *Regional Essential Fish Habitat geospatial assessment and framework for offshore sand features*. Sterling (VA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2020-002 and NOAA NCCOS Technical Memorandum 270. https://doi.org/10.25923/akzd-8556 121 pp.

Pickens, B. A., Carroll, R., & Taylor, J. C. 2021a. Predicting the distribution of penaeid shrimp reveals linkages between estuarine and offshore marine habitats. Estuaries and Coasts. doi:https://doi.org/10.1007/s12237-021-00924-3

Pickens, B. A., Taylor, J. C., Finkbeiner, M., Hansen, D., & Turner, L. 2021b. Modeling sand shoals on the US Atlantic Shelf: moving beyond a site-by-site approach. Journal of Coastal Research*,* 37(2), 227-237.

PSDS. (2020). Program for the Study of Developed Shorelines, Beach Renourishment Database, Western Carolina University. http://beachnourishment.wcu.edu/.

Queiroz, N., Humphries, N. E., Mucientes, G., Hammerschlag, N., Lima, F. P., Scales, K. L., . . . Sims, D. W. 2016. Ocean-wide tracking of pelagic sharks reveals extent of overlap with longline fishing hotspots. Proceedings of the National Academy of Sciences of the United States of America*,* 113(6), 1582-1587.

Reine K, Clarke D. 1998. Entrainment by hydraulic dredges-A review of potential impacts. Technical Note. Vicksburg (MS): DOER-EL U.S. Army Corps of Engineers, Environmental Laboratory.

Rothermel, E. R., Balazik, M. T., Best, J. E., Breece, M. W., Fox, D. A., Gahagan, B. I., . . . Secor, D. H. 2020. Comparative migration ecology of striped bass and Atlantic sturgeon in the US Southern mid-Atlantic bight flyway. PloS One*,* 15(6), 24. doi:10.1371/journal.pone.0234442

Rutecki D, Dellapenna T, Nestler E, Scharf F, Rooker J, Glass C, Pembroke A. 2014. Understanding the habitat value and function of shoals and shoal complexes to fish and fisheries on the Atlantic and Gulf of Mexico outer continental shelf. Literature synthesis and gap analysis. Herndon (VA): Prepared for the U.S. Dept. of the Interior, Bureau of Ocean Energy Management. BOEM 2015-012. 176 pp.

SAFMC. 1998. Final habitat plan for the South Atlantic region: Essential fish habitat requirements for fishery management plans of the South Atlantic Fishery Management Council. Charleston (SC).

SAFMC. 2008. Fishery Ecosystem Plan of the South Atlantic region. Volume II: South Atlantic habitats and species, public hearing draft. Charleston (SC)

SAFMC. 2009. Comprehensive ecosystem-based Amendment 1 for the South Atlantic region. . Charleston (SC)

Schmidt, D. J., Collins, M. R., & Wyanski, D. M. 1993. Age, growth, maturity, and spawning of Spanish Mackerel, *Scomberomorus-Maculatus* (Mitchill), from the Atlantic Coast of the southeastern United-States. Fishery Bulletin, 91(3), 526-533.

Shaffer, R. V., & Nakamura, E. L. 1989. Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae). NOAA Technical Report NMFS 82.

Shepard, F. P., & Wanless, H. R. 1971. *Our changing coastlines.* New York: McGraw-Hill.

Slacum Jr, H. W., Burton, W. H., Methratta, E. T., Weber, E. D., Llansó, R. J., & Dew-Baxter, J. 2010. Assemblage structure in shoal and flat-bottom habitats on the inner continental shelf of the Middle Atlantic Bight, USA. Marine and Coastal Fisheries, 2(1), 277-298.

Smith, J. A., Flowers, H. J., & Hightower, J. E. 2015. Fall spawning of Atlantic Sturgeon in the Roanoke River, North Carolina. Transactions of the American Fisheries Society, 144(1), 48-54.

Stein, A. B., Friedland, K. D., & Sutherland, M. 2004. Atlantic sturgeon marine distribution and habitat use along the northeastern coast of the United States. Transactions of the American Fisheries Society, 133(3), 527-537.

Stockwell, J. D., Weber, T. C., Baukus, A. J., & Jech, J. M. 2013. On the use of omnidirectional sonars and downwards-looking echosounders to assess pelagic fish distributions during and after midwater trawling. Ices Journal of Marine Science, 70(1), 196-203. doi:10.1093/icesjms/fss139

Stone, G. W., Condrey, R. E., Fleeger, J. W., Khalil, S. M., Kobashi, D., Jose, F., . . . Reynal, F. 2009. Environmental investigation of long-term use of Ship Shoal sand resources for large scale beach and coastal restoration in Louisiana. New Orleans, LA: 278

Suedel, B. C., Kim, J., Clarke, D. G., & Linkov, I. 2008. A risk-informed decision framework for setting environmental windows for dredging projects. Science of the Total Environment, 403(1-3), 1-11.

Sutter, F. C., Williams, R. O., & Godcharles, M. F. 1991. Movement patterns and stock affinities of king mackerel in the southeastern United States. Fishery Bulletin, 89(2), 315-324.

Taylor Engineering Inc. 2020. South Atlantic Division sand availability and needs determination summary report. Prepared for U.S. Army Corps of Engineers W912BU-15-D-006.

Teter, S. M., Wetherbee, B. M., Fox, D. A., Lam, C. H., Kiefer, D. A., & Shivji, M. 2015. Migratory patterns and habitat use of the sand tiger shark (Carcharias taurus) in the western North Atlantic. Marine and Freshwater Research, 66(2), 158-169.

Thorpe, T., Jensen, C. F., & Moser, M. L. 2004. Relative abundance and reproductive characteristics of sharks in southeastern North Carolina coastal waters. Bulletin of Marine Science, 74(1), 3-20.

Tomlinson B.N., Petterson, J. S., Glazier E. W., Lewis, J., Selby I., , Nairn R., Kenny T., . . . Cooke R. L. 2007. Investigation of dredging impacts on commercial and recreational fisheries and analysis of available mitigation mesaures to protect and preserve resources. Herndon (VA): U.S. Department of the Interior, Marine Minerals Branch. OCS Report MMS 2006-0065. pp. 233

Trenkel, V. M., Ressler, P. H., Jech, M., Giannoulaki, M., & Taylor, C. 2011. Underwater acoustics for ecosystem-based management: state of the science and proposals for ecosystem indicators. Marine Ecology Progress Series, 442, 285-301.

Trent, L., Palko, B. J., Williams, M. L., & Brusher, H. A. 1987. Abundance of king mackerel, *Scomberomorus-Cavalla*, in the Southeastern United-States Based on CPUE data from Charterboats, 1982-85. Marine Fisheries Review*,* 49(2), 78-90.

Ulrich, G. F., Jones, C. M., Driggers, W., Drymon, J. M., Oakley, D., & Riley, C. (2007). *Habitat utilization, relative abundance, and seasonality of sharks in the estuarine and nearshore waters of South Carolina.* Paper presented at the American Fisheries Society Symposium.

USACE. 2020. Regional sediment management optimization update, South Atlantic Division. Jacksonville (FL): USACE.

USACE Wilmington District and Land Management Group Inc. 2014. Village of Bald Head Island shoreline protection project. Final environmental impact statement, Brunswick County, North Carolina.

Vatnehol, S., Pena, H., & Handegard, N. O. 2018. A method to automatically detect fish aggregations using horizontally scanning sonar. ICES Journal of Marine Science*,* 75(5), 1803-1812. doi:10.1093/icesjms/fsy029

Walsh, H. J., Marancik, K. E., & Hare, J. A. 2006. Juvenile fish assemblages collected on unconsolidated sediments of the southeast United States continental shelf. Fishery Bulletin*,* 104, 256-277.

Weber, A., & Blanton, J. 1980. Monthly mean wind fields for the South Atlantic Bight. Journal of Physical Oceanography*,* 10(8), 1256-1263.

Wenger, A. S., Harvey, E., Wilson, S., Rawson, C., Newman, S. J., Clarke, D., . . . Evans, R. D. 2017. A critical analysis of the direct effects of dredging on fish. Fish and Fisheries*,* 18(5), 967-985. doi:10.1111/faf.12218

Wentworth, C. K. 1922. A scale of grade and class terms for clastic sediments. The Journal of Geology*,* 30(5), 377-392.

Wickliffe, L. C., F.C. Rohde, K.L. Riley, & J.A. Morris Jr. 2019. An Assessment of Fisheries Species to Inform Time-of-Year Restrictions for North Carolina and South Carolina. Beaufort, NC: 268

Wuenschel, M. J., Able, K. W., Buckel, J. A., Morley, J. W., Lankford, T., Branson, A. C., . . . Stormer, D. 2012. Recruitment patterns and habitat use of young-of-the-year bluefish along the United States East Coast: insights from coordinated coastwide sampling. Reviews in Fisheries Science*,* 20(2), 80-102. doi:10.1080/10641262.2012.660999

Xia, M., Xie, L., & Pietrafesa, L. J. 2007. Modeling of the Cape Fear River Estuary plume. Estuaries and Coasts*,* 30(4), 698-709. doi:10.1007/bf02841966

Young, J. M., Bowers, M. E., Reyier, E. A., Morley, D., Ault, E. R., Pye, J. D., . . . Ellis, R. D. 2020. The FACT Network: philosophy, evolution, and management of a collaborative coastal tracking network. Marine and Coastal Fisheries*,* 12(5), 258-271.

Appendix A. Interview Methods

Text A1. Introduction and questions to guide interviews with technical experts.

Introduction to Interview Process and Interview Team

A colleague of yours recommended that I contact you to solicit your expertise and advice around convening a scientific workshop on Frying Pan Shoals, NC that my firm, Kearns & West, is helping the Bureau of Ocean Energy Management (BOEM) facilitate. Kearns & West is a private, independent stakeholder engagement and conflict resolution firm with offices in in Washington, DC and San Francisco. I would appreciate a few minutes of your time to explain the details of the technical workshop and how we are hoping you can contribute. Have Brad Introduce himself and his role.

The issue: Current coastal resilience strategies for specific North Carolina communities include the use of Frying Pan Shoals (FPS) as a long term sand resource to support future beach nourishment projects. Alternative long-term sand resource options are severely limited. However, FPS is currently designated by the NMFS as an EFH and a HAPC, and dredging is considered a significant threat to EFH and EFH HAPCs. NMFS has expressed concern that long term and repeated dredging operations could significantly impact the habitat value that supports several important commercial and recreational fisheries.

The Bureau of Ocean Energy Management (BOEM) is looking to convene a scientific workshop that will bring together technical experts from academia as well as state/federal agencies to discuss this issue in late summer or fall 2020. The purpose of the workshop is to examine current scientific understanding of the habitat uniqueness, value, and function of Frying Pan Shoals and attached shoal complexes for benthic and fish communities, identifying critical gaps in understanding. Results from this collaborative workshop will be used to summarize the current physical and biological characteristics of Frying Pan Shoals the potential dredging implications/concerns, and the priority data gaps and research questions that may serve as a long term science strategy to support future decision making at Frying Pan Shoals.

My firm, Kearns & West, has been hired by BOEM to support planning and facilitation of this workshop. To begin our work, we're conducting a "situation assessment" to learn more about the issues, interests, and information needs involved in this effort (i.e., to get a better sense of the "lay of the land").

As part of our assessment process, we are conducting a set of informal, semi-structured interviews with key parties like yourself. The goal is to inform the process design for the anticipated scientific workshop. Information collected from our interviews will be synthesized into an assessment report with findings and recommendations and shared with BOEM and its partners.

We anticipate that this interview will take about 45-60 minutes. Your responses will be kept confidential: in our report, we will not attribute specific responses to specific interviewees. We do intend to list everyone we interview in our assessment, and to identify themes that emerge through interviews.

Do you have any questions before we begin?

QUESTIONS

The questions below are intended to serve as a guide for these semi-structured interviews. Depending on information needs and time constraints, the interviewer may elect not to ask every question.

Background

1. Please describe your role in your organization and relevant expertise that you could offer for the purpose of this meeting.

2. Please describe any relevant research that you or your colleagues have conducted, or plan to conduct at, or near, Frying Pan Shoals and/or similar cuspate foreland systems or offshore sand shoal complexes in the Carolina's.

Interests and Aspirations

3. What are the primary interests you represent with regard to this broader topic and the priorities you would like to see achieved?

4. For BOEM and NMFS EFH staff] What would be a productive outcome of the process?

Issues and Concerns

5. In your view, what are the primary **issues** relevant to the habitat value and function of Frying Pan Shoals and subsequent dredging that need to be addressed through this process? Please speak to the following potential issues/probes (with and without dredging scenarios):

    a. Geological characteristics

    b. Oceanographic conditions

    c. Biological resources

    d. Data gaps and priority research needs

6. Which are most important?

Information Needs

7. Within your area of expertise, what key scientific publications exist or research studies are underway that BOEM should be aware of to help inform our planning for the workshop?

Workshop Process Design

8. Participation: Who needs to participate in the workshop? What areas of expertise need to be represented to contribute to a holistic view of Frying Pan Shoals as fish habitat?

9. Workshop design: When you have attended other interdisciplinary workshops, what have you found has/hasn't worked well? What advice do you have for us as far as designing a technical workshop?

Other

Is there any other information that would be helpful for K&W to know as part of our assessment?

Text A2. Introduction and questions to guide interviews with project stakeholders.

Project Proponents - Situation Assessment Interview Questions

Introduction to Interview Process

Hi, a colleague of yours recommended that I contact you to solicit your expertise and advice around convening a scientific workshop on Frying Pan Shoals, NC that our firm, Kearns and West, is helping the Bureau of Ocean Energy Management (BOEM) facilitate. We are a private, independent stakeholder engagement and conflict resolution firm with offices in in Washington, DC and San Francisco. I would appreciate a few minutes of your time to explain the details of the technical workshop and how we are hoping you can contribute.

The issue: Current coastal resilience strategies for specific North Carolina communities include the use of Frying Pan Shoals as a long term sand resource to support future beach nourishment projects. Alternative long-term sand resource options are severely limited. However, Frying Pan Shoals is currently designated by the NMFS as an EFH and a HAPC, and dredging is considered a significant threat to EFH and EFH HAPCs. NMFS has expressed concern that long term and repeated dredging operations could significantly impact the habitat value that supports several important commercial and recreational fisheries.

In the spring/summer of 2020, the Bureau of Ocean Energy Management (BOEM) is looking to convene a scientific workshop that will bring together technical experts from academic and state/federal agencies to discuss this issue. The purpose of the scientific workshop is to examine current scientific understanding of the habitat uniqueness, value, and function of FPS and attached shoal complexes for benthic and fish communities, identifying critical gaps in understanding. Results from this collaborative workshop will be used to summarize the current physical and biological characteristics of Frying Pan Shoals the potential dredging implications/concerns, and the priority data gaps and research questions that may serve as a long term science strategy to support future decision making at Frying Pan Shoals.

Following the scientific workshop, BOEM would like to convene a meeting with local stakeholders and prospective users of these sand resources to discuss the outcomes of the scientific workshop and consider the implications for future sand borrowing projects. It is in this regard that we are reaching out to you.

My firm, Kearns & West, has been hired by BOEM to support planning and facilitation of both the scientific workshop and the follow-on stakeholder meeting. To begin our work, we're conducting a "situation assessment" to learn more about the issues, interests, and information needs involved in this effort (i.e., to get a better sense of the "lay of the land").

As part of our assessment process, we are conducting a set of informal, semi-structured interviews with key stakeholders like yourself who have a potential interest in the use of these offshore sand resources. The goal is to inform the process design for the anticipated stakeholder meeting. Information collected from our interviews will be synthesized into an assessment report with findings and recommendations and shared with the BOEM conveners.

We anticipate that this interview will take about 45-60 minutes. Your responses will be kept confidential: in our report, we will not attribute specific responses to specific interviewees. We do intend to list everyone we interview in our assessment, and to identify themes that emerge through interviews.

Are you willing to participate in a confidential interview? Do you have any questions before we begin?

QUESTIONS

The questions below are intended to serve as a guide for these semi-structured interviews. Depending on information needs and time constraints, the interviewer may elect not to ask every question.

Background

1. Please describe your role in your organization and relevant expertise that you could offer for the purpose of this meeting.

2. Describe any prior experience you may have working with federal and state resource agencies to permit use of Frying Pan Shoals as a borrow area? Describe your understanding of what the issues were, what, if anything, was proposed to mitigate those concerns, and what new information you may have that may be worth sharing?

Interests and Aspirations

3. What are the primary interests you represent with regard to this broader topic and the priorities you would like to see achieved?

4. What would be a productive outcome of the process?

Issues and Concerns

5. In your view, what are the primary **issues** relevant to future sand resource needs and subsequent dredging at FPS and what needs to be addressed through this process? *[Probes]*

    a. Projected sand resource needs and availability

    b. Existing mitigations to avoid and/or reduce potential impacts

    c. Path forward for achieving a sustainable win-win solution

6. Do you have upcoming sand resource needs that it would be good for BOEM to know about? Please describe?

Workshop Process Design

7. Participation: Who needs to participate in the stakeholder meeting in order for it to be meaningful?

8. Meeting design: When you have attended other stakeholder meetings, what have you found has/hasn't worked well? What advice do you have for us as far as designing the meeting?

Other

Is there any other information that would be helpful for K&W to know as part of our assessment?

Text A3. Introduction and questions to guide interviews with individuals and organizations representing fishers.

Fisher Interview Notes

<u>**QUESTIONS**</u>

The questions below are intended to serve as a guide for these semi-structured interviews. Depending on information needs and time constraints, the interviewer may elect not to ask every question.

Background – Fishing Around Frying Pan Shoals

10. Please describe your focus as a fisherman and familiarity with Frying Pan Shoals.

11. To the best of your knowledge, what fisheries may occur on or in the vicinity of Frying Pan Shoals? Generally, where, what time of year, etc.? Do fishers target the shoal complex proper, focus on the outer flanks, shoal ridges vs. swales, etc.?

Interests, Concerns, and Aspirations

12. What concerns do you have related to potential sand dredging at Frying Pan Shoals?

13. What priorities or desired outcomes would you like to see achieved from any future possible dredging at Frying Pan Shoals?

Information Needs

14. What are the outstanding key information needs or data gaps from your perspective?

Engagement Approach

15. Recognizing the importance of including the fishing community throughout these discussions, what are the best ways to communicate and engage with fishermen on this topic moving forward?

16. What the names of other key fishing community representatives that BOEM needs to be engaging with on this topic that would supplement and/or complement your own perspective?

Other

17. Is there any other information that would be helpful for us to know to inform the White Paper

Text A4. List of interviewees.

Technical experts:

Larry Cahoon, University of North Carolina Wilmington (UNCW)
Chip Collier, South Atlantic Fishery Management Council (SAFMC)
Jennifer Cudney, NOAA
Anne Deaton, North Carolina Division of Marine Fisheries (NC DMF)
Bob Diaz, Virginia Institute of Marine Science
Bryan Frazier, South Carolina Department of Natural Resources (SC DNR)
Paul Gayes, Coastal Carolina University
Andrew Herndon, NOAA
Joseph Iafrate, Eric Reiyer, and Debra Jean Murie, Canaveral Shoals
Lynn Leonard, UNCW
Dylan McNamara, UNCW
Jesse McNinch, U.S. Army Corps of Engineers (USACE)
James Morley, East Carolina University (ECU)
Martin Posey, UNCW
Ken Riley, National Oceanic and Atmospheric Administration (NOAA)
Chris Taylor, NOAA

Project proponents:

Layton Bedsole, New Hanover County Shore Protection Coordinator
Braxton Davis, Tancred Miller, and Heather Coates, North Carolina Department of Natural Resources (NC DNR)
Bill Hansen and Russ Zimmerman, Great Lakes Dredge and Dock
Kevin Hart, North Carolina Department of Environmental Quality (NC DEQ)
Johnny Martin, Moffit & Nichols
Christian Preziozi, Land Management Group
Fisher 1, commercial
Fisher 2, recreational

Appendix B. Technical Expert Workshop Summary

Text B1. Agenda for technical workshop regarding FPS as a potential sand source.

Frying Pan Shoals Technical Workshop (2 days)

October 13, 2020; 1:00 - 5:00 PM ET
October 16, 2020; 8:30 AM – 12:30 PM ET
Video Conference / Webinar Platform: Webex

Workshop Objectives: 1) Understand sand resources and its demand in the Cape Fear Region, 2) recognize the potential effects of sand dredging, and 3) examine the current scientific understanding of the habitat uniqueness, value, and function of Frying Pan Shoals for fish communities and identify critical knowledge gaps. Results from this collaborative workshop will be used to summarize the current physical and biological characteristics of Frying Pan Shoals, potential dredging implications and concerns, and to prioritize data gaps and research questions that may serve as a long-term science strategy to support future decision making at Frying Pan Shoals.

The Bureau of Ocean Energy Management (BOEM) is a federal agency within the U.S. Department of the Interior that is charged with managing development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. BOEM has contracted Kearns & West, a stakeholder engagement and collaborative solutions firm, to support planning and facilitation of this workshop.

Day 1 – October 13, 2020

Time (ET)	Item
1:00 PM	Opening Remarks: Introductions, workshop objectives, agenda review, and ground rules
1:15 PM	History and Background: How did we get here? (Doug Piatkowski, BOEM)
1:45 PM	Setting the Context – Assessment of Sand Availability, Need, and Frying Pan Shoals • Sand Availability and Needs (Clay McCoy, USACE) • Dredging 101- Dredging Methods and Technologies (Bill Hansen, Great Lakes Dredge and Dock)
2:15 PM	Overview of Potential Sand Dredging Effects, Interviews, and Key Findings of White Paper (Brad Pickens, CSS-Inc. and NOAA)
2:30 PM	*Break*
2:50 PM	Technical Presentations – Physical Processes • Cuspate Foreland Processes (Jesse McNinch, USACE) • Geology (Paul Gayes, Coastal Carolina University) • Q&A and summary conclusions
3:35 PM	Technical Presentations – Biological Processes • Case study of sand shoals and fish (Eric Reiyer, NASA, and Debra Murie, U. of Florida) • Benthic Ecology, Biological Insights, and UNCW Research Overview (Martin Posey, UNC Wilmington) • Q&A and summary conclusions

4:15 PM	Open Discussion - Discussion Questions: 1. Based on what we know, what are the risks, and are there any red flags to dredging specific parts of Frying Pan Shoals? 2. What are the main unknowns?
4:50 PM	Preview of and preparations for Day 2 (Oct 16)
5:00 PM	*Adjourn*

Day 2 – October 16, 2020

Time (ET)	**Item**
8:30 AM	Introductions, Day 2 objectives, agenda review, ground rules, and recap of Day 1 (October 13)
8:45 PM	Breakout group discussions. Key topics and discussion questions include: • Topic 1 (physical scientist group) 1. Information needs and gaps: What do we know, what is missing from the white paper, and what are the critical knowledge gaps that we need to fill? 2. Critical areas: Within Frying Pan Shoals, where are possible optimum locations to dredge based on sediment compatibility, infilling recovery, and shoal integrity? 3. Research priorities: Develop strawman priority research plan a. What are the priority issues and/or gaps from the White Paper that require further research? b. Develop a research strategy that addresses the top issues and gaps. • Topic 2 (biological scientist group): 1. Information needs and gaps: What do we know, what is missing from the white paper, and what are the critical knowledge gaps that we need to fill to understand the importance of Frying Pan Shoals to fish? 2. Critical areas and times: a. Within Frying Pan Shoals, what are the most productive, or important, places for fish? b. What are the particular times of the year or other mitigations measures that would reduce the impact to fish? 3. Research priorities: Develop strawman priority research plan a. What are the priority issues and/or gaps from the White Paper that require further research? b. Develop a research strategy that addresses the top issues and gaps.
10:25 AM	*Break*
10:45 AM	Reports back and discussion • Topic 1 breakout group report back • Topic 2 breakout group report back • Discussion: What insights can be drawn from the results of the two breakout groups?
12:10 AM	Recap of Next Steps and Action Items • How to stay engaged? o Additional sharing of information • BOEM's Studies Program process and Frying Pan Shoals research next steps • Upcoming stakeholder/project proponent meeting
12:30 PM	*Adjourn*

Text B2. Participant list for technical workshop regarding FPS as a potential sand source.

Frying Pan Shoals Technical Workshop

Bureau of Ocean Energy Management

Marine Minerals Program

October 13 and 16, 2020

<u>In Attendance</u>

Physical Scientists

1. Joni Backstrom – UNCW
2. Mark Finkbeiner – NOAA
3. Paul Gayes – CCU
4. Bill Hanson – Great Lakes Dredge and Dock
5. Andrea Hawkes – UNCW
6. Joe Iafrate – Navy
7. Shannon Klotsko – UNCW
8. Joe Long – UNCW
9. Lynn Leonard – UNCW
10. Clay McCoy – USACE
11. Jesse McNinch – USACE Field Research Facility
12. Jeff Reidenauer – BOEM

Biological Scientists

1. Troy Alphin – UNCW
2. Leighann Brandt – BOEM
3. Larry Cahoon – UNCW
4. Jen Cudney – NMFS Highly Migratory Species Management Division
5. Anne Deaton – NC DENR
6. Bob Diaz – Virginia Institute of Marine Science
7. Wilson Freshwater – UNCW
8. Kimberlee Harding – NC DENR
9. James Harrison – NC DENR
10. Andrew Herndon – NOAA
11. Brian Hooker – BOEM
12. Ursula Howson – BOEM
13. Casey Knight – NC DENR
14. James Morley – ECU Coastal Studies Institute
15. Debra Murie – University of FL
16. Martin Posey – UNCW
17. Eric Reiyer – NASA
18. Ken Riley – NOAA Center for Coastal Fisheries and Habitat Research
19. Chris Taylor – NOAA Center for Coastal Fisheries and Habitat Research

Planning/Organizing Team

1. Deena Hansen – BOEM
2. Jacob Levenson – BOEM
3. Doug Piatkowski – BOEM
4. Brad Pickens – NOAA
5. Eric Poncelet – Kearns & West
6. Sam Ramsey – Kearns & West
7. Kyle Vint – Kearns & West

Other BOEM Staff Participating

1. Shannon Cofield
2. Kerby Dobbs
3. Ashley Long

Text B3. Meeting summary for technical workshop regarding FPS as a potential sand source.

BOEM
Bureau of Ocean Energy Management

Meeting Summary

Bureau of Ocean Energy Management Marine Minerals Program

Frying Pan Shoals Technical Workshop

October 13 & 16, 2020

Introduction

This summary captures the main outcomes from the Bureau of Ocean Energy Management (BOEM) Marine Minerals Program's (MMP's) Frying Pan Shoals Technical Workshop held virtually on October 13 & 16, 2020. The information contained within is intended to serve as an important reference to support a long term science strategy and future planning decisions related to the potential use of sand resources at Frying Pan Shoals.

Frying Pan Shoals Technical Workshop Objectives:

1. Understand the need and availability of sand resources in the Cape Fear North Carolina region.
2. Recognize the potential effects of sand dredging.
3. Examine current scientific understanding of the habitat uniqueness, value, and function of Frying Pan Shoals for fish communities and identify critical knowledge gaps.

This document summarizes key outcomes and next steps resulting from the meeting. It focuses on participant discussions and input shared rather than the formal presentations made. It is not intended to be a detailed transcript. The meeting was facilitated by Kearns & West (K&W).

This meeting summary is organized into the following sections:

I. Introduction
II. Day 1 (October 13) Discussion Highlights
   A. Opening Remarks
   B. History and Background: How did we get here?
   C. Setting the Context – Assessment of Sand Availability, Need, and Frying Pan Shoals
   D. Overview of Potential Sand Dredging Effects and Key Findings of the White Paper
   E. Technical Presentations – Physical Processes
   F. Technical Presentations – Biological Processes
   G. Open Discussion
III. Day 2 (October 16) Discussion Highlights
   A. Opening Remarks
   B. Breakout Group Discussions
   C. Reports Back and Discussion
   D. Wrap-Up and After-Action Review
IV. Additional information
   A. Day 1 Presentations
   B. Information Needs Document: Physical Scientist Breakout Group
   C. Information Needs Document: Biological Scientist Breakout Group
   D. Post-Day 1 Survey Results
   E. Post-Meeting Survey Results

Day 1 (October 13) Discussion Highlights

Opening Remarks
Jeff Reidenauer, Marine Minerals Division Chief, opened the workshop by welcoming participants, providing an overview of BOEM's jurisdiction and science mission and the MMP, and by introducing Doug Piatkowski, a Marine Biologist in the Marine Minerals Division. Mr. Piatkowski described the meeting objectives and desired outcomes of the Frying Pan Shoals Technical Workshop, including the products that would be informed by workshop discussions. He offered context for the meeting to help orient participants to their role during the workshop and how they can continue to contribute after the meeting. Mr. Piatkowski emphasized that results from this collaborative workshop will be used to summarize the current physical and biological characteristics of Frying Pan Shoals, potential dredging implications and concerns, and prioritize data gaps and research questions that may serve as a long-term science strategy to support future decision making at Frying Pan Shoals.

Eric Poncelet, a facilitator with K&W, reviewed the meeting ground rules and invited participants to introduce themselves and their affiliation. Approximately 40 technical experts attended the virtual meeting. The list of participants in attendance at the workshop may be found in Appendix B.

History and Background: How did we get here?
Doug Piatkowski, Marine Biologist at BOEM's Marine Minerals Division, provided a presentation of the history and background of projects considering use of Frying Pan Shoals sand resources. Mr. Piatkowski began his presentation by providing a timeline of projects and permit requests associated with Frying Pan Shoals, dating from 2008 to present-day activities. He explained that Frying Pan Shoals was first identified as a potential sand borrow resource in 2008 during the Brunswick County Beaches Coastal Storm Damage Reduction Project when Lockwood Folly Inlet, Jay Bird Shoals, and Shallotte Inlet were confirmed to have insufficient sand resources to support the project duration.

Between 2009–2012, there was a large investment by the USACE Wilmington District (USACE) to assess the sand resource availability at Frying Pan Shoals, analyze potential dredging implications to physical and biological processes, and identify strategies to mitigate risk. The USACE conducted an extensive literature review and collected biological and geological data from the shoals. This information contributed to the USACE's borrow area design, mitigation plan, and draft environmental impact statement (EIS) for Frying Pan Shoals. Although the project was not completed, extensive research and analysis were coordinated around the shoals.

In 2017, Frying Pan Shoals was proposed as a borrow area alternative for a Village of Bald Head Island (VBHI) permit request. However, based on the proposed borrow area design, the request for use of the Frying Pan Shoals borrow area alternative was denied. In the South Atlantic Fishery Management Council (SAFMC) response letter, SAFMC noted that Frying Pan Shoals is designated as Essential Fish Habitat (EFH), is further designated as a HAPC, and is a productive fish habitat for commercial, recreational, and ecologically important fish species. These habitat functions may be directly impacted by the proposed borrow area design and were not adequately assessed in the permit request. In the NMFS Habitat Conservation Division's letter, they recommended that Frying Pan Shoals be eliminated from the project design and the VBHI should further evaluate borrow area alternatives within the Outer Continental Shelf (OCS) as the least environmentally damaging alternative.

Mr. Piatkowski concluded his presentation by emphasizing that Frying Pan Shoals is a unique and highly productive shoal system. FPS is designated by SAFMC and NMFS as EFH and a HAPC; the Environmental Protection Agency lists it as an Aquatic Resource of National Importance (ARNI). He noted the increasing need for a regional assessment of sand resource and associated tradeoff analysis of effects and reiterated the substantial data gaps constraining effective analyses of Frying Pan Shoals as a potential resource. Mr. Piatkowski listed proactive planning considerations, including 1) prioritizing data gaps and risks relative to scope and scale, 2) compiling a long-term borrow area use strategy, 3) developing a comprehensive biological and physical research framework, and 4) promoting science-informed decisions and adaptive management.

Setting the Context – Assessment of Sand Availability, Need, and Frying Pan Shoals

The purpose of the agenda item was to provide a concise overview of the sand resource need and availability in Southeast North Carolina, the associated deficits in Brunswick and New Hanover County, and potential sand sources currently available to support long-term project needs (e.g., Frying Pan Shoals). Presenters offered an overview of the availability of sand resources in North Carolina and discussed dredging technologies and methods that could be employed to collect the sand. Key takeaways from this session include the results of the USACE's Sand Availability and Needs Determination (SAND) study, recommendations to ensure that southeastern counties in North Carolina can address their 50-year sand need deficits, and understanding of the different dredging methods and associated operations.

Sand Availability and Needs in Southeast North Carolina.

Clay McCoy, Acting Director of the Regional Sediment Management (RSM) Regional Center of Expertise at USACE, offered an overview of sand resources in and around Frying Pan Shoals. He highlighted the recent completion of the SAND study, a key product of the South Atlantic Coastal Study (SACS). SAND is a 50-year needs assessment study to determine the total sand needs for all permitted or near-permitted beach renourishment projects in the South Atlantic Division. The study also assessed the total amount of sand available to meet these needs based on likely offshore sand sources in state and federal waters. The study found that 1.2 billion yd^3 (1.1 billion m^3) of sand are needed in the South Atlantic Division over the next 50 years to meet renourishment project needs.

Dr. McCoy noted that each state within the South Atlantic Division has areas with significant sediment deficits. Within North Carolina, the southeastern shoreline has substantial 50-year sand need deficit, specifically New Hanover and Brunswick counties. According to SAND results, existing data suggests that Frying Pan Shoals has an estimated 35 million yd^3 (32 million m^3) of potential sand resources; however, further data acquisition and environmental analysis is needed to define a volume of compatible material that avoids and/or minimizes impacts.

Overarching recommendations from the SAND study include continued coordination with coastal management communities, industry, and stakeholders to support research and development, technology, and techniques to maximize the efficiency of accessing resources. The study also recommends developing priorities and strategies to address sediment resource needs.

Dredging 101.

Bill Hanson, Senior Vice President of Government Relations and Business Development at Great Lakes Dredge and Dock Company, provided an overview of dredging methods and technologies. Mr. Hanson characterized the different dredging techniques and processes that could be used on Frying Pan Shoals, including cutter suction and hopper dredges. He explained that cutter suction dredges are stationary and excavate sediment using a cutterhead buried just beneath the seafloor to loosen materials into a sand and water "slurry" that are hydraulically pumped directly to the final placement site via a pipeline. Hopper dredges are mobile and use two drag arms lowered to the sea floor to hydraulically excavate sediment through a series of pumps with discharge directly into the ship's hull or "hopper." Once a productive load of sediment is achieved in the hopper, the dredge mobilizes to an offshore pump-out location, re-fluidizes the sediment within the hopper, and hydraulically pumps it to the desired placement location. Mr. Hanson also described specific dredging tools designed to help mitigate environmental impacts during the dredging process.

Overview of Potential Sand Dredging Effects and Key Findings of the White Paper
Brad Pickens, a Federal Contractor with CSS-Inc. and NOAA as well as an Adjunct Research Associate at the University of North Carolina Wilmington (UNCW), provided a briefing on the development of the scientific White Paper focused on Frying Pan Shoals. Dr. Pickens described that the White Paper was informed by a literature review, which was focused on concerns and considerations identified from 16 situation assessment interviews. These interviews were conducted with scientific experts familiar with Frying Pan Shoals or related habitats. To note, these interviewees also comprised some of the scientific experts in attendance at the Technical Workshop. The interviews focused on the knowns, unknowns, and concerns associated with Frying Pan Shoals and potential sand dredging. The goal of the White Paper was to provide an overview of potential dredging effects and highlight the collective knowledge of Frying Pan Shoals, and its oceanographic, geologic, and biological conditions. Key findings of the White Paper are summarized below:

Oceanographic Conditions.
Dr. Pickens described key oceanographic findings documented within the White Paper. He explained that eddies and upwellings are hypothesized as major sources of energy and productivity of cape-associated shoal habitats. There was some concern amongst interviewees that broad-scale changes in shoals, and therefore disruptions to eddies and upwellings, could disrupt the productivity of this system. The literature review also found that there are dynamic salinity gradients based on seasonal winds and the amount of river discharge. Additionally, there are cross-shelf temperature gradients that may affect the distribution of overwintering fish and may determine habitat use of migratory fish.

Geological Conditions.
Dr. Pickens highlighted the White Paper's key geological findings. He explained that sediment grain size was commonly brought up by interviewees. They noted that while sediment grain size information is limited, addressing this data gap will help determine dredging locations, infilling grain size, and, subsequently, how quickly the shoal recovers. Sediment and shoal accretion rates are concerns, and most current information is based on research from Cape Lookout, NC. Lastly, hardbottom fish habitats and shipwrecks have been located in the vicinity of Frying Pan Shoals.

Biological Conditions.
Dr. Pickens provided an overview of biological conditions described within the White Paper. The assessment interviews highlighted that shoals are thought to be extremely productive marine environments for a variety of trophic levels ranging from phytoplankton to forage fish to sharks. He highlighted the significance of Frying Pan Shoals as an estuary-ocean connection and seasonal migration pathway for fish. Dr. Pickens emphasized the need for additional data regarding fish communities and habitat use at Frying Pan Shoals.

Overall, knowledge gaps regarding Frying Pan Shoals range from having no relevant information available to topics with some relevant knowledge obtained elsewhere, including Cape Lookout (NC), Cape Canaveral (FL), or other similar ecosystems. Dr. Pickens emphasized that many knowledge gaps exist, and research priorities are needed to address data gaps and inform sand management of Frying Pan Shoals.

Technical Presentations – Physical Processes
The purpose of this agenda item was to concisely communicate key geological/geomorphic considerations and associated physical processes at Frying Pan Shoals. Presenters discussed physical processes—such as wave dynamics, wind patterns, and tidal currents—that impact and shape the shoal and regional sand resources in and around Frying Pan Shoals. Key takeaways from this session include the belief that physical processes of cape-associated shoals can be generalized across other, similar systems, as well as the fact that large amounts of sand are being pulled from the shoreline due to wave dynamics.

Physical Processes of Cape-Associated Shoals
Jesse McNinch, Research Oceanographer at the USACE Field Research Facility, detailed the characteristics that influence and shape cape-associated shoals, including waves, winds, and tides. He began his presentation by stating that physical process findings can be generalized across cape-associated shoals since they have common origins and morphological features. Dr. McNinch highlighted that cuspate foreland shorelines across the world share a similar geomorphology since they are created and maintained by the wave climate of the shoals. He highlighted that cape-associated shoals are linked to regional sediment transport, such as longshore drift and beach erosion, and this maintains a consistent sediment supply. Dr. McNinch established that the location of cape-associated shoals is controlled by ongoing physical processes, not past geological features.

Dr. McNinch conducted field observations at Cape Lookout, NC using current meters and found that currents move towards the shoal crest, and currents on the shoal crest moved seaward. This research helped to inform the direction of sediment transport along cape-associated shoals. He emphasized that the process of sand transport is a wave-dominated phenomenon on the shoals, as sand from the beaches and other sources in the region accumulate at the shoals.

Dr. McNinch explained that wind is significant to cape-associated shoals because it drives wave direction and creates high-angle waves near cuspate foreland shorelines. The shore-parallel winds help drive sub-tidal flow parallel to the shore. In turn, a seaward flow is created along the shoal crest, which helps to maintain the shoal. To test whether shore-parallel winds are associated with cuspate foreland shorelines generally, Dr. McNinch surveyed 5,270 kilometers of shoreline along the U.S. East Coast, Gulf of Mexico region, and Alaska. He found that for non-cuspate shorelines, the two dominant wind directions were not as shore parallel. For cuspate foreland shorelines, there was an average shoreline orientation relative to the wind of approximately five degrees.

The wind and wave dynamics enable cape-associated shoals to be accretional features since sediment transport patterns deliver sediment to the shoal. As such, Dr. McNinch explained that there is strong evidence that these shoals are sedimentary sinks that receive and intake large quantities of sediment each year. Researchers estimate that Cape Lookout, Frying Pan Shoals, and Diamond Shoals each contain approximately 1 billion yd^3 of sand.

Dr. McNinch concluded by noting that more research is needed to understand the detailed sediment transfer mechanism from shore to shoal. He noted that this will help inform recharge rates, borrow locations, and borrow area design.

Regional Sand Resource Framework in the Vicinity of Frying Pan Shoals.
Paul Gayes, Executive Director at Coastal Carolina University's Burroughs and Chapin Center for Marine and Wetland Studies, presented an overview of sand resources offshore South Carolina. Dr. Gayes displayed maps of the region, showing where sediment is known to be available. He highlighted that the adjacent shelf is a sediment starved area with only localized patches of sediment

throughout the shelf. Dr. Gayes noted that there is primarily a massive amount of materials going offshore into the cape. He highlighted a fundamental change in the morphodynamic state of the submerged shoreface, indicating that the shoreface has extended significantly further offshore compared to 20 years ago.

As an alternative to major renourishment projects, Dr. Gayes noted that some organizations are pursuing a surgical dredging approach for renourishment of beaches. This approach involves sourcing sand that has been locally pushed offshore, reutilizing infilled borrow areas. Surgical dredging is intended to serve as patchwork between major offshore nourishment projects to limit impacts to larger sediment reserves.

Technical Presentations – Biological Processes

The purpose of this agenda item was to communicate what is known about the ecology of Frying Pan Shoals or similar cape-associated shoals, outline past research related to Frying Pan Shoals, identify how Frying Pan Shoals could be impacted by dredging, and identify potential mitigation strategies for avoiding these impacts. Presenters described a recent study on dredging impacts near Cape Canaveral, Florida, and presented key findings and lessons learned from the project. They also provided an overview of the species associated the Cape Canaveral Shoals with implications for the biological communities Frying Pan Shoals. Key takeaways from this part of the workshop included the view that shoal habitats, especially Frying Pan Shoals, are very dynamic, as well as the importance of seasonality in determining fish and invertebrate habitat use and abundance. Participants cautioned against comparing other shoal habitats and offshore sand habitats too closely to Frying Pan Shoals, emphasizing that many factors impact and influence individual shoal habitats.

Ecology of Sand Shoals off Cape Canaveral in Relation to Dredging Events.

Debra Murie, Professor at the University of Florida, and Eric Reyier, Fisheries Biologist at the Kennedy Space Center Ecological Program, presented on the ecology of sand shoal habitat near Cape Canaveral, FL in the context of recent dredging events. Dr. Murie described the study's goals, which included monitoring the effects and recovery of sand dredging activities on biological communities, determining the biological services that might be compromised by dredging, and investigating the recovery of invertebrate and fish communities associated with these habitats.

Dr. Murie explained that the sampling of the shoals focused on the trophic dynamics and interactions over space and time. Her team assessed benthic recovery through two different lenses: whether the post-dredge assemblages were returned to pre-dredge community assemblages or whether they returned to comparable community assemblages that still served the same ecological functions. Dr. Murie noted that most of this research is still in progress; however, she offered two key considerations from the study so far. She emphasized that species assemblages and abundances, from phytoplankton to fish, were highly dependent on the season. Secondly, sand shoal habitats are highly dynamic and have a large amount of natural variability, particularly in invertebrate assemblages. This is important to recognize because researchers must be able to distinguish impacts due to dredging relative to the natural variability of the shoal.

Eric Reyier provided an overview of the Kennedy Space Center Ecological Program's study on fish behavior and habitat use related to Canaveral Shoals. The study employed fish tracking, longline surveys, wave glider surveys, and sea turtle satellite telemetry to track individual movements. The goals of the study were to gain a better understanding of the distribution of fish within Cape Canaveral Shoals, as well as its habitat value for various species. Dr. Reyier described the key takeaways from this study, which included: (1) the importance of seasonality as a predictor of fish presence, (2) water clarity as an important factor for several fish species, and (3) the value of shoals to fish is species-specific.

Benthic Ecology, Biological Insights, and UNCW Research Overview.
Martin Posey, Professor at UNCW, described the benthic communities that are typically found in the Frying Pan Shoals region. Beginning with hardbottom habitats, Dr. Posey explained that these types of habitats are recognized as highly productive since they typically have substantial aggregations of fish and have distinct, unique community types. Hardbottom habitats tend to be very dynamic and have strong connections with the adjacent sand bottoms. He noted that hardbottom habitats are common throughout the region around Frying Pan Shoals.

Dr. Posey provided an overview of sand veneer communities, explaining that they occur in areas of shallow sand cover overlying a hard substrate. This habitat attracts a mix of organisms, including benthic-oriented fish, macro-crustaceans, and hard substrate organisms, such as soft corals and sponges. Deeper sand communities occur in areas that consistently have greater than one meter of sand depth. They attract benthic-oriented fish, macro-crustaceans, deeper burrowing polychaetes, larger clams, and deeper burrowing shrimp and crabs. Importantly, when looking at the recovery of this type of habitat after sediment removal, the effects of disturbance were shown to last greater than one year post-borrow with lower diversity and varied species recovery.

The Cape Fear River plume creates a complex mosaic of habitats that are associated with various benthic organisms. Due to the influence of the Cape Fear River estuary, there is a unique mix of estuarine and coastal ocean species in the region of Frying Pan Shoals. Additionally, this habitat serves as a corridor for the movement of critical species, including penaeid shrimp and Sciaenid fish, as well as a spawning area for blue crab. Dr. Posey noted that, based on the adaptability of organisms within the plume, this is likely a resilient habitat.

Regarding Frying Pan Shoals, the specific benthos dominating this area is less well known than some of the adjacent habitats, such as Onslow Bay. Dr. Posey cautioned against comparing other shoal habitats and offshore sand habitats to Frying Pan Shoals. He explained that the validity of the comparison depends on salinity impacts from the Cape Fear River, sediment characteristics across the shoal, predator use of the shoals as a feeding habitat, nursery habitat function, and water movement over the shoal areas.

Dr. Posey concluded his presentation by highlighting the expertise of researchers at UNCW's Center for Marine Science. An overview of research and expertise can be found on the Center for Marine Science's webpage.

Open Discussion
Eric Poncelet facilitated an open discussion among the technical experts to determine answers to key questions surrounding sand needs and potential environmental impacts. Discussion questions explored any perceived risks or red flags associated with dredging Frying Pan Shoals, as well as identifying the main unknowns of Frying Pan Shoals from biological, geological, and sediment management perspectives. The key considerations expressed during this discussion are captured below.

Considerations from a Biological and Ecological Perspective

- Collect more data on primary production and zooplankton/demersal zooplankton.
- Understand how dredging could affect the productivity of the shoal and how it could impact fish assemblages in Frying Pan Shoals.

- Consider the importance of the Cape Fear River plume on fish and how dredging could impact the dynamics of this plume.
- Understand how seasonality predicts fish presence, abundance, and biomass.
- Confirm which times of year, or seasons, offer the best environmental window for dredging Frying Pan Shoals.
- Confirm whether there are species of particular concern that should be considered when determining dredging windows.

Considerations from a Geological and Physical Perspective

- Learn about the recharge and infilling rates of Frying Pan Shoals post-dredging and confirm how this process could impact the benthic community and associated food chain.
- Understand the detailed sediment transport mechanism from shore to shoal to better quantify recharge rates and better understand the potential sensitivity to borrow locations and borrow area design.

Considerations from a Sediment Management Perspective

- Establish how dredging logistical tradeoffs might affect an environmental assessment.
- Determine whether dredging projects would require an access channel.
- Consider how an access channel, or a navigation channel created to access sand resources, could impact biological communities in and around the shoal.

Other Considerations

- Determine the applicability of data from other, similar locations and ecosystems.
- How does the uniqueness of Frying Pan Shoals impact extrapolation from other similar locations (e.g., migratory corridor, proximity to the river, interannual variation)?
- Incorporate perspectives and insights from the local fishing community.
- Consider the uniqueness of the Cape Fear River's estuary system on Frying Pan Shoals compared to other, similar ecosystems, such as at Cape Canaveral.
- Consider how interannual variation will be accounted for in a potential, future study. Due to Frying Pan Shoals' high variability, capturing a baseline is essential.

Preview and Preparation for Day 2

Deena Hansen, Marine Scientist at BOEM's Marine Minerals Division, provided an overview of the Frying Pan Shoals Technical Workshop Agenda for Day 2. She previewed how the second portion of the workshop would be structured and described the function and purpose of the biological and physical scientist breakout groups. Ms. Hansen reviewed the discussion questions that would be posed to each breakout group and emphasized the need to prioritize identified research gaps.

Day 2 (October 16) Discussion Highlights

Opening Remarks

Eric Poncelet, facilitator from K&W, opened the meeting by welcoming participants and providing an overview of the agenda for Day 2. He reviewed activities from Day 1 of the Technical Workshop and described how Day 2's discussion will help to further inform products related to Frying Pan Shoals. He explained that participants will divide into biological scientist and physical scientist breakout groups to advance Frying Pan Shoals research questions about each sector. Mr. Poncelet reviewed the meeting ground rules and invited participants to introduce themselves and their affiliation.

Physical Scientist Breakout Group

Overview

The purpose of this agenda item was to complete a smaller group discussion around the physical processes related to Frying Pan Shoals. Key discussion topics that participants explored included:

- **Information needs and gaps**: What do we know, what is missing from the White Paper, and what are the critical knowledge gaps that we need to fill?
- **Critical areas**: Within Frying Pan Shoals, where are possible optimum locations to dredge based on sediment compatibility, infilling recovery, and shoal integrity?
- **Research priorities**: Develop a strawman priority research plan
  - What are the priority issues and/or gaps from the White Paper that require further research?
  - Develop a research strategy that addresses the top issues and gaps.

Discussion highlights and proposed research priorities from these discussions and are summarized below. More detailed notes are available in Appendix D.

Information Needs and Gaps

Breakout group participants identified several key information needs and gaps related to the physical processes of Frying Pan Shoals. Participants noted a need to address outstanding spatial and temporal questions regarding sand transport on the shoals. They emphasized the importance of gaining a deeper understanding of the climatology and micro-dynamics at play along the shoal. Notably, workshop participants identified an opportunity for research overlap between studying the geophysical and fine-scale biological mapping of Frying Pan Shoals.

Participants noted that while there has been some geophysical surveying in and around Frying Pan Shoals, accessing the data and augmenting it to better understand where the beach usable sand exists is a key need. Participants highlighted that the total magnitude, depth, and scope of sand potentially extracted will impact and inform mitigation measures for Frying Pan Shoals. They also discussed opportunities for exploring adaptive management measures, specifically through the use of small pilot projects that could help inform research activities and ground truth feasibility constraints.

The group discussed several studies that have been conducted around Frying Pan Shoals by partner agencies. They noted that this might be a helpful opportunity to delineate where usable sand does and does not exist and identify where research efforts should occur. Participants also suggested incorporating these studies as potential supplemental resources for the White Paper.

Next, participants discussed the differences in the topography of Frying Pan Shoals between the crests and flanks of the shoal. They discussed how shoal location might impact the coarseness or usability of sediment. Participants generally agreed that beach-compatible sand is located on the crest of the shoal and that this could serve as a benchmark for where studies can expect to be conducted.

The breakout group considered the ancillary impact of any action on adjacent sand resources. They also explored whether Frying Pan Shoals functions as a sink, such that its sand resources recharge within the system after they are used.

Critical Areas
Breakout group participants referenced a map of Frying Pan Shoals to explore its geography and identify where optimal dredging areas might exist, understand the feasibility and logistical constraints, and examine how this might impact shoal integrity, infill and recovery rates. Participants noted that the crest of the shoal typically contains the most usable sand due to the wave and current dynamics that recharge and refresh sand in that area. There is typically less beach-compatible sand along the flanks of the shoal. Understanding where areas of beach-compatible sand might exist will help inform where studies and pilot projects can occur.

Participants identified two items for consideration regarding feasibility and logistical constraints. Firstly, there exists the potential for user conflicts, specifically related to the Wilmington East wind project and its associated export cables that might impact dredging areas of Frying Pan Shoals. Secondly, shipwrecks and other limiting archaeological factors could impact where dredging might occur on Frying Pan Shoals.

Notably, breakout group participants highlighted an opportunity to layer biological mapping with geophysical mapping to understand how dredging might impact specific habitats.

Research priorities
The breakout group identified a primary research priority that addresses identified information needs. The key knowledge gap relates to the specific role that waves, tides, and currents have on geomorphology, both the mesoscale and microscale features of the shoal. The purpose of the research priority is to understand how storms, recharging rates, and sediment transport function in and along the shoal.

Key questions to test as a part of this priority information need include:

- What are the refill rates and how might that impact biology?
- How does Frying Pan Shoals sand availability relate to the amount of sand volume needed over the next 50 years by the two adjacent counties?
- How sensitive is the mesoscale morphology on Frying Pan Shoals to affecting broader sediment pathways?

Participants identified several areas of future research to address these questions. The first method involves employing additional buoys for active monitoring in and around Frying Pan Shoals. Another potential method involves conducting additional sediment sampling to learn more about the shoals' mineralogy and what currently exists in the system. Participants noted that this research priority could be addressed using a pilot dredging site to address feasibility and validate model predictions. This would also facilitate ground truthing on infill rates, sediment type, and adaptive management opportunities.

Participants also identified a need for remote sensing. They noted that expanding the Cape Point sensing system to simultaneously measure wave information and bathymetry would allow researchers to gain a greater understanding of the micro-dynamics that occur at Frying Pan Shoals. Necessary components of this method include full bathymetric data, modern surveys of the shoal, and targeted fine-scale bathymetry for wave and current dynamics.

Participants identified a secondary research priority need that would further identify geophysical knowledge gaps. The group recognized that there are some geophysical data, including chirp and core data, that have already been collected at Frying Pan Shoals. They highlighted a need to review, assess, and share the current state of data to better understand what additional research needs to be conducted.

Biological Scientist Breakout Group

Overview

The purpose of this agenda session was to complete a smaller group discussion around the biological processes related to Frying Pan Shoals. Key discussion topics that participants explored included:

- **Information needs and gaps**: What do we know, what is missing from the White Paper, and what are the critical knowledge gaps that we need to fill to understand the importance of Frying Pan Shoals to fish?
- **Critical areas and times**:
  - Within Frying Pan Shoals, what are the most productive, or important, places for fish?
  - What are the particular times of the year, or other mitigations measures that would reduce the impact to fish?
- **Research priorities**: Develop a strawman priority research plan
  - What are the priority issues and/or gaps from the White Paper that require further research?
  - Develop a research strategy that addresses the top issues and gaps.

Key outcomes from these discussions and proposed research priorities are summarized below. More detailed notes are available in Appendix E.

Information Needs and Gaps

Breakout group participants identified several key information needs and gaps related to the biological processes of Frying Pan Shoals. Participants noted a need to gather additional information and data on infauna and benthic communities. Specific questions raised around infauna and benthic communities related to which communities exist in Frying Pan Shoals, the community dynamics, the impacts of seasonality, and how dredging might impact the productivity of these communities. Participants also highlighted a need to understand what role the shoal ecosystem plays as a habitat for organisms, both directly and indirectly, as well as whether the edges of the shoal serve as particularly important habitats for larger fish and crustaceans.

Participants explored the estuarine to offshore link, including larvae transport, juvenile and adult fish movements, and spawning near the estuary or nearby coastal habitats. Participants highlighted the interplay between the river flow and winds that affect the location of the Cape Fear River plume. Participants questioned if potential larvae at Frying Pan Shoals would go westward towards the estuary and river. They noted that obtaining information on the seasonal patterns of larval species might be helpful. Participants also suggested examining FPS as a larval transport corridor to examine which specific locations might be larval corridors and spawning grounds.

The group highlighted a need for additional information and data regarding habitat use and spatial distribution of key species. Participants noted that specific fish habitat use within the shoal system is important. They suggested that understanding how large prey species use the shoal may provide significant insights into spatial patterns of species on Frying Pan Shoals. Participants generally agreed that the spatial distribution of species may not be transferable from one shoal to another. They questioned the relationship of Frying Pan Shoals to other adjacent areas and whether the adjacent river and estuary affects fish habitat use on Frying Pan Shoals. Participants flagged highly migratory species (HMS) and certain time periods for essential fish habitats (EFH) as having limited data. They noted that federal or state-managed species will be an important consideration moving forward. They also inquired about the connection between the benthic-pelagic community linkages.

Participants noted that biological information gaps are related to the applicability of data from other, similar ecosystems onto Frying Pan Shoals. Specifically, whether the uniqueness of Frying Pan Shoals might impact extrapolation from other similar locations due to its function as a migratory corridor, ocean-estuary habitat, and seasonal differences. They noted that the biological systems and dynamic natures of the shoals create a unique and complex pattern for species assemblages and spatial-temporal distribution, which can inhibit transferring biological knowledge, except in the case of general seasonal patterns and life histories for species in the broader region.

Critical Areas

Breakout group participants assessed critical areas of Frying Pan Shoals to examine the most productive areas for fish and habitat use within the shoal complex. At the beginning of the conversation, participants emphasized habitat use of Frying Pan Shoals is poorly understand, although some generalizations from other work might be able to be applied. Participants identified that the lee of the shoal is typically where species spend most of their time. They noted that this area should be monitored before dredging to get a baseline of species' use along the shoal. Participants also noted that HMS are generally distributed on either side of the shoal and less on the top of the shoal. They highlighted that areas adjacent to the estuary or river mouth will be key spawning areas and migratory pathways for fish.

Following this discussion, participants assessed critical areas of Frying Pan Shoals and discussed whether there are certain times of the year that are more important to fish. Again, they emphasized that there is little site-specific information for Frying Pan Shoals, although some data exists on when certain shark species use the shoal. When discussing potential mitigation measures, participants noted that the scope of dredging and timing of the project will be key elements. Participants suggested leaving a refuge patch so that there is an undisturbed area from which benthic invertebrates can begin to recolonize post-dredging. They emphasized that this small footprint will be important for fostering emigration into adjacent areas.

Research Priorities

The biology breakout group identified three research priorities to address identified information needs. They emphasized that these studies need to be coordinated and concurrent since they are interrelated and move up trophic levels. The first research priority involves gathering baseline data for benthic communities in Frying Pan Shoals. This priority would involve sampling and gathering data over multiple seasons and years to gain a greater understanding of the variability and physical environment of Frying Pan Shoals. They emphasized that gathering multi-year data is especially important, due to the interannual variability of the Cape Fear River plume.

The second research priority involves gathering baseline data for the habitat and spatial distribution of key species, including pelagic fish and sharks. Participants identified several methods for addressing this priority, including gillnet or longline tagging studies for sharks, placing receivers in and around the potential borrow site, and assessing data from other tagged species in the south and mid-Atlantic. Participants also identified this priority as an opportunity to engage local shrimpers and fishermen about species use of the area.

The last priority involves researching the linkages and interplay between benthic and higher trophic levels. Potential methods to address this research priority include isotope testing, diet studies, and studying the different food chains within the shelf to understand the connection between benthic resources and fish that may be transiting the area.

Open Discussion

The purpose of this agenda item was to create a shared understanding of action items, key information, and research gaps and understanding. It started with reporters from each breakout group making detailed presentations on key outcomes from the breakout group discussions. Following the breakout group reports, workshop participants engaged in a conversation around the linkages and synergies between the two breakout group discussions.

Participants considered potential magnitudes of possible borrow sites. Participants clarified that borrow sites in this region are typically between 500,000 to 10 million yd^3; however, Frying Pan Shoals would likely have a borrow site of 1–2 million yd^3 of sand per dredge event.

Participants discussed the potential size of a refuge patch, noting that it should be relative to the size of the borrow area. They talked about the benthic communities that occur in greater than 3 ft of sand and what the different physical environment dynamics look like. Participants also noted that delineating species by water depth would be a helpful data gap to address.

Participants were asked to consider the importance of coordinating concurrent biological and physical studies. Workshop participants generally agreed that concurrent studies should take place where there is an overlap of data so that efforts, logistics, and equipment can be leveraged. Biological studies were characterized as having longer timescales than physical processes studies, due to the need to capture data on the interannual variability of Frying Pan Shoals. One participant noted that a biological study would ideally span three years to capture an accurate baseline of the natural variations of the shoal complex system. Conversely, physical studies can typically involve shorter processes, since there is 30-40 years of historical data on climatology that can be factored into a study. Importantly, geophysical and sedimentological survey data exist that could be used to inform biological studies.

Next, participants were asked whether there are specific approaches to collect data in Frying Pan Shoals' challenging environment. Throughout the discussion, participants emphasized the need to employ a diversity of approaches for collecting data. Participants noted that weather and shoal conditions will make collecting data untenable at times, which is why it is essential to have flexible scheduling and proximity to the site through local field offices. Specific tools mentioned for data collection included passive acoustic monitors, sonar, wave gliders, environmental DNA (eDNA) for sampling diverse species, and a modified wave grab sampler for collecting benthos data.

Additional insights and information provided by participants in post-meeting surveys can be found in Appendix F and G.

Wrap-Up and After-Action Review

Eric Poncelet concluded the workshop by informing participants on the next steps in the process. He presented how participants can stay engaged and continue to share information with BOEM moving forward (send to Doug Piatkowski at douglas.piatkowski@boem.gov). He also explained that information from this meeting will be captured into a meeting summary and incorporated into the evolving Frying Pan Shoals white paper.

Mr. Poncelet noted that BOEM intends to convene a Stakeholder Meeting in December 2020 to engage local and regional project proponents on these issues and provide a briefing on the White Paper and information captured from the Technical Workshop. Lastly, Doug Piatkowski explained that BOEM is looking to incorporate information from the Technical workshop into its Studies Program to help inform longer-term research activities.

Additional Information: Day 2 Breakout Session - Physical Data Gaps

<u>Physical scientist breakout group</u>

1. **Information needs and gaps**: What is missing from the white paper and what are the most critical knowledge gaps that we need to fill to identify if sand dredging is physically sustainable?
   - Addressing outstanding spatial/temporal questions about sand transport on the shoal
     - What effects do storms have on Frying Pan Shoals dynamics, how does the climatology of waves and other dynamics impact the system.
     - How can we use partition or segment analysis of the shoal to get a better sense of micro-dynamics. Mapping potential infilling rates. Identify exact roles of the forcing processes.
       - Develop sand transport models for the different conditions.
       - Climatology of the waves *and* the wind.
       - Better understand the effects of noreaster or southwester, etc.
     - Specifying the level of detail required for accurate assessment.
       - Remote sensing that could support the modeling.
   - Niche or microscale dynamics in and around the shoal.
     - Sloughs, bars, jutting areas of the shoal and how they are recharged and the biological aspects.
     - Specific data about areas receiving more or less sand via transport.
     - Assess how conditions impacts or limits operational capacities around the shoal.
   - Types of sediment and how that relates to dredging scale and depth. Will impact mitigation measures.
   - Potential for small "pilots" rather than full beach nourishment to assess infill (adaptive management).
   - What geotechnical and geophysical work has been done in the area?
     - MMIS has some of this data collection and upcoming sand report will have some of this data.
     - Overlap what has been surveyed with what may not be accessible or usable.
     - **Action Items**:
       - Create graphic of known areas of geophysical and geotechnical work.
       - Draw delineation mark for where sand shifts from compatible to not compatible.
       - Share information from Oak Island work.
   - Difference between sediment nature between the crest and the flanks when it comes to beach compatibility.
     - Identify how it impacts usability and necessary study areas.
     - **Action Item:** USACE to redraft as a technical report the white paper / lit review describing these processes.
   - Ancillary impact of any action on adjacent sand resources and the big picture that comes from that?
     - What is known about how much is proposed to be removed and is there a different sand management strategy that could meet that need.
   - Does Frying Pan Shoals act as a sink keeping sand resources in the system?
     - There are multiple lines of evidence that the sand sediment is from cuspate foreland and the nearshore.
     - How do storms, wind, and wave conditions impact this on a micro level?

2. **Critical areas**: Within Frying Pan Shoals, where are possible optimum locations to dredge based on sediment compatibility, infilling recovery, shoal integrity, and feasibility of logistical constraints?
   - Crests and flanks for identification of usable sand.
     - More work on how this lines up with dredging operations.
   - Consideration of multiple use including the Wilmington East wind project and associated export cables.
   - Shipwrecks and other limiting factors.
   - *Opportunities to layer biological mapping (if done) with geophysical and how dredging might impact niche habitats.

3. Research priorities (develop strawman priority research plan):

   a) **Priority Info Need 1: Sediment Transport Dynamics**
   - What is the knowledge gap to be addressed? Describe why it is important that this particular research priority is filled in the context of potential sand dredging.
     - Specific role of waves, tides, and currents.
       - Helps to understand how actions could impact niche habitats or features.
     - Dynamism of the meso and microscale features of Frying Pan Shoals.

   - Hypothesis to test?
     - What are the refill rates and how might that impact the biology?
     - How does Frying Pan Shoals handle the amount of sand volume needed over the next 50 years by the two counties?
     - How sensitive is the mesoscale morphology on Frying Pan Shoals to affecting larger scale sediment pathways?

   - Describe potential methods and outcomes.
     - What new locations would be required for buoys?
     - Sediment sampling, knowing more about minerology to better understand what there is to move would be key.
       - Would coring help capture what is needed here? Would need more info about placement and depth.
     - Pilot dredge site to assess feasibility and to validate models. Get some ground truthing on infill rates, sediment type, adaptive management opportunities.
     - Remote sensing at the cape point – radar RIO(?) system to measure bathymetry and wave information simultaneously.
     - Map bathymetry of shoal feature that is in play (accessible, quality sand, etc.) to model sediment infilling and movement rates.
     - Model extraction scenarios and assess how those extraction scenarios impact the meso and micro scales.
     - *What level of detail would be needed here to run the models – is it total shoal multibeam?
       - Full bathymetric
       - Modern survey of the shoal
       - For smaller scale sediment transport will need bathymetry on smaller scale as well as wave and current dynamics.

   b) **Priority Info Need 2: Geophysical Knowledge Gaps**
   - What is the knowledge gap to be addressed? Describe why it is important that this particular research priority is filled in the context of potential sand dredging.
     - Geophysical knowledge gaps – identifying gaps in the knowledge repository.

- Hypothesis to test?
    - What are the volumes in a three-dimensional sense?

- Describe potential methods and outcomes.
    - Assess the data that exists / make that data more accessible
    - Chirp and core data
    - Potential use of a test site

Additional Information: Day 2 Breakout Session - Biological Data Gaps

Biological scientist breakout group

1. **Information needs and gaps (40 min):**
   What is missing from the white paper, and what are the most critical knowledge gaps that we need to fill to assess the impact of potential sand dredging?
   a. Data on primary production, zooplankton/demersal zooplankton
   b. How dredging would affect productivity and how would it impact fish congregation in the area of Frying Pan Shoals
   c. Importance of Cape Fear River plume to fish and what are the dynamics of this plume?
   d. Seasonal abundance and determination if there is a less risky time of year for dredging (across the board)
   e. Capacity to capture environmental windows or to identify species of particular concern to identify similar windows for activities
   f. NC is unique geographically, representing a major biogeographical break and coastal NC is migratory corridor with large biomass movement. How those fish interact with Frying Pan Shoals is key unknown.
   g. **Infauna and benthic communities*. Which communities are there? We have info from adjacent areas (e.g., Jaybird). Smaller dredging efforts have recovered more quickly. Timing will be important and size/footprint. (Troy)
      - Are we interested in timing of sand deposition? (Jim) Concerns of smothering of inshore benthic fauna.
   h. **Estuarine to offshore link for larval transport and spawning (in and out of estuarine areas)*. Cape Fear flow goes westward. Need to look at region west of Frying Pan Shoals as larval transport corridor. What is role that Frying Pan Shoals plays as larval transport corridor. (Larry) Interplay between offshore river flow and westward flow (Chris). How many larva go into inlet versus westward? What are the locations of the larval corridors and spawning grounds?
   i. **Habitat use and spatial distribution of key species*. (Shannon, Chris). Spatial distribution may not be transferable from one shoal to another. Plus, temporal variability as well. Where along the shoal makes a big difference. Hard to predict where fish will be on the shoal (vs. benthos).
      - HMS species are data poor (Jennifer); we lack data for some time periods for EFH. Lack continuity temporally. Delineation of EFH.
      - Interplay of geomorphology and oceanography.
      - Frying Pan Shoals is more inhospitable to work on than other shoals. Farther away from research outposts. Weather.
   j. **Benthic-pelagic coupling.* What are the key species here that would be useful to look at? Do isotope studies looking at carbon level? Diet study?

k. Are there priorities for fed/state-managed species? BOEM trying to take an integrated approach, but ESA listed get special attention.
l. What is import of Frying Pan Shoals to other adjacent areas and habitats? Do other habitats affect fish on Frying Pan Shoals?

Other considerations

- How applicable is data from other, similar locations/ecosystems?
- How does the uniqueness of Frying Pan Shoals impact extrapolation from other similar locations (migratory corridor, proximity to river, interannual variation)?
- Tradeoffs between dredging technologies and distances. (Jim) These environmental impacts are typically studied prior to projects.
- Understanding the impacts of timing on both the borrow and deposition is critical when trying to understand the magnitude of impact on the various biological communities.

2. **Critical areas and times (20 min):**

a. Within Frying Pan Shoals, what are the most productive, or important, places for fish? Habitat use within shoal complex.
   - Canaveral data: species spent more time on <u>lee of shoals</u>. Should be monitored. Finer sand and mud to the west of Frying Pan Shoals. (Eric) Jennifer's data support this too.
   - HMS will be distributed on either side and less on top of the shoals.
   - Areas adjacent to estuary/river mouth. Key spawning area for fish (e.g., ESA, aggregations). Spawning and migration paths.
   - Most is TBD.

b. Are there particular times of the year that are critical to fish on Frying Pan Shoals? Seasons, or times of the year, that are of less importance to fish on Frying Pan Shoals? Other mitigation measures that could be taken?
   - Sharks
     - Small coastal sharks use shoal in summer (March–Oct).
     - Sandbar sharks – year round.
     - Larger sharks – broader time than coastal sharks.
   - *What mechanisms to reduce the impact*? Borrow less sand? Dredge in certain ways (so shoal rebuilds). Timing will impact which species will be impacted. How long will the dredging be taking place (typical is 3–5 months, but can be reduced with multiple dredges)? Refuge patch (leaving undisturbed areas to recolonize the dredged areas). Good to have footprint small so immigration from adjacent areas can take place.
   - Most is TBD.

3. **Research priorities (develop strawman priority research plan) (35 min):**

These studies need to be coordinated and concurrent.

a) **Priority Info Need 1**: Benthic communities - baseline data
   - Hypothesis to test?

   - Describe potential methods and outcomes.
     - Physical environment – connect physical world to biological
     - Look over various seasons (seasonal sampling, but not monthly)
     - Multiple years to get at variability

- Sampling of nekton involved with Cape Fear River plume
- Larvae and juveniles transiting the area

b) **Priority Info Need 2**: Habitat and spatial distribution of key species/pelagics/sharks – baseline data

- Hypothesis to test?

- Describe potential methods and outcomes.
    - Gillnet or long line tagging studies for sharks
        - Canaveral: best data sets came from coastal sharks
    - Look at data from other tagged species in south/mid Atlantic.
    - Receivers near borrow site. Using fewer scattered is OK.
    - Receivers on dredge itself.
    - Receiver array of ½–1 mile apart; receivers around and on the shoal.
    - Ask local shrimpers/fishermen about use of the area. Need to reach out to them up front to help design the study. Fishing clubs, gillnet, long liners.
    - Sample snappers in particular, which use these type of sandy shoals. They/juveniles use the corridor to the river; currently no sampling taking place outside of the river. Compare to historic data.
    - Seabirds?

c) Priority Info Need 3: Interplay among benthic and higher tropic levels

- Hypothesis to test?
    -
- Describe potential methods and outcomes.
    - Isotope testing (carbon, nitrogen, sulfur)
    - Study different food chains
    - Diet studies (what benthic resources are being consumed)
    - Seasonality needs to match benthic and pelagic
    - Modeling?
        - For analyzing isotopes; partition modeling
        - Ecopath modeling (ask Deb)
        - Community composition (spatial associations with prey)
    - Seabirds?

4. Other Comments

- Scale is important. What is size of borrow area? Ans: 1–2 nm by 2–3 nm? Geographic scale is important. Timescale as well.
    - Longer time scale (50 years); borrow every 3–5 years is typical. Common to go back to same borrow area that is well studied. Need to know volume of sand to be borrowed.
- Other shoals have provided sand. We're thinking of Frying Pan Shoals because Jaybird shoals will eventually become exhausted.

Dredging larger area does not necessarily mean more environmental impact.

Appendix C. Stakeholder Workshop Summary

Text C1. Agenda for technical workshop regarding FPS as a potential sand source.

Frying Pan Shoals Project Proponent and Stakeholder Meeting

December 10, 2020; 1:00 – 4:30pm ET

Meeting Objectives:

The Bureau of Ocean Energy Management (BOEM) is convening a meeting with local stakeholders and prospective users of sand resources related to Frying Pan Shoals to discuss the status of scientific understanding of these sand resources and associated ecosystems, consider the implications for future sand borrowing projects, and discuss stakeholder perspectives and next steps. Specific objectives include:

1. Receive an update on the outcomes of a recent technical workshop focused on Frying Pan Shoals. The purpose of this workshop was to assemble members of the scientific community to confirm current scientific (i.e., biological, oceanographic, and geological) understandings of Frying Pan Shoals and identify priority data gaps.
2. Discuss project proponent and stakeholder sand management needs and interests.
3. Explore possible dredging options and application of mitigations to jointly address needs around sand resources, availability, and environmental protection in the context of scientific data gaps.

BOEM is a federal agency within the U.S. Department of the Interior that is charged with managing development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. BOEM has contracted Kearns & West, a stakeholder engagement and collaborative solutions firm, to support planning and facilitation of this meeting.

December 10, 2020

Time (ET)	Item
1:00pm	Opening Remarks: Introductions, meeting objectives, agenda review, and ground rules
1:20pm	History and Background: How did we get here? Assessment of sand availability, need, and Frying Pan Shoals? (Doug Piatkowski, BOEM) • Clarifying questions and discussion
1:55pm	Overview of Potential Sand Dredging Effects: Key Findings of white paper and October 13 & 16 Technical Workshop (Brad Pickens, CSS-Inc. and NOAA) • Clarifying questions and discussion
2:35pm	*Break*
2:50pm	Roundtable Discussion - Project Proponent and Stakeholder Needs and Interests • Each meeting participant will have the opportunity to describe sand management needs and interests related to Frying Pan Shoals. Please note, this is a voluntary opportunity; sharing is not required. If a participant elects to speak, they will have approximately 2–4 minutes to share.
3:50pm	Open Discussion • Explore possible approaches to address the joint needs around sand resources, availability, and environmental protection
4:20pm	Wrap up and next steps
4:30pm	*Adjourn*

Text C2. Participant list for stakeholder workshop regarding FPS as a potential sand source.

Stakeholders and Project Proponents

1. Mayor Deborah Ahlers – Town of Caswell Beach
2. Layton Bedsole – New Hanover County
3. Heather Coats – NC DENR, Coastal Management
4. Kevin Conner – USACE
5. Marty Cook – Brunswick County
6. Greg Currey – USACE
7. Maria Dunn – NC Wildlife Resources Commission
8. Kate Finegan – Moffatt and Nichol
9. Jeff Griffin – Town of Caswell Beach
10. Kevin Hart – NC DENR, Coastal Management
11. Douglas Huggett – Moffatt and Nichol
12. Mindy Joiner – Moffatt and Nichol
13. Johnny Martin – Moffatt and Nichol
14. Tancred Miller – NC DENR, Coastal Management
15. Chris McCall – Village of Bald Head Island
16. Erik Olsen – Olsen Associates
17. Marc Pages – Brunswick County
18. Christian Preziozi – Land Management Group
19. Steve Stone – Brunswick County
20. Ronne Smith – USACE, Regulatory
21. Micky Sugg – USACE, Regulatory
22. Fran Way – ATM
23. Ken Willson – Coastal Protection Engineering
24. Dawn York – Moffatt and Nichol

Technical Experts

1. Anne Deaton – NC DEQ, Division of Marine Fisheries
2. Jennifer Cudney – NMFS
3. Kim Harding – NC DEQ
4. James Harrison – NC DEQ
5. Robb Mairs – NC DEQ
6. Pace Wilber – NMFS

Bureau of Ocean Energy Management (and supporting contractor staff)

1. Shannon Cofield – BOEM
2. Deena Hansen - BOEM
3. Ashley Long – BOEM
4. Doug Piatkowski - BOEM
5. Brad Pickens – CSS-Inc.
6. Eric Poncelet – Kearns & West
7. Samantha Ramsey – Kearns & West
8. Jeff Reidenauer – BOEM
9. Kyle Vint – Kearns & West

Text C3. Meeting summary for stakeholder workshop regarding FPS as a potential sand source.

Bureau of Ocean Energy Management Marine Minerals Program

Frying Pan Shoals Stakeholder and Project Proponent Meeting

December 10, 2020; 1:00 – 4:30 p.m. ET

Introduction

This summary captures the main outcomes from the Bureau of Ocean Energy Management (BOEM) Marine Minerals Program's (MMP's) Frying Pan Shoals Stakeholder and Project Proponent Meeting held virtually on December 10, 2020. The information contained within is intended to serve as an important reference to support a long-term science strategy and future planning decisions related to the potential use of sand resources at Frying Pan Shoals in the Cape Fear Region of North Carolina (NC).

Frying Pan Shoals Stakeholder and Project Proponent Meeting Objectives:

1. Receive an update on the outcomes of the October 13 & 16, 2020, technical workshop focused on Frying Pan Shoals. The purpose of this workshop was to assemble members of the scientific community to confirm current scientific (i.e., biological, oceanographic, and geological) understandings of Frying Pan Shoals and identify priority data gaps.
2. Discuss project proponent and stakeholder sand management needs and interests.
3. Explore possible dredging options and application of mitigations to jointly address needs around sand resources, availability, and environmental protection in the context of scientific data gaps.

Forty individuals representing local jurisdictions (and their consulting firms) and state and federal agencies participated in the virtual meeting.

This document summarizes key outcomes and next steps resulting from the meeting. It focuses on participant discussions and input shared rather than the formal presentations made. It is not intended to be a detailed transcript. The meeting was facilitated by Kearns & West (K&W). Appendix C contains meeting presentations.

This meeting summary is organized into the following sections:

V. Introduction
VI. Discussion Highlights
    A. Opening Remarks
    B. History and Background: How did we get here?
    C. Overview of Potential Sand Dredging Effects and Key Findings of the White Paper
    D. Roundtable Discussion – Stakeholder and Project Proponent Needs and Interests
    E. Open Discussion
    F. Recap of Next Steps and Action Items
VII. Appendices
    A. Frying Pan Shoals Stakeholder and Project Proponent Meeting Agenda
    B. Participant List
    C. Presentations

Discussion Highlights

Opening Remarks

Jeff Reidenauer, BOEM Marine Minerals Division Chief, opened the meeting by welcoming participants, providing an overview of BOEM's jurisdiction and science mission and the MMP, and by introducing Doug Piatkowski, a Marine Biologist in the Marine Minerals Division. Mr. Piatkowski described the objectives and desired outcomes of the Frying Pan Shoals Stakeholder and Project Proponent Meeting, including the products that would be informed by meeting discussions.

To help orient participants to their role throughout the meeting, Mr. Piatkowski explained that the purpose of the meeting was to: provide an update to local stakeholders and prospective project proponents regarding BOEM's development of a white paper detailing the knowns and unknowns of Frying Pan Shoals from a scientific perspective, share outcomes of a recent technical workshop on the subject, and discuss how BOEM may use this information to inform future research and leasing decisions. He added that this meeting was intended to be a collaborative discussion that captures the perspective of key stakeholders, as BOEM continues to address the implications and science around possible dredging at Frying Pan Shoals. Mr. Piatkowski explained that the preceding technical workshop convened regional scientific experts in October 2020 to examine the current scientific understanding of the habitat uniqueness, value, and function of Frying Pan Shoals and attached shoal complexes for benthic and fish communities, and to identify critical gaps in understanding. Mr. Piatkowski emphasized that results from this collaborative stakeholder meeting will be used to update the white paper and summarize the current physical and biological characteristics of Frying Pan Shoals, the potential dredging implications and concerns, and the priority data gaps and research questions that may serve as a long-term science strategy to support future decision making at Frying Pan Shoals.

Eric Poncelet, a facilitator with Kearns & West, reviewed the meeting ground rules and invited participants to introduce themselves and their affiliation.

History and Background: How did we get here?

History of Frying Pan Shoals

Doug Piatkowski presented on the history and background of projects considering the use of Frying Pan Shoals sand resources. Mr. Piatkowski began his presentation by providing a timeline of projects and permit requests associated with Frying Pan Shoals, dating from 2008 to present-day activities. He explained that Frying Pan Shoals was first identified as a potential sand borrow resource in 2008 during the Brunswick County Beaches Coastal Storm Damage Reduction Project when Lockwood Folly Inlet, Jay Bird Shoals, and Shallotte Inlet were confirmed to have insufficient sand resources to support the project. Following these findings, Mr. Piatkowski facilitated a Resource Agency Coordination Meeting in January 2009 to discuss borrow area alternatives for the Brunswick County Beaches project. Mr. Piatkowski's role in facilitating this meeting occurred while he was employed by the USACE Wilmington District. With the consideration of Essential Fish Habitat (EFH) concerns at Frying Pan Shoals relative to the size and complexity of neighboring borrow shoal systems, meeting participants proposed a borrow area use plan with the recommendation to begin considering Frying Pan Shoals as a dredging option.

With this recommendation, there was a large investment by the USACE Wilmington District between 2009–2012 to assess the sand resource availability at Frying Pan Shoals, analyze potential dredging implications to physical and biological processes, and identify strategies to mitigate risk. The USACE conducted an extensive literature review and collected biological and geological data from the shoals.

This information contributed to the USACE's borrow area design, mitigation plan, and draft environmental impact statement (EIS) for Frying Pan Shoals. Although the project was not completed, extensive research and analysis were coordinated around the shoals.

In 2017, Frying Pan Shoals was proposed as a borrow area alternative for a Village of Bald Head Island (VBHI) permit request. However, based on the proposed borrow area design, the request for use of the Frying Pan Shoals borrow area alternative was denied. In the South Atlantic Fishery Management Council (SAFMC) response letter, SAFMC noted that Frying Pan Shoals is designated as Essential Fish Habitat (EFH), is further designated as a HAPC, and is a productive fish habitat for commercial, recreational, and ecologically important fish species. These habitat functions may be directly impacted by the proposed borrow area design and were not adequately assessed in the permit request. In the NMFS Habitat Conservation Division letter, they recommended that Frying Pan Shoals be eliminated from the project design and the VBHI should further evaluate borrow area alternatives within the Outer Continental Shelf (OCS) as the least environmentally damaging alternative.

In 2019, BOEM provided a geophysical and geotechnical (G&G) authorization to the Town of Oak Island to continue efforts and investments to find additional sand resource alternatives offshore of Brunswick County, NC. Extensive survey work was conducted within the OCS. In addition to several sites located off Brunswick County, geophysical lines and cores were also collected at Frying Pan Shoals, reinforcing the potential interest and need for sand at that location. Mr. Piatkowski relayed that, with the exception of Frying Pan Shoals, sand resources offshore of Brunswick County are limited, as survey work did not yield sand sources of significant volume.

Sand Availability and Needs in Southeast North Carolina

Following his overview of projects considering the use of Frying Pan Shoals, Mr. Piatkowski reviewed the findings of the Sand Availability and Needs Determination Study (SAND), conducted by the USACE. SAND is a 50-year needs assessment study to determine the total sand needs for all permitted or near-permitted beach renourishment projects in the South Atlantic Division. The study also assessed the total amount of sand available to meet these needs based on likely offshore sand sources in state and federal waters. The study found that 1.2 billion yd^3 of sand are needed in the South Atlantic Division over the next 50 years to meet renourishment project needs. Within North Carolina, the southeastern shoreline has a substantial 50-year sand need deficit. Mr. Piatkowski underscored the significant sand deficit of Brunswick County by highlighting that the County has a 29.6 million cubic yard (MCY) deficit, based on the projected need and overall volume of sand resources identified offshore. Review the SAND report at https://www.sad.usace.army.mil/Portals/60/siteimages/SACS/508%20SAND_FINAL_Report_15Sep_CC.pdf?ver=0m6wxMybXbFmX_UJdid1kg%3d%3d.

Mr. Piatkowski emphasized that this Stakeholder and Project Proponent Meeting helps fulfill some recommendations of the SAND Study, including continued coordination with coastal management communities, industry, and stakeholders to support research and development, technology, and techniques to maximize the efficiency of accessing resources.

Mr. Piatkowski concluded his presentation by highlighting that Frying Pan Shoals is a unique and highly productive shoal system. Frying Pan Shoals is designated by SAFMC and NMFS as EFH and a HAPC; the Environmental Protection Agency lists it as an Aquatic Resource of National Importance (ARNI). He emphasized the need to identify additional sand resources and maximize use of existing sand resources. Mr. Piatkowski noted that there are significant data gaps related to dredging Frying Pan Shoals, though the October Technical Workshop was a helpful start in addressing these gaps. Mr. Piatkowski listed proactive planning considerations, including: 1) recognizing the limitations of current project-centric planning approaches, 2) assessing the current state of science, 3) prioritizing data gaps and risks relative to scope and scale, 4) developing a long-term borrow area use strategy, 5) developing a comprehensive biological and physical research framework, and 6) promoting science-informed decisions and adaptive management.

Overview of Potential Sand Dredging Effects and Key Findings of the White Paper

Brad Pickens, a Federal Contractor with CSS-Inc. and NOAA as well as an Adjunct Research Associate at the University of North Carolina Wilmington (UNCW), provided a briefing on the development of the scientific white paper focused on Frying Pan Shoals, as well as proposed research priorities identified during the Technical Workshop to address data gaps related to Frying Pan Shoals. Dr. Pickens shared that the white paper was informed by a literature review, which was focused on concerns and considerations identified from 22 situation assessment interviews. Sixteen of these interviews were conducted with scientific experts familiar with Frying Pan Shoals or related habitats. To note, these interviewees also comprised some of the scientific experts who participated in the Technical Workshop. The interviews focused on the knowns, unknowns, and concerns associated with Frying Pan Shoals and potential sand dredging. Dr. Pickens added that project proponents, some of whom were attending the Stakeholder and Project Proponent Meeting, were also interviewed during this process. The goal of the white paper was to provide an overview of potential dredging effects and highlight the collective knowledge of Frying Pan Shoals, and its oceanographic, geologic, and biological conditions. Mr. Pickens added that the white paper will be updated to incorporate input received on important knowledge gaps and research priorities identified during both the Technical Workshop and this Stakeholder and Project Proponent Meeting.

Key findings from the white paper are summarized below:

Oceanographic Conditions

Dr. Pickens described key oceanographic findings documented within the white paper. He explained that eddies and upwellings are hypothesized as major sources of energy and productivity of cape-associated shoal habitats. There was some concern amongst interviewees that broad-scale changes in shoals, and therefore disruptions to eddies and upwellings, could disrupt the productivity of these systems. The literature review also found that there are dynamic salinity gradients based on seasonal winds and the amount of river discharge. Additionally, there are cross-shelf temperature gradients that may affect the distribution of overwintering fish and may determine the habitat use of migratory fish.

Geological Conditions

Dr. Pickens highlighted the white paper's key geological findings. He explained that sediment grain size was commonly brought up by interviewees. They noted that while sediment grain size information is limited, addressing this data gap will help determine dredging locations, infilling grain size, and, subsequently, how quickly the shoal recovers. Sediment and shoal accretion rates are concerns, and most current information is based on research from Cape Lookout, NC. Lastly, hardbottom fish habitats and shipwrecks have been located in the vicinity of Frying Pan Shoals.

Biological Conditions

Dr. Pickens provided an overview of biological conditions described within the white paper. The assessment interviews highlighted that shoals are thought to be extremely productive marine environments for a variety of trophic levels ranging from phytoplankton to forage fish to sharks. He highlighted the significance of Frying Pan Shoals as an estuary-ocean connection and seasonal migration pathway for fish. Dr. Pickens emphasized the need for additional data regarding fish communities and habitat use at Frying Pan Shoals.

With the findings of the white paper in mind, Technical Workshop participants proposed research priorities to address data gaps related to Frying Pan Shoals. Key research priorities from the Technical Workshop are summarized below:

Physical Science Research Priorities

Dr. Pickens relayed key physical science research priorities and knowledge gaps identified during the Technical Workshop. A first research priority is to gain a greater understanding of sediment transport mechanisms from shore to shoal. Participants explained that this will help to inform recharge rate estimates, as well as the ideal borrow location and design. A second research priority is to quantify post-dredging sediment recharge and infilling rates specific to Frying Pan Shoals. Dr. Pickens explained that this priority creates validation of the first research priority in understanding sediment transport. Outstanding knowledge gaps from the Technical Workshop include:

a) How much sand is required in the long term? What is the area and volume projected to be dredged?
b) Would dredging require an access channel? Would a channel affect the projected impact on biological communities?
c) Where is dredging likely to occur? This may affect biological concerns and research priorities.

Biological Science Research Priorities

Dr. Pickens reviewed key biological science research priorities and knowledge gaps identified during the Technical Workshop. A first biological research priority is to determine what drives the high productivity of shoal systems and explore how dredging might affect productivity. A second research priority is to determine when and where the Cape Fear River plume occurs on or near Frying Pan Shoals and how often. A third research priority seeks to determine whether Frying Pan Shoals is an important pathway in seasonal migrations for fish such as mackerel, cobia, and sharks. Technical experts also noted that it will be important to determine the best environmental window for dredging, considering fish abundance, biomass, and spawning across seasons. Outstanding knowledge gaps from the Technical Workshop include:

a) How does fish habitat use within Frying Pan Shoals vary (e.g., on the shoal vs. the edge of the shoal vs. the lee of the shoal)?
b) How does dredging location affect estuary-ocean connectivity for larvae and anadromous fish? Are these fish pathways narrow or broad?

Overall, knowledge gaps regarding Frying Pan Shoals range from having no relevant information available to topics with some relevant knowledge obtained elsewhere, including Cape Lookout (NC), Cape Canaveral (FL), or other similar ecosystems. Dr. Pickens concluded his presentation by noting that the white paper synthesizes the current state-of-knowledge concerning the potential sand dredging of Frying Pan Shoals. He explained that the white paper is currently a living document, originally informed by the situation assessment interviews; it will be updated to incorporate key findings from the Technical Workshop and Stakeholder and Project Proponent Meeting.

Roundtable Discussion – Stakeholder and Project Proponent Needs and Interests

The purpose of this agenda item was to provide an opportunity for local jurisdiction and agency representatives to share their perspectives, interests, and challenges related to sand needs and potential for future dredging activities on Frying Pan Shoals. Each of the presentations made is summarized below.

New Hanover County. Layton Bedsole, Shore Protection Coordinator for New Hanover County, shared that the County is very interested in identifying a potential regional borrow source that may recharge itself or be amenable to recharging from other projects' compatible material. Mr. Bedsole emphasized that the County hopes to avoid dredging multiple borrow areas along the coast of North Carolina that might impact regional ecosystems and wave climates.

Village of Bald Head Island. Christian Preziozi, Principal Consultant at Land Management Group and consultant to the Village of Bald Head Island (VBHI), began his comments by thanking BOEM for convening the Stakeholder and Project Proponent Meeting and reiterating the need to address knowledge gaps related to Frying Pan Shoals. Mr. Preziozi informed participants that the VBHI is currently the only entity with an active permit request to harvest sand from Frying Pan Shoals. He explained that Land Management Group submitted the permit request on behalf of the VBHI to the North Carolina Department of Environmental Quality (NC DEQ) Division of Coastal Management approximately one year ago. The submission was a permit modification request for the use of a 190-acre proposed borrow site located in state waters, which could yield up to 2.4 MCY of sand resources. The proposed borrow site is also predicted to have a rapid infilling rate. The project design employs several mitigative measures and best management practices (BMPs). Mr. Preziozi explained that this project is proposed as a one-time borrow event with post-construction monitoring. He added that this project is viewed as a pilot study that can provide additional supplemental information for BOEM's research studies.

Mr. Preziozi explained that the VBHI has previously sponsored efforts to address knowledge gaps, including archaeological and bathymetric surveys, geotechnical investigations, sand search investigations, and 3D modeling along the VBHI's shoreline and the river that feeds into Frying Pan Shoals. He noted that the data collected on behalf of the VBHI can be shared with BOEM as part of the effort to advance understanding of Frying Pan Shoals. Mr. Preziozi concluded his remarks by emphasizing that the VBHI can contribute to the body of knowledge surrounding Frying Pan Shoals from physical and biological standpoints.

Erik Olsen, Principal at Olsen Associates and consultant to the VBHI, noted that substantial data and information exist that could be productive additions to the white paper. He explained that the sediment demand that has been assigned to the VBHI by the SAND Study is far less than anticipated, especially if the Wilmington Harbor Sand Management Plan stays in place. Over a 50-year period, the VBHI anticipates that their sand demand will be 10 MCY. The VBHI has studied Frying Pan Shoals as a potential borrow site and has also identified an alternative quasi-renewable borrow site at Jay Bird Shoals.

Mr. Olsen also discussed the dredging process. He recognized that different types of dredges utilize various techniques to excavate a borrow site, which affects environmental impacts. He recommended differentiating the types of dredging technology to correlate the environmental impacts with the respective technology. Mr. Olsen also shared that the availability and cost of dredging have affected VBHI's ability to do work. Mr. Olsen concluded his comments by reiterating the VBHI's desire to share additional data and information related to Frying Pan Shoals with BOEM.

Town of Caswell Beach. Jeff Griffin, Town Manager for the Town of Caswell Beach, shared that the Town of Caswell Beach requires approximately 1 MCY of sand resources every six years, primarily due to erosional hotspots that thin the shoreline. Mr. Griffin explained that the Town's principal concern is the economic challenges associated with accessing offshore borrow sites and transporting sand long distances. Mr. Griffin proposed exploring opportunities to coordinate a multi-beach nourishment project that might improve the financial feasibility of dredging.

Town of Oak Island. Johnny Martin, Engineer at Moffatt and Nichol and consultant for the Town of Oak Island, shared that the Town of Oak Island is currently developing its Master Plan to address coastal management issues. Moffatt and Nichol is reevaluating sand need estimates and anticipates that the project will increase due to erosional hotspots. To date, the town has invested $1.5 million in geotechnical investigations located in state waters and offshore to identify potential borrow sources but has not been successful in finding compatible beach material outside of shoal systems. He added that Moffatt and Nichol is willing to share this data with BOEM, pending the Town's approval. Mr. Martin shared that, within the next six months, they are hopeful to have a clearer sense of the Town's 50-year sand need as well as where available sediment might be located.

Brunswick County. Steve Stone, Assistant Manager for Brunswick County, shared that Brunswick County is aware of the storm damage reduction project needs of their municipal partners in the study area. Mr. Stone explained that the County supports obtaining appropriate materials from Frying Pan Shoals and other areas that are economically efficient and minimize negative impacts to surrounding ecosystems.

Marty Cook, Commissioner for Brunswick County, stated that regional ecosystems adapt to disturbances. Mr. Cook emphasized the urgent need for sand for local communities to address coastal management concerns. He implored meeting participants to approach this discussion with balance.

Marc Pages, Senior Planner for Brunswick County, suggested incorporating representatives from the City of Fort Caswell in future activities and discussions.

Town of Holden Beach. Fran Way, Senior Coastal Engineer at ATM and consultant for the Town of Holden Beach, relayed that the Town of Holden Beach was an active participant during the 2008–2012 USACE Wilmington District project and was disappointed to see that the draft EIS for Frying Pan Shoals was never completed. He shared that the Town is coordinating with the USACE Civil Works program to determine whether the project could be reactivated.

Mr. Way explained that Frying Pan Shoals is likely not a high priority borrow area for the Town of Holden Beach, since it is located 20 miles away. However, he reiterated that a multi-beach project might make it more economically viable for the Town. Mr. Way suggested that a small portion of Frying Pan Shoals could be dredged without impacting the overall system due to the size of the entire shoal. He concluded his remarks by emphasizing that he is looking forward to continuing research coordination with BOEM and the USACE Civil Works program.

North Carolina Department of Environmental Quality, Division of Coastal Management. Heather Coats, Beach & Inlet Management Project Coordinator within the NC DEQ Division of Coastal Management, began her comments by recognizing the limited sand resources offshore Brunswick County. Ms. Coats explained that, as a regulatory agency, the Division of Coastal Management's primary role is to ensure that projects minimize adverse impacts to North Carolina's natural resources and are consistent with state laws, policies, and use-standards.

North Carolina Department of Environmental Quality, Division of Marine Fisheries. Anne Deaton, Habitat Assessment Program Manager within the NC DEQ Division of Marine Fisheries, reiterated that Frying Pan Shoals is a highly productive area for fish and fisheries, with special federal and state designations for biological productivity. As such, Ms. Deaton emphasized that caution and additional research are needed before deciding whether to dredge at Frying Pan Shoals. She explained that she would like to gain a greater understanding of fish habitat use along Frying Pan Shoals and how dredging might impact that. She concluded her comments by recommending that sand being dredged for navigation channels, such as from Cape Fear River, be used for beach renourishment to minimize the need for dredging new and important resources.

National Oceanic and Atmospheric Administration National Marine Fisheries Service. Pace Wilbur, Branch Chief at the NMFS, stated that the NMFS is not advocating for a particular project; NMFS's goal is to ensure that all of the relevant environmental statutes and regulations that NMFS is responsible for are being applied to the review of any proposed dredging at Frying Pan Shoals. Mr. Wilbur noted that BOEM's involvement in this process helps facilitate the opportunity to address research questions and gaps outside the context of a monitoring effort.

Jennifer Cudney, a Fish Biologist at NMFS, offered comments from the perspective of NMFS's Highly Migrated Species Division. Ms. Cudney noted that additional research is needed to gain a greater understanding of how highly migratory species are utilizing and migrating through Frying Pan Shoals. Addressing this research gap will help to inform identification of the best time of year for dredging.

U.S. Army Corps of Engineers, Regulatory. Mickey Sugg, a Chief of Regulatory Program within the USACE, provided context on the function of the USACE's Regulatory Program. He explained that the Regulatory Program is not a project proponent; rather, they are responsible for reviewing applications for dredging projects. Mr. Sugg explained that it is important for the Regulatory Program to participate in these conversations since it provides them insight into borrow area alternatives, sand deficiencies, and resources concerns.

Mr. Sugg emphasized that BOEM's efforts to develop a white paper and convene the Technical Workshop and Stakeholder and Project Proponent Meeting are a recognition that there will be future permit applications for dredging Frying Pan Shoals. He added that this process will help determine whether Frying Pan Shoals can be used as a resource for beach nourishment projects. Mr. Sugg concluded by advising other participants to approach the upcoming Open Discussion agenda item with a solution-oriented mindset.

Open Discussion

Following the Roundtable Discussion, participants engaged in a collaborative discussion to explore tangible next steps that could lead toward authorizing the extraction of sediment resources from Frying Pan Shoals while at the same time avoiding or minimizing impacts to Essential Fish Habitat (EFH). Key recommendations and insights from this conversation are summarized below.

Share Additional Data and Information with BOEM. Participants communicated a willingness to share additional data and information with BOEM to further inform the white paper, identification of data gaps, and studies development process.

Address Key Data and Knowledge Gaps. Participants identified several data and knowledge gaps associated with Frying Pan Shoals that might warrant further exploration. A first data gap involves examining the size of the Frying Pan Shoals system to determine how that relates to the magnitude of impacts the shoal can withstand. Participants proposed exploring the volume of sediment coming into the shoal to determine whether a portion of the system re-charges more rapidly than other portions. Another potential approach involved gaining a greater understanding of the benefits associated with bringing new sand into the littoral system. Participants also recommended leveraging existing data about sediment transport, specifically from Olsen Associates, Moffatt and Nichol, and the USACE, to better understand the variability of the shoal and the potential impacts of dredging.

Participants suggested conducting additional research on Atlantic sturgeon to better understand the fish's migration patterns. Offshore tagging and monitoring of sturgeon could be a potential research method. NMFS noted that BOEM would need to coordinate with the owners of the tags to confirm data publication requirements. BOEM and NMFS plan to conduct a follow-up conversation to discuss array placement for Atlantic sturgeon tracking.

Continue Regional Coordination Efforts. Participants expressed a strong interest in continuing and building upon regional coordination around coastal management and dredging activities. They highlighted the positive results of other jurisdictions throughout North Carolina that have participated in coordinated regional efforts for beach renourishment projects.

Participants discussed the potential for shifting to a regional sediment management approach to proactively evaluate future projects and permit areas. They emphasized a need to assess projects and tradeoffs holistically rather than on a project-by-project basis to avoid overuse of one area or system.

Understand Dredging Technologies. Participants recommended future coordination with dredging contractors and the USACE to better understand how dredging with hopper dredges might occur on Frying Pan Shoal. These efforts would help inform dredge location and might minimize dredge areas over time.

Inform Future BOEM Studies. From the Technical Workshop and Stakeholder and Project Proponent Meeting, BOEM will begin to compile key information gaps into a research study framework that addresses research gaps and needs. NMFS expressed interest in reviewing the research plan methodology for future BOEM-funded studies. Both agencies agreed that this coordination will help ensure that methodologies and approaches are not developed in a vacuum.

When clarifying the timeline of future research activities, BOEM staff noted that the proposed research project would likely receive funding in 2022 and begin pursuing work in 2023. They emphasized that existing data and information is very helpful in refining research priorities and asked participants to share any background information following the meeting that might be useful.

Recap of Next Steps and Wrap-Up

Eric Poncelet concluded the meeting by informing participants on the next steps in the process. He described that participants can stay engaged with BOEM moving forward by coordinating directly with Doug Piatkowski at douglas.piatkowski@boem.gov. He also explained that information from this meeting will be captured in a meeting summary and incorporated into the evolving Frying Pan Shoals white paper.

Lastly, Deena Hansen explained that BOEM is looking to incorporate information from the Technical Workshop and Stakeholder and Project Proponent Meeting into its Studies Program to help inform longer-term research activities.

A recap of other next steps discussed during the meeting is as follows:

- Local jurisdictions and consultants to share relevant physical and biological information with BOEM; transmit information to Doug Piatkowski at douglas.piatkowski@boem.gov.
- Local jurisdictions to continue discussing the possibility of regional coordination around coastal management and dredging activities.
- BOEM to coordinate with NMFS in developing future studies.
- BOEM and NMFS to schedule a conversation to discuss array placement for Atlantic sturgeon tracking.

Appendix D. FPS Data Availability

Table A1. Available data and reports relevant to Frying Pan Shoals.

Description	Title, citation, or URL	Contact for further information
Report describing collection of data and results regarding bathymetry, cultural resources, sediment grain sizes, & seismic sub-bottom surveys	Frying Pan Shoals sand search investigation. A report prepared for Village of Bald Head Island, NC (2016)	Olsen Associates, Inc. 2618 Herschel St. Jacksonville, FL 32204 olsen-associates.com (904) 387-6114
Summary of the set-up and calibration of a numerical computer model to simulate tides, currents, waves, nearshore sediment transport, and the resulting seabed changes (shoaling and erosion) at the Cape Fear River Entrance near Wilmington, NC	Calibration of a Delft3D model for Bald Head Island and the Cape Fear River Entrance Phase I. A report prepared for Village of Bald Head Island, NC (2012)	Olsen Associates, Inc. 2618 Herschel St. Jacksonville, FL 32204 olsen-associates.com (904) 387-6114
U.S. Army Corps of Engineers South Atlantic Division data and reports. Information on Regional Sediment Management and the SAND (Sand Availability and Needs Determination) report and geodatabase	https://www.sad.usace.army.mil/SACS/ https://www.sad.usace.army.mil/Portals/60/siteimages/SACS/508%20SAND_FINAL_Report_15Sep_CC.pdf?ver=0m6wxMybXbFmX_UJdid1kg%3d%3d	
Bureau of Ocean Energy Management, Marine Minerals Information System	https://mmis.doi.gov/BOEMMMIS/	

Appendix E. Scientific Names of Species

Table E1. Scientific names of species in the report.

Common Name	Scientific Name	Common Name	Scientific Name
Alewife	*Alosa pseudoharengus*	Menhaden	*Brevoortia* spp.
American shad	*Alosa sapidissima*	North Atlantic right whale	*Eubalaena glacialis*
Anchovies	Family: Engraulidae	Nurse shark	*Ginglymostoma cirratum*
Atlantic sharpnose shark	*Anchoa* spp.	Penaeid shrimp	*Peneaus* spp.
Atlantic sturgeon	*Acipenser oxyrinchus*	Pinfish	*Lagodon rhomboides*
Atlantic tomcod	*Microgadus tomcod*	Porgie	*Calamus* spp.
Blacknose shark	*Carcharhinus acronotus*	Red drum	*Sciaenops ocellatus*
Black sea bass	*Centropristis striata*	River herring	*Alosa* spp.
Blacktip shark	*Carcharhinus limbatus*	Sea mullet	*Mugil cephalus*
Blueback herring	*Alosa aestivalis*	Shortfin mako	*Isurus oxyrinchus*
Blue crab	*Callinectes sapidus*	Shortnose sturgeon	*Acipenser brevirostrum*
Blue shark	*Prionace glauca*	Silverside	*Menidia* spp.
Bonnethead shark	*Sphyrna tiburo*	Sandbar shark	*Carcharhinus plumbeus*
Brown shrimp	*Penaeus aztecus*	Sand tiger shark	*Odontaspis taurus*
Croaker	*Micropogonias undulatus*	Southern flounder	*Paralichthys lethostigma*
Finetooth shark	*Carcharhinus isodon*	Southern kingfish	*Menticirrhus americanus*
Gag grouper	*Mycteroperca microlepis*	Spanish mackerel	*Scomberomorus maculatus*
Great hammerhead shark	*Sphyrna mokarran*	Spinner shark	*Carcharhinus brevipinna*
Green sea turtle	*Chelonia mydas*	Spiny dogfish	*Squalus acanthias*
Gulf sturgeon	*Acipenser oxyrinchus*	Spot	*Leiostomus xanthurus*
Hawksbill sea turtle	*Eretmochelys imbricata*	Spotted seatrout	*Cynoscion nebulosus*
Hickory shad	*Alosa mediocris*	Striped bass	*Morone saxatilis*
Humpback whale	*Megaptera novaeangliae*	Summer flounder	*Paralichthys dentatus*
Kemp's Ridley sea turtle	*Lepidochelys kempii*	Tiger shark	*Galeocerdo cuvier*
King mackerel	*Scomberomorus cavalla*	White shrimp	*Penaeus setiferus*
Leatherback sea turtle	*Dermochelys coriacea*	Winter flounder	*Pseudopleuronectes americanus*

Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM's Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).