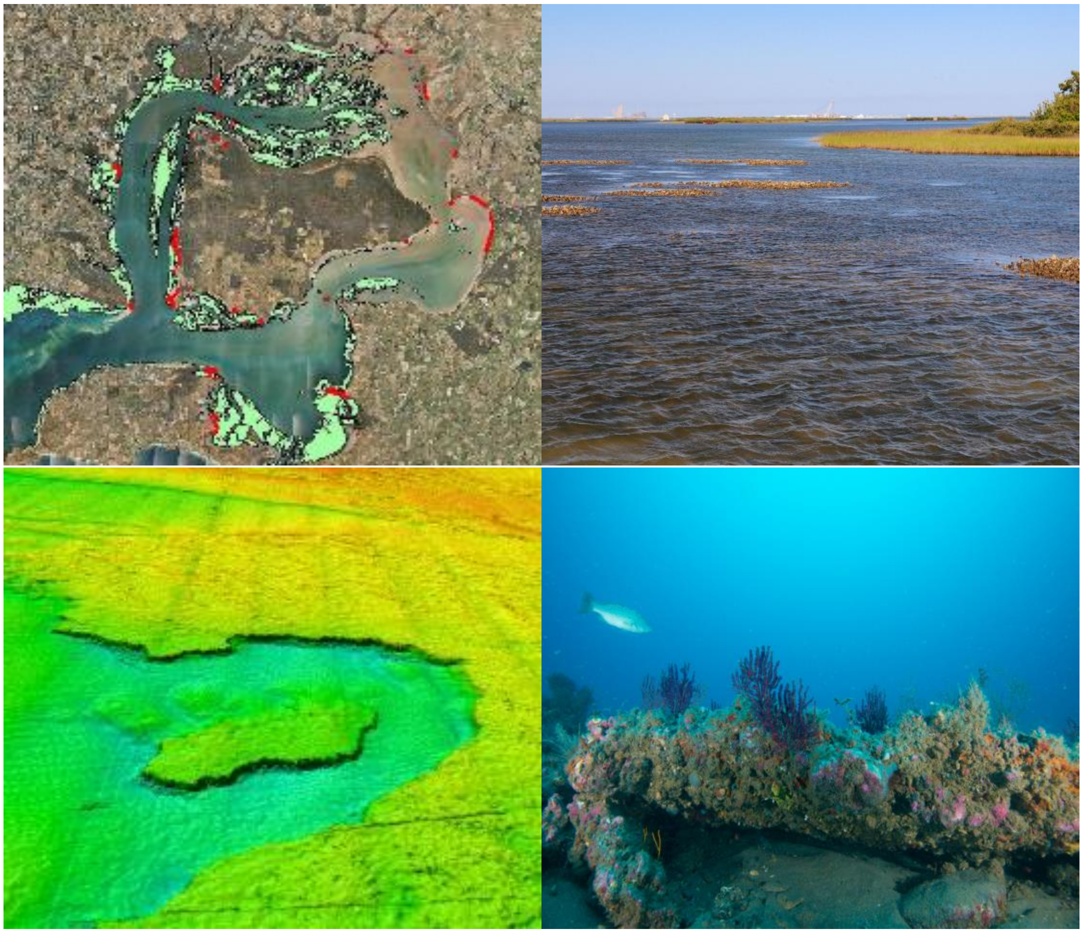
Improving Seafloor Habitat Mapping Coordination on the Southeast US Coast and Outer Continental Shelf



A Report from Workshops Hosted by

NOAA's Southeast and Caribbean Regional Collaboration Team

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NOAA Office for Coastal Management
North Charleston, South Carolina

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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NATIONAL OCEAN SERVICE
Nicole LeBeouf, Assistant Administrator

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1 Introduction

Seafloor habitats from the upper estuary to the outer continental shelf (OCS) support living marine resources and ecosystems of the Southeast (SE) US Atlantic (Figure 1-1) and in turn support the economies of our coastal communities through fisheries, ecotourism, and other services. Recent population growth and urbanization of watersheds in this region are placing increasing pressures on these critically important habitats.

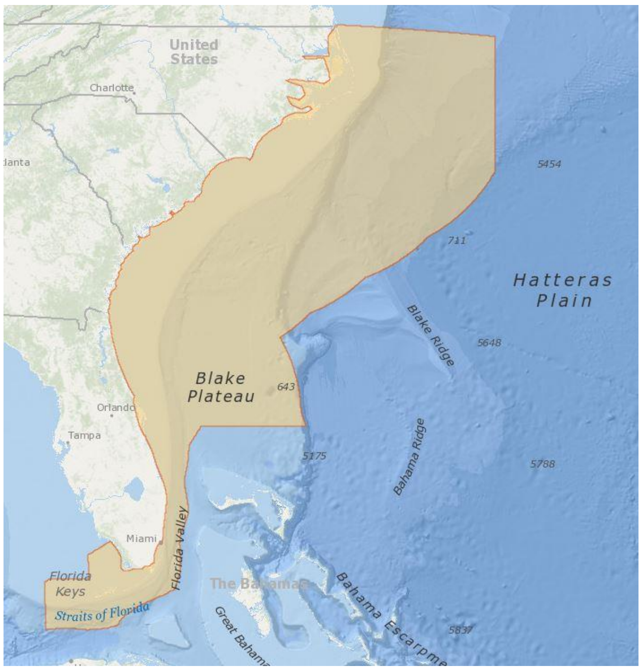

Figure 1-1 The area of interest, in orange, for the Southeast Seafloor Habitat Mapping Workshop, including state and federal waters in the Southeast Atlantic.

Thirty-nine percent of the US population live near the coast, and the Southeast US is experiencing the most rapid recent population growth of any coastline across the US (NOAA 2017). Population growth is increasing the recreational use of the coastal ocean, whether it be in the form of recreational fishing or ecotourism activities, like boating or scuba diving. Expanding coastal communities encroach on watersheds of tidal rivers and estuaries, altering the flow of water and sediments into the watershed and changing the shape of the shorelines. Increased commercial shipping is requiring expansion and deepening of channels to support major ports of Wilmington, North Carolina, Charleston, South Carolina, Savannah, Georgia and Miami, Florida. Deepening channels involves dredging and disposal of sediment and bedrock materials into the coastal ocean. Extraction of resources like sand and minerals is needed to replace sand beaches and restore eroded shorelines following storms. Unlike the West coast and Gulf of Mexico, the SE and Atlantic coast in general has yet to develop permanent renewable offshore wind or oil and gas extraction facilities. However, recent legislation and executive orders are calling for expanding offshore energy infrastructure along the Atlantic coast.

The emerging and expanding uses of the coastal ocean have sparked interest in regional planning to understand ocean-based needs and how to manage them to minimize conflicts among user groups and reduce impacts of these activities on the natural resources and ecosystems. Inventories of natural resources, such as seafloor habitat maps, are essential for effective marine spatial planning. By understanding the arrangement of seafloor habitats and recognizing where data gaps exist, managers and stakeholders within the SE Atlantic coast will be better equipped to make informed decisions about potential impacts to these resources and how to best focus future data collection efforts.

2 Regional coordination of seafloor mapping to improve management

Many of the complex challenges that drive the NOAA mission are place-based and require interdisciplinary approaches and regionally tailored solutions. The Regional Collaboration network addresses regional challenges by engaging and connecting people and resources within the regions and with headquarters, in ways that are rich in regional insight and that inform action. In 2014 NOAA's Southeast and Caribbean Regional Collaboration Team (SECART) identified regional seafloor habitat mapping as a focus area to assist with coordination across NOAA offices, other federal agencies, state coastal zone and fisheries management agencies, non-governmental conservation organizations, and academic researchers. While the SECART contains both the Southeast US and US Caribbean in its jurisdiction, the initial focus is being applied to the Southeast US, including North Carolina, South Carolina, Georgia, and the Atlantic coast of Florida (see Figure 1-1).

The SECART hosted the first of a series of workshops in March 2016 with the following objectives:

1. Introduce government agencies, academia and non-governmental organizations to regional collaboration to enhance awareness of seafloor mapping activities in the SE region
2. Inventory seafloor survey data available from NOAA archives or program offices, other government survey data, as well as survey data from industry and academia
3. Develop an online, open-access data viewer displaying existing seafloor survey data resources not readily available in the NOAA archives
4. Initiate discussion on management needs, requirements for habitat mapping information, and best practices for collecting data to produce habitat maps
5. Identify immediate and near-term habitat mapping data priorities by management agencies and research institutions

The March 2016 workshop was the first opportunity in the region to bring together representatives from a broad group of agencies and organizations to share resources, expertise and needs for continuing to develop seafloor habitat maps for the coastal ocean. Organizers and participants quickly discovered that there are barriers to effective communication that has resulted in a general lack of awareness of seafloor mapping activities between agencies and organizations. The 2016 workshop succeeded in opening these communication channels for sharing data. A significant outcome was the sharing of large seafloor data compilations within the Department of Defense that added 20 percent to the SE US continental shelf survey coverage. Awareness of another project conducted by NOAA's National Centers for Coastal Ocean Science (NCCOS) eliminated the need for surveys by NOAA's Office of Coast Survey for updating nautical charts, saving almost $1M in additional survey costs.

Improved communication and data sharing during the 2016 workshop saved NOAA $1M in costs of conducting a duplicate seafloor survey off the coast of NC

Discovering data that were not already on NOAA's or other federal archives or data portals, workshop organizers developed an online inventory to encourage data access and sharing. Despite adding new coverage areas, significant gaps in seafloor maps in the SE US still exist. Tools are needed to prioritize these data gaps based on management needs so that resources can be identified and allocated to achieve multiple management and research missions of the region's agencies and research organizations.

Participants at the 2016 workshop were asked to identify management needs that require seafloor habitat maps. The top two management areas were (1) protecting sensitive biogenic coral, deep coral, and rocky reef habitats, and (2) improving maps for sand mining and sand resource management. Additional highly ranked management needs included informing fishery resource assessments, siting offshore energy development, and identifying and conserving historically significant shipwrecks and cultural resources. Participants were also asked to identify the most important seafloor habitat types to focus mapping efforts. These were (1) sand shoals and (2) offshore rocky reefs and deep corals. An additional habitat type also highlighted by participants, but poorly represented due to low attendance by state management agencies, was (3) shallow estuarine habitats like seagrass and oyster reefs.

The 2018 workshop built upon the 2016 workshop in three areas:

Receive additional seafloor habitat mapping data from NOAA offices and external partners, sharing through an online data viewer

In preparation for the 2018 workshop, members of the SECART and others with NOAA NCCOS created an ArcGIS tool for inventorying seafloor mapping data, primarily focusing on datasets that are not yet available via the NOAA NCEI Bathy Viewer. The result of this effort was an inventory of approximately 400 footprints for mapping data across the Southeast Atlantic, with attributes attached to the footprints to provide information to the user about the data and methods for obtaining the data. Those who have relevant data can contact Chris Taylor (Chris.Taylor(AT)noaa.gov) for more information on contributing to this inventory.

Develop a regional habitat mapping prioritization application for participants to contribute agency and research priorities for habitat mapping to identify mutual areas of interest

A web application was created in order to both share the data inventory and to provide an interface for a regional habitat mapping prioritization application. The application is hosted through NOAA's ArcGIS Online interface and constructed utilizing the help and previous efforts of NOAA NCCOS. The tool will be described in more detail in Chapter 4: Developing a regional seafloor mapping prioritization tool for inter-agency coordination.

Identify management requirements and summarize best practices for developing seafloor habitat maps in three coastal ocean habitat types, identified during the 2016 workshop:

- Shallow estuarine habitats including seagrass and oyster reefs
- Coastal ocean sand shoals
- Continental shelf rocky reefs and deep coral reefs, including FL Keys

The aim was to document different management drivers and how they influence the methods of data collection and data products produced. Chapter 5: Defining management requirements and best practices for seafloor mapping elaborates on the findings of this workshop session.

3 Improving awareness of seafloor mapping data resources and activities

One of the objectives of the 2018 workshop included creating a more comprehensive understanding of seafloor mapping data for the SE Atlantic. Before prioritizing where we need to map in the future, first it is necessary to know where the seafloor has already mapped. There are several publicly available online resources available for seafloor mapping data and agencies concurrently coordinating seafloor mapping data collection and archival in the region. During the workshop, participants presented “lightning round” talks describing their agency’s data resources, ongoing mapping activities, and initiatives. Highlights of some of these talks are below, a complete list of presenters and their topics can be found in Table 3-1 relevant data resources are listed in Table 3-2.

NOAA National Centers for Environmental Information

One of the main resources for federally sourced bathymetric data is maintained by NOAA’s National Centers for Environmental Information (NCEI), formerly the National Geophysical Data Center (Figure 3-1). NCEI is responsible for preserving and providing public access to geophysical data and related information. They manage multiple databases that contain bathymetric and hydrographic survey data, data viewers (see Table 3-2) facilitate data discovery and download. These databases include over 2,600 published cruises and provide approximately 17 terabytes of data for download. The data are archived with associated metadata documentation on who, how, when, and where the data were collected. Bathymetry grids, points, or continuous surfaces are generally available for all data, but some survey archives also provide data in a raw multibeam sensor format, which require special expertise and specialized software to process and interpret to bathymetry surfaces that can be read in GIS programs like ESRI ArcGIS.

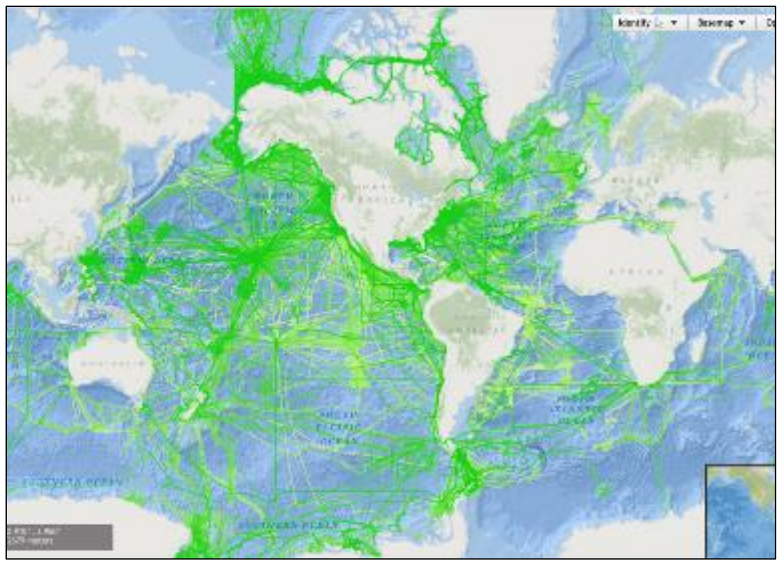

Figure 3-1. A map showing the global data coverage available through the NCEI Bathymetric Data Viewer. Source: NOAA NCEI, last referenced September 2018

NOAA and Intergovernmental Working Group on Integrated Ocean and Coastal Mapping

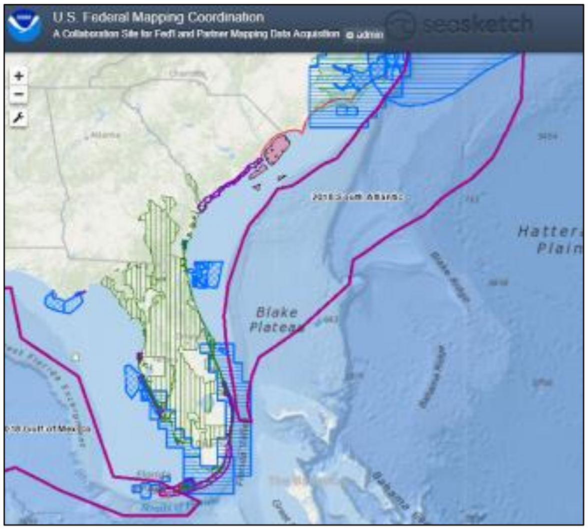

Figure 3-2. The Sea Sketch Federal Mapping Coordination online web map, used for planning and documenting mapping activities. Source: Ashley Chappell and Paul Turner, NOAA IOCM

The NOAA Integrated Ocean and Coastal Mapping (IOCM) program has two efforts underway: 3D Nation and Seabed 2030 (see Table 3-2 for relevant links). The primary goals in these efforts involve coordinating data acquisition, facilitating end-to-end data management, and getting the most use and reuse of the data available by creating tools for archiving and sharing.

Mapping a 3D Nation is another initiative lead by NOAA through IOCM to survey other agencies on elevation data needs and to build upon a study completed by USGS in 2012. The previous study focused primarily on terrestrial environment. The new goal is to understand inland, nearshore, and offshore bathymetric data requirements. The Seabed 2030 initiative, led by The Nippon Foundation and the General Bathymetric Chart of the Oceans (GEBCO), hopes to map the entirety of the ocean basins by 2030. Part of this international effort has begun with government agencies conducting a thorough gap analysis to locate mapping data needs within the US exclusive economic zone (EEZ, Figure 3-2). In addition to these initiatives, IOCM maintains a participatory online mapping tool to assemble ongoing mapping activities and needs across federal agencies through the SeaSketch platform. This mapping effort is described in more detail below (see Figure 4-1).

NOAA Office of Exploration and Research

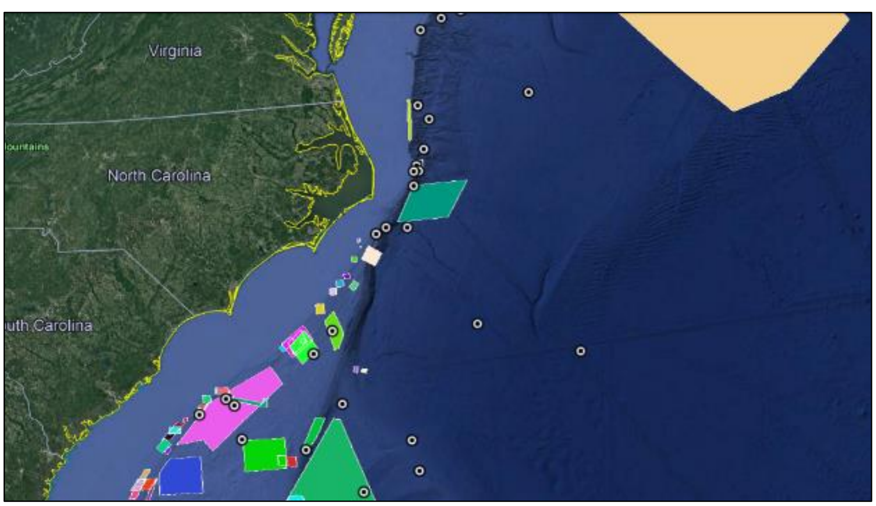

Figure 3-3. Priority mapping polygon areas submitted to OER for consideration in future mapping activities. Source: Derek Sowers and Kasey Cantwell, NOAA OER

An initiative through the NOAA Office of Exploration and Research (OER) has utilized SeaSketch to survey stakeholders for mapping priorities that may be integrated into NOAA Ship *Okeanos Explorer* future research and exploration missions. The ongoing survey collects both polygon areas for surveying and points for ROV locations, and these priority areas are available online on SeaSketch.

The *Okeanos Explorer* is equipped with nine scientific sonars, a custom-build ROV system that can travel to depths of up to 6,000 meters, CTD, and cutting edge telepresence technology. The data collected on the *Okeanos* are quickly checked for quality control and made publicly available. The ship's focus for 2017 and 2018 will be in the SE Atlantic. In 2019 and 2020, the ship will likely continue work in the Southeast, potentially expanding to the Caribbean. Another current mapping initiative is DEEP SEARCH (Deep Sea Exploration to Advance Research on Coral/Canyon/Cold Seep Habitats). This is an interagency exploration and research initiative coordinated by NOAA, the Bureau of Ocean Energy Management and the USGS. The goal is to study deep sea environments and understand the linkages between benthic habitats and the organisms they support and understand the connectivity across deep sea habitats separated by ocean basins.

NOAA National Marine Fisheries Service Southeast Fishery Independent Survey

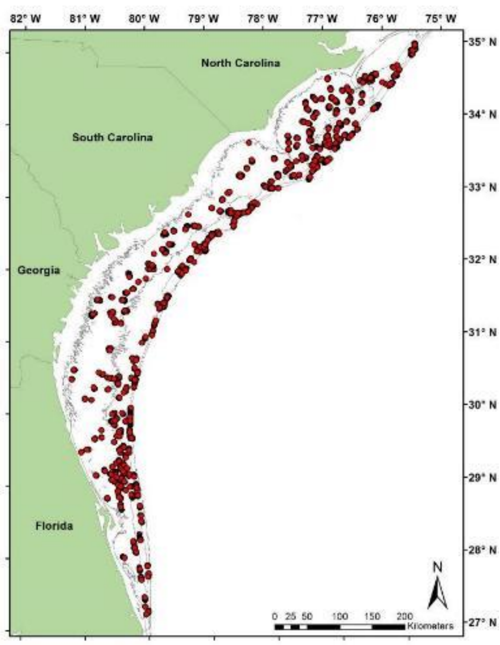

Figure 3-4. Sampling point coverage by SEFIS as of 2017. Source: Nate Bacheler, NOAA NMFS

The NOAA National Marine Fisheries Service (NMFS) Southeast Fishery-Independent Survey (SEFIS) based out of NOAA's Beaufort Laboratory in North Carolina, is a program that has been collecting and using multibeam sonar data since 2010. The target habitat for data collection is hardbottom reef areas spanning between Cape Hatteras and South Florida. The data are collected on the NOAA Ship *Pisces*, with an estimated coverage of 300 square kilometers in 30 days at sea per year. These multibeam data are primarily used for object detection to select appropriate hard bottom habitats to survey reef fish assemblages but the data are available for many other applications. The NOAA Ship *Pisces* has a fishery multibeam that can be used to map the seafloor. Staffed by primarily fishery scientists, SEFIS relies heavily on partnerships with program offices in NOAA and external partners to provide expertise in hydrographic surveys. In addition to bathymetric data, there is accompanying point specific underwater video coverage in areas of interest that are categorized by researchers and can be used as ground validation observations for interpreting seafloor habitats from multibeam survey data.

Bureau of Ocean Energy Management (BOEM)

An effort through the BOEM Marine Minerals Program, the Marine Minerals Information System (MMIS), is a developing tool to support a National Outer Continental Shelf Sand and Sediment Inventory and to foster access to the nation's offshore mineral resources. When published and made available online, the tool will host a variety of data from BOEM and other federal, state, and non-governmental agencies. Most of the data included will be derived data, including identified sand resources, dredge areas, lease areas, beach placement areas, core and grab samples, and more. The online GIS tool will also incorporate the Coastal and Marine Ecological Classification Standard (CMECS) into available data products.

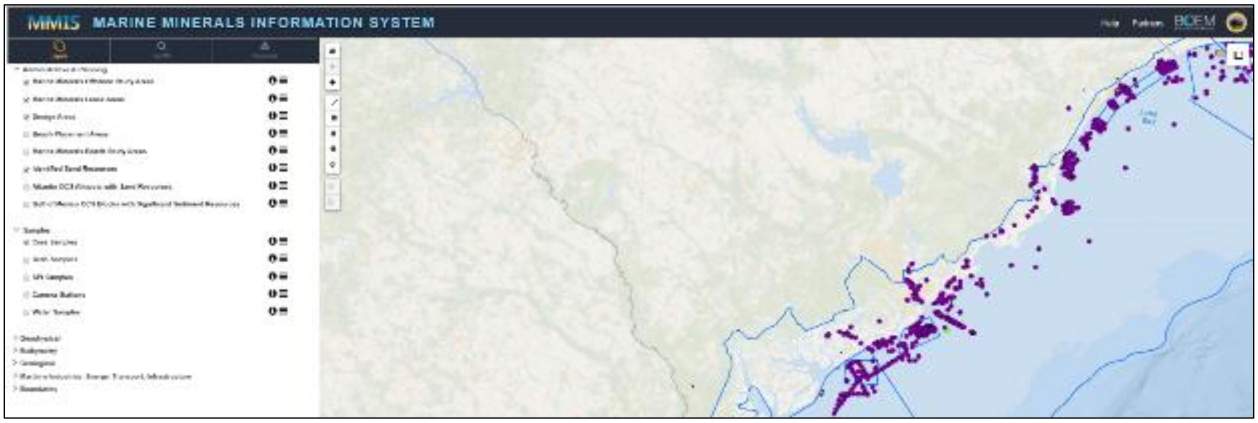

Figure 3-5. The MMIS online web application, which is an initiative by BOEM to facilitate access to offshore mineral resources. Source: Lora Turner, BOEM

South Carolina Department of Natural Resources

Figure 3-6. Identified data gaps, in red, off in South Carolina state waters. Source: Andrew Tweel, SCDNR

In cooperation with BOEM and College of Charleston, South Carolina Department of Natural Resources (SCDNR) is working to identify existing geophysical and geotechnical data and data gaps in South Carolina state waters. Targeted area of interest for this effort is 3-8 nautical miles offshore. The BOEM State Sand Cooperative aims to assess sand needs in South Carolina and compile relevant data resources. Because of the very high cost of nourishment activities, it is important to know where these resources are located. Understanding current data gaps and analyzing sand usage and available resources will aid in more efficiently using these resources in the future. Analyses thus far have identified data gaps away from populated and/or eroded beaches, where more information is needed in these areas.

US Army Corps of Engineers (USACE) – Charleston District

The Charleston USACE District is primarily a civil works mission, which is connected to navigation (dredging), conditions surveys, disaster response (pre and post event), and environmental restoration. In completing these missions, the Corps collects a large amount of backscatter and multispectral backscatter data. Typically singlebeam sonar is used to conduct conditions surveys in shallow waters to assess changes in channel depth and shoaling. Multibeam sonar with a 3-foot resolution is mainly used to compute dredge volumes (pre and post dredging), with other supplementary data, including backscatter. In addition to these survey methods, the Corps also has the ability to collect very high multibeam sonar (700 kHz) and mobile LiDAR capabilities by both boat and ATV. Mobile LiDAR is regularly used for beach nourishment assessments as well as disaster response. Much of the 3-foot resolution multibeam data are available through the US Army Corps of Engineers data portal, eHydro. All other data are available to the public via Freedom of Information Act (FOIA) request.

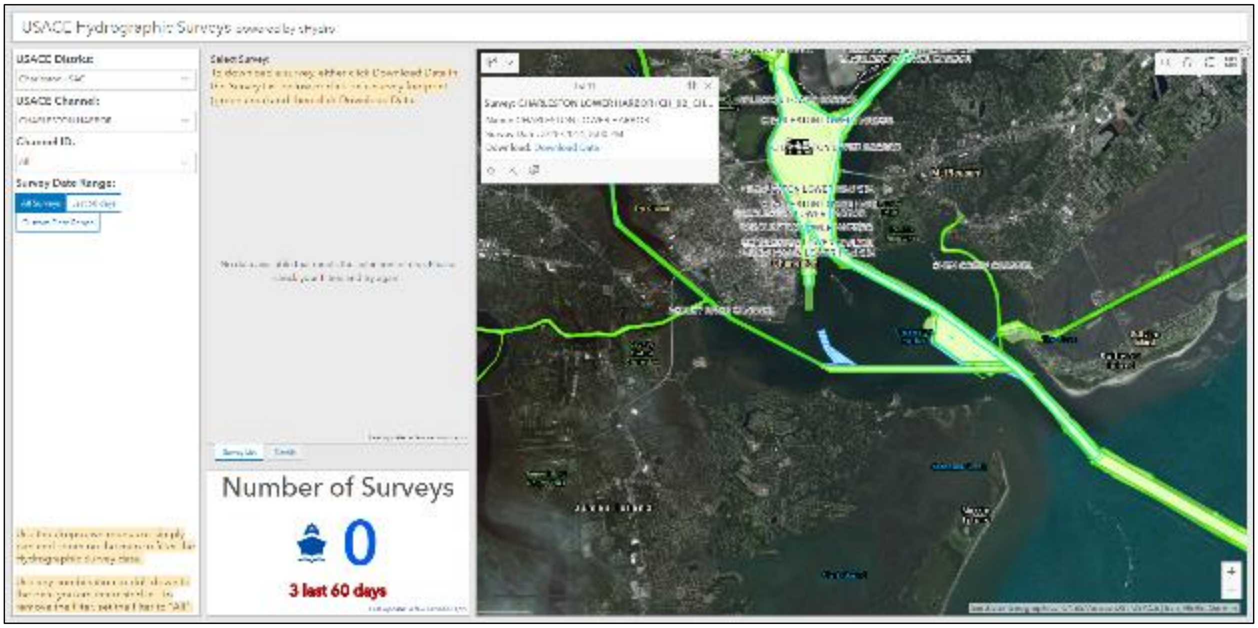

Figure 3-7. eHydro is an online data portal through USACE that allows for searching and downloading hydrographic survey data. Source: Jennifer Kist and Matt Boles, USACE

Georgia Skidaway Institute of Oceanography

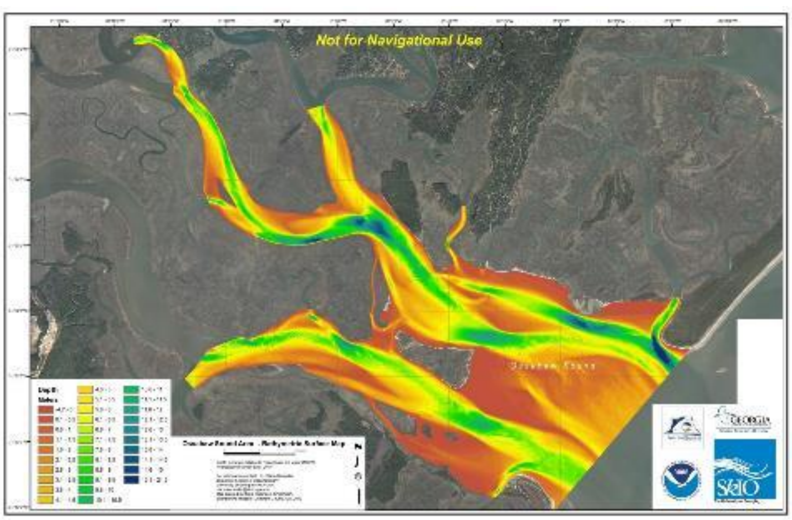

Figure 3-8 An example of mapping efforts in Georgia state waters. Source: Clark Alexander, UGA

In Georgia state waters, the University of Georgia Skidaway Institute of Oceanography is mapping nearshore resources using the following methods: vibracores, sidescan, subbottom, and multibeam sonar. Funded by the state of Georgia, but a collaborative effort across multiple agencies and institutions, the goal of these efforts is to more comprehensively map the sounds of Georgia, identifying benthic habitats, fish habitats, and other unique features.

Table 3-1. Lightning round presentations during 2018 workshop.

Presenter Name	Affiliation	Presentation Title
Christine Buckel	NOAA NOS NCCOS	Mapping Where We've Mapped
Ashley Chappell & Paul Turner	NOAA NOS IOCM	NOAA Integrated Ocean and Coastal Mapping (IOCM) Program Overview, Avenues for Collaborative Mapping, 3D National Study, Seabed 30
Lora Turner	BOEM Marine Minerals Program	BOEM Marine Minerals Program Geographic Information System (MMPGIS)
Andrew Tweel	SC DNR	SC DNR / BOEM State Sand Cooperative
Derek Sowers & Kasey Cantwell	NOAA OAR OER	NOAA Okeanos Explorer / OER Plans
Nate Bacheler	NOAA NMFS SEFIS	NOAA NMFS Southeast Fishery Survey
Jennifer Kist & Matt Boles	USACE Charleston District	USACE Backscatter & Multispectral Backscatter Data Collection and Access
Aaron Rosenberg & Scott Cross	NOAA NESDIS NCEI	NOAA NCEI Archives and Data Access
Scott Harris	College of Charleston	College of Charleston Mapping Activities
Clark Alexander	University of Georgia	Georgia Regional Status Update

Continuing to Foster Data Discovery and Data Sharing

Realizing that the agencies are not always the best stewards of data, the organizers understood there are data that have not yet been archived or captured in one of the known online data portals *(see Table 3.2)*. By creating an inventory of data not formerly archived through NCEI or other publicly accessible data portals, the SECART and partners hoped to fill in these gaps. The effort to create an inventory of footprints of seafloor mapping data was performed by a NOAA NCCOS team based at the Beaufort lab, so the data are likely biased to the work performed out of this laboratory. The ArcGIS-based tool that was developed *(see Figure 3.9)* performs the following processes: (1) processes the data, (2) creates polygon footprints of the data files, and (3) creates associated documentation with the footprint. Attributes are both provided as input from the user of the tool and extracted from the data files. Examples of the documentation attributes include spatial reference, depth range, data resolution, chief scientist, date, and information on locating and downloading the data.

Realizing that this inventory is not complete, we are continuing to expand the inventory and would welcome other data resources that are not yet included. The data inventory is not publicly available, but will be utilized in the prioritization application. We also anticipate integrating the inventory into SeaSketch and other relevant online mapping resources soon. If you would like to add your data to our inventory, please contact Chris Taylor to gain access to the footprint tool.

A postage stamp at a time, an outcome of this workshop is a network that contributes to a more comprehensive collection of available seafloor mapping data for the Southeast Atlantic.

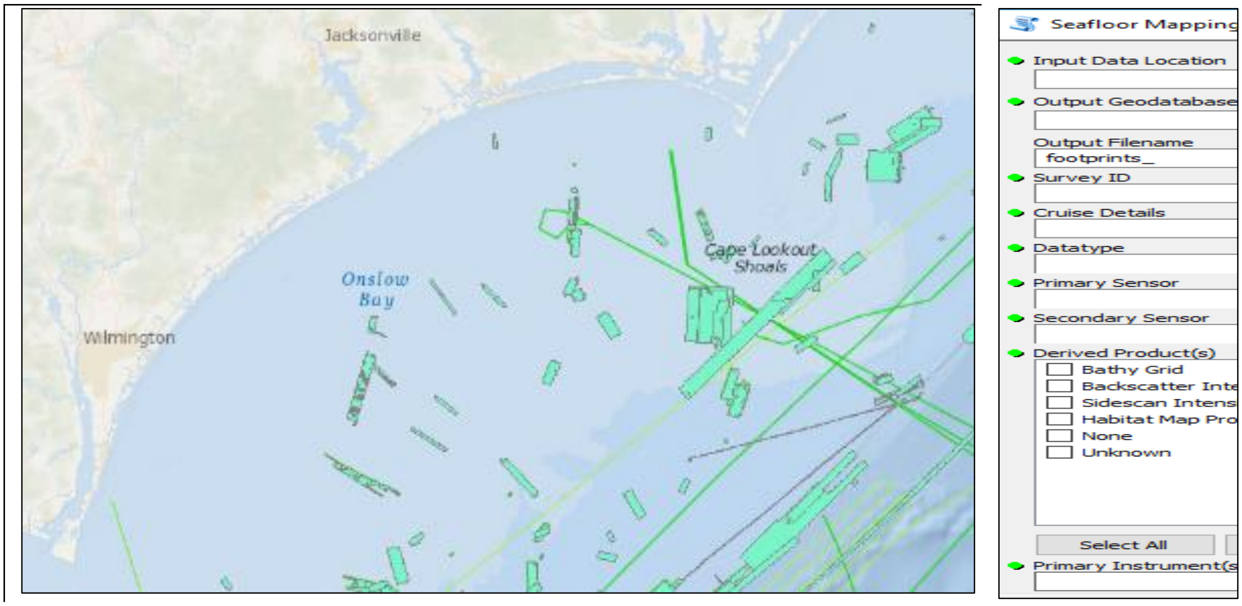

Figure 3-9. An example of the components of the Seafloor Mapping Footprint User Tool. Shown at left are output footprints (in pale green) and user inputs (right). Also shown, in green and yellow, are multibeam tracklines from the NCEI archive. Source: Chris Taylor, NOAA NCCOS

Table 3-2. Data resource table for online data portals for multibeam bathymetric data in the Southeast Atlantic region.

Data Resource	**Agency / Organization**	**Description**	**URL**
NCEI Bathymetric Data Viewer	NOAA	National archive for multibeam bathymetric data	https://maps.ngdc.noaa.gov/viewers/bathymetry/
NCEI Hydrographic Data Viewer	NOAA	National archive for hydrographic data	https://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html
U.S. Interagency Elevation Inventory	NOAA	Comprehensive, nationwide listing of known high-accuracy topographic and bathymetric data for the United States and its territories	https://coast.noaa.gov/inventory/
eHydro	USACE	Data	http://navigation.usace.army.mil/Survey/Hydro#state=PR%23channel=CESAJ_AH_01_ARE
FL Coastal Mapping Program Project Footprints	USGS & partners	Footprints of bathymetric data off the coasts of Florida from a variety of data sources	http://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=b7a8190f3f7141a0828d18209472d9c6
SAFMC Managed Areas	South Atlantic Fisheries Management Council	Map viewer containing data layers for management zones in the South Atlantic	http://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=40c022fb73e84bc99d4c1fb3e3b154b9

4 Developing a regional seafloor mapping prioritization tool for inter-agency coordination

4.1 Approaches to prioritizing seafloor mapping activities

A top priority for the 2018 workshop was not only to make inter-agency connections in order to better utilize and share data, but also to develop a regional geospatial framework for successfully prioritizing future mapping needs in the Southeast Atlantic. There are several approaches for prioritizing mapping needs that have been implemented previously and were discussed during the workshop in a series of presentations (see Table 4-1).

Table 4-1. Presentations relating to seafloor mapping prioritization approaches and initiatives at 2018 workshop.

Presenter Name	Affiliation	Presentation Title
Ashley Chappell & Paul Turner	NOAA NOS IOCM	IOCM Mapping Prioritization Survey Using SeaSketch
Cheryl Hapke	USGS	Florida Coastal Mapping Program
Tim Battista	NOAA NOS	The Interactive Prioritization Approach
Ginny Crothers	NOAA NOS NCCOS	Southeast Seafloor Mapping Prioritization Tool

Addressing National Needs for Seafloor Data – IOCM SeaSketch Project

The NOAA Integrated Ocean and Coastal Mapping (IOCM) Program detailed a prioritization survey that they are currently executing using the SeaSketch.org online spatial planning tool. The IOCM approach allows users to share information on data acquisition plans and needs. The interface also facilitates inter-agency project coordination through various applications, such as forums for discussion and tools for sketching and sharing survey priority areas. The goal is to detail 3D inland elevation data needs, in addition to coastal and ocean needs. The SeaSketch interface is a resource that will be utilized in the Southeast prioritization mapping exercise, as well.

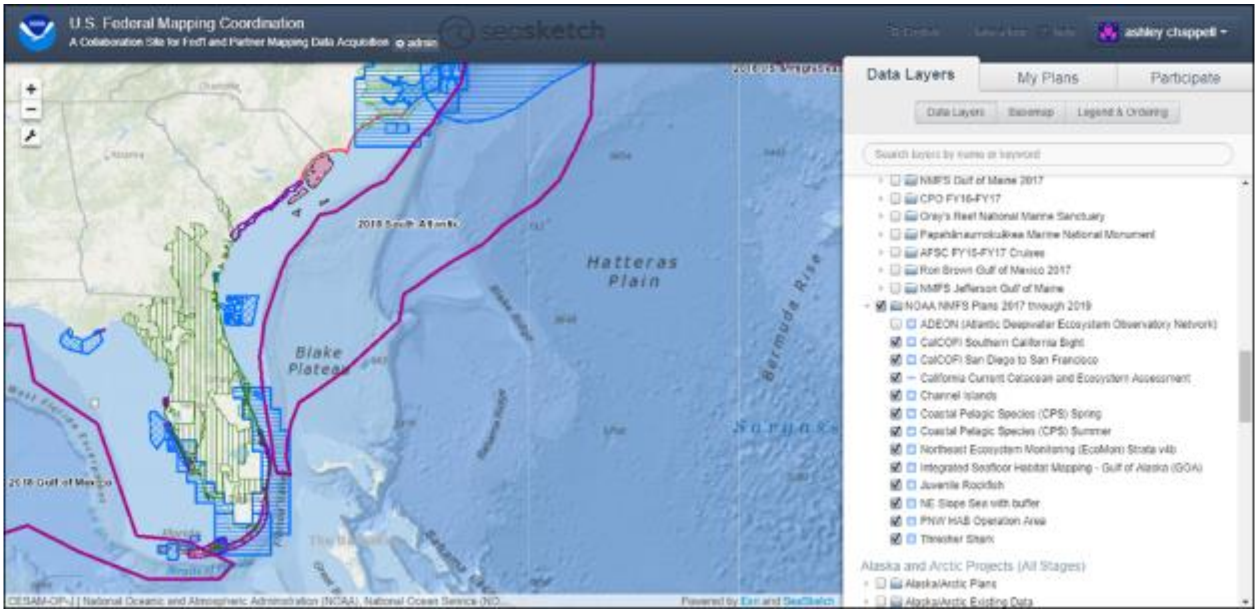

Figure 4-1. The U.S. Federal Mapping Coordination tool through SeaSketch for prioritizing and coordinating seafloor mapping activities. Source: Ashley Chappell, NOAA OCS IOCM

Addressing State-Specific Mapping Needs in Florida

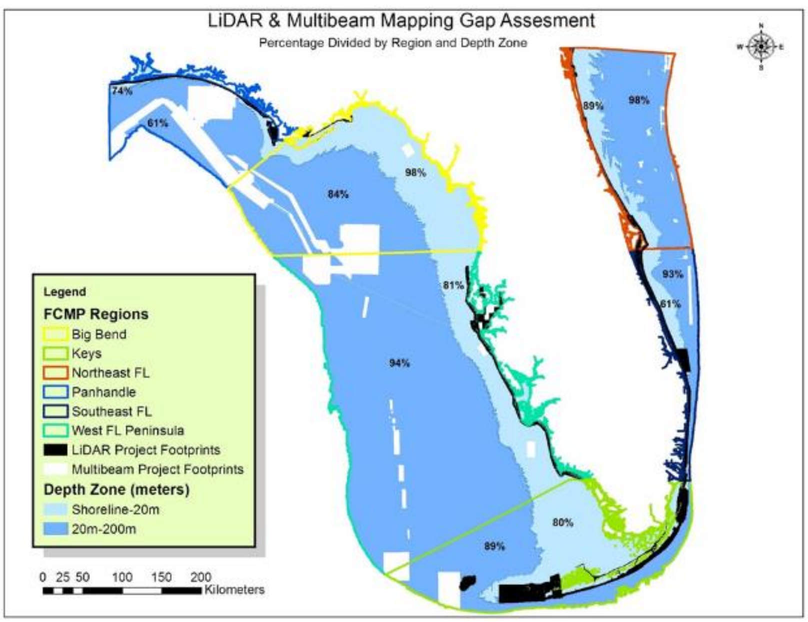

Figure 4-2. Results of a gap analysis completed by USGS Florida Coastal Mapping Program (FCMP) for six identified coastal and ocean regions in Florida. Source: Cheryl Hapke, USGS

Through the Florida Coastal Mapping Program, USGS and partners are executing a separate, but somewhat similar approach to gather data, conduct a gap analysis, and create a data portal for seafloor mapping data in Florida state and federal waters. Prior to conducting a gap analysis, the technical team – including experts from USGS, Florida Institute of Oceanography, and other agencies and academic institutions – divided the coast into six regions in order to address stakeholder needs on a regional basis. Through a workshop, the team gained a better understanding of the current state of coastal seafloor bathymetry data, created guidance for future mapping projects and priorities, and built a foundation to inform a multi-year strategy to fill in critical gaps in seafloor mapping data. Next steps will include reporting these findings, creating an online prioritization application, and launching that effort through outreach and regional workshops with stakeholders. So far, the resulting data footprints can be viewed in the FCMP Project Footprints data viewer.

4.2 An approach to participatory mapping to prioritize seafloor mapping

A process for prioritizing seafloor mapping has been evolving within NOAA that is different from other approaches previously described. Through this methodology, priority mapping areas are not only identified, but are given a ranking as to the level of priority or the level of need for data in a given area. In addition to ranking areas of priority, associated attributes are included, further defining the narrative of (1) when and where the data are needed, (2) why the data are needed or what the data will be used for, and (3) what kind of data and data products are needed to make the associated management decisions.

This NCCOS approach for prioritizing seafloor mapping was first implemented in Long Island Sound in 2012, but more recently has been implemented in Washington State, Southern California, and Lake Michigan. Typically, the project timeline for this process involves several phases, including (1) gathering stakeholders, (2) holding an initial workshop, (3) launching the spatial prioritization exercise via an online application, and (4) planning a follow-up workshop to synthesize results. The tool synthesizes user input across agencies by identifying one agency representative to use the tool and submit the agency's priority areas (see Figure 4-3). Through these agency respondents, the tool facilitates participatory GIS and aggregates inter-agency mapping priority information.

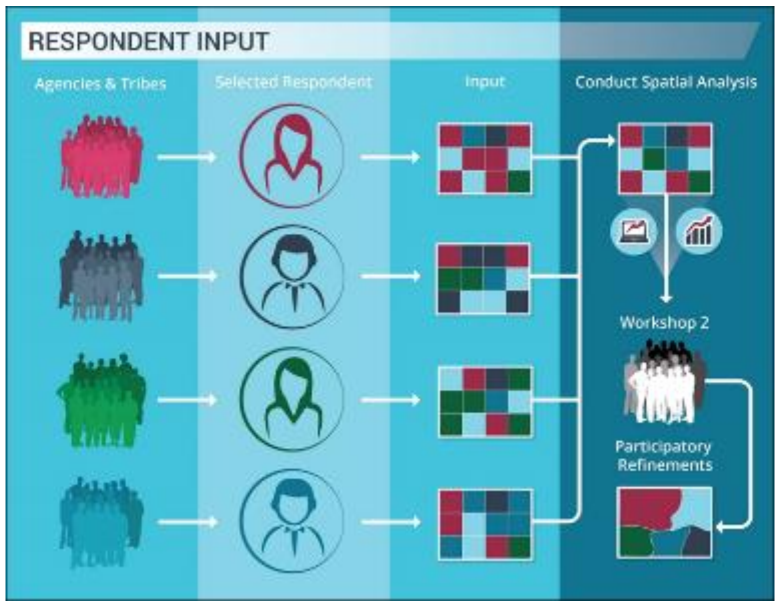

Figure 4-3. How the prioritization tool synthesizes input across agencies by identifying one agency representative. Source: Tim Battista, NOAA NCCOS

This prioritization tool implements a grid approach to spatial prioritization (see Figure 4-4). The grid can vary depending on a number of factors, including the size of the area of interest and the grid size and unit of measurement most logical or relatable for the users of the tool. Another key concept within this approach is the idea of allocating priority "tokens" in one of two methods: (1) restricting the maximum number of priority tokens for the entire area of interest, or (2) restricting tokens across each prioritization category (e.g., high, medium, and low priority levels). Implementing this idea of tokens forces the user to further prioritize within a more limited framework. However, tokens do not have to be implemented for the tool to be functional.

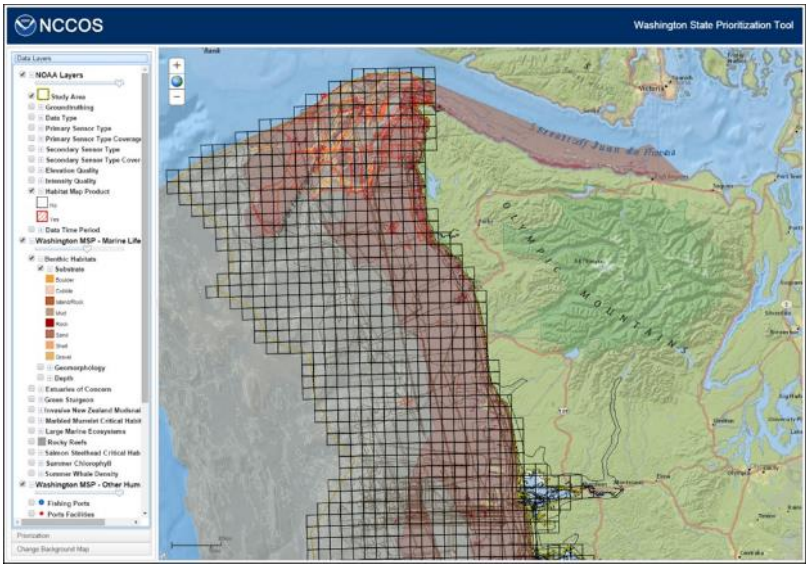

Figure 4-4. The Washington State Prioritization Tool data viewer, which provides a wide range of supplementary data to aid users in drawing priority mapping areas on the map grid. Source: Tim Battista, NOAA NCCOS

The prioritization tool is implemented using the ESRI Web App Builder for ArcGIS interface. The application makes it easy to integrate an interactive map, data layers, and the prioritization tool into one website. Examples of other prioritization tools built by this team at NOAA include:

[Washington State Spatial Prioritization Data Viewer](#)
[Wisconsin-Lake Michigan Lakebed Mapping Prioritization](#)

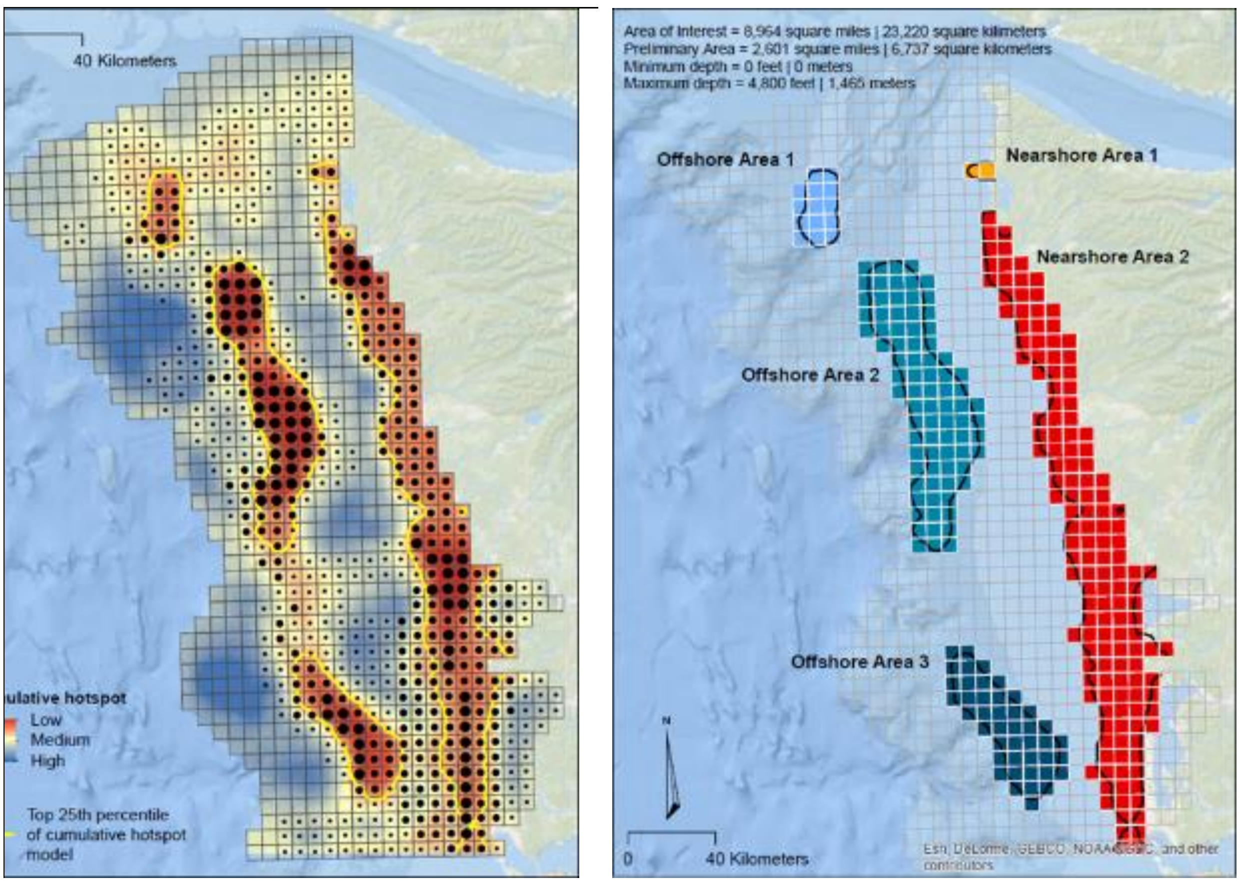

Figure 4-5. Hot spot analysis results for the Washington State Prioritization (left) and the resulting priority areas identified from the analysis (right) colors represent unique areas identified by prioritization exercise. Source: Tim Battista, NOAA NCCOS

After executing the prioritization application and getting input from the agency respondents, the tool enables priority analysis to gain meaningful statistical patterns from the user input. Not only can hot spot analysis be done cumulatively across all responses (see Figure 4-5, left panel), it can be split into categories across any of the attributes integrated into the prioritization tool. From the hotspot analysis, priority areas can also be designated across the grid (see Figure 4-5, right panel). Defining the priority areas from the analysis often involves input from stakeholders during a supplementary workshop.

4.3 A candidate tool for prioritizing seafloor mapping in the Southeast

Building upon the work already done in building these other prioritization applications, the Southeast Seafloor Mapping Prioritization web application aims to:

- *Visualize existing data*
- *Receive individualized priorities*
- *Compile and analyze priorities to coordinate future mapping activities*

The prioritization application is hosted by the ArcGIS Online NOAA GeoPlatform and is not public, but will be accessible to invited users (agency respondents). The interface for the tool includes an interactive web map and several toolbars for navigating and using the application (see Figure 4-6). The web map shows the extent of the study area for the prioritization tool, which includes state and federal waters in the Southeast.

The web application includes not only the prioritization tool, but also operates as a data viewer for visualizing relevant data that may aid in designating priority areas. Included in the Southeast Seafloor Mapping Prioritization web application are protected and managed areas, such as South Atlantic Fisheries Management Council (SAFMC) management zones, and web services for multibeam data, such as the NCEI Bathymetric Data Viewer and the NOAA Multibeam Inventory built using the Seafloor Mapping Footprint User Tool described in Chapter 3: Improving awareness of seafloor mapping data resources and activities.

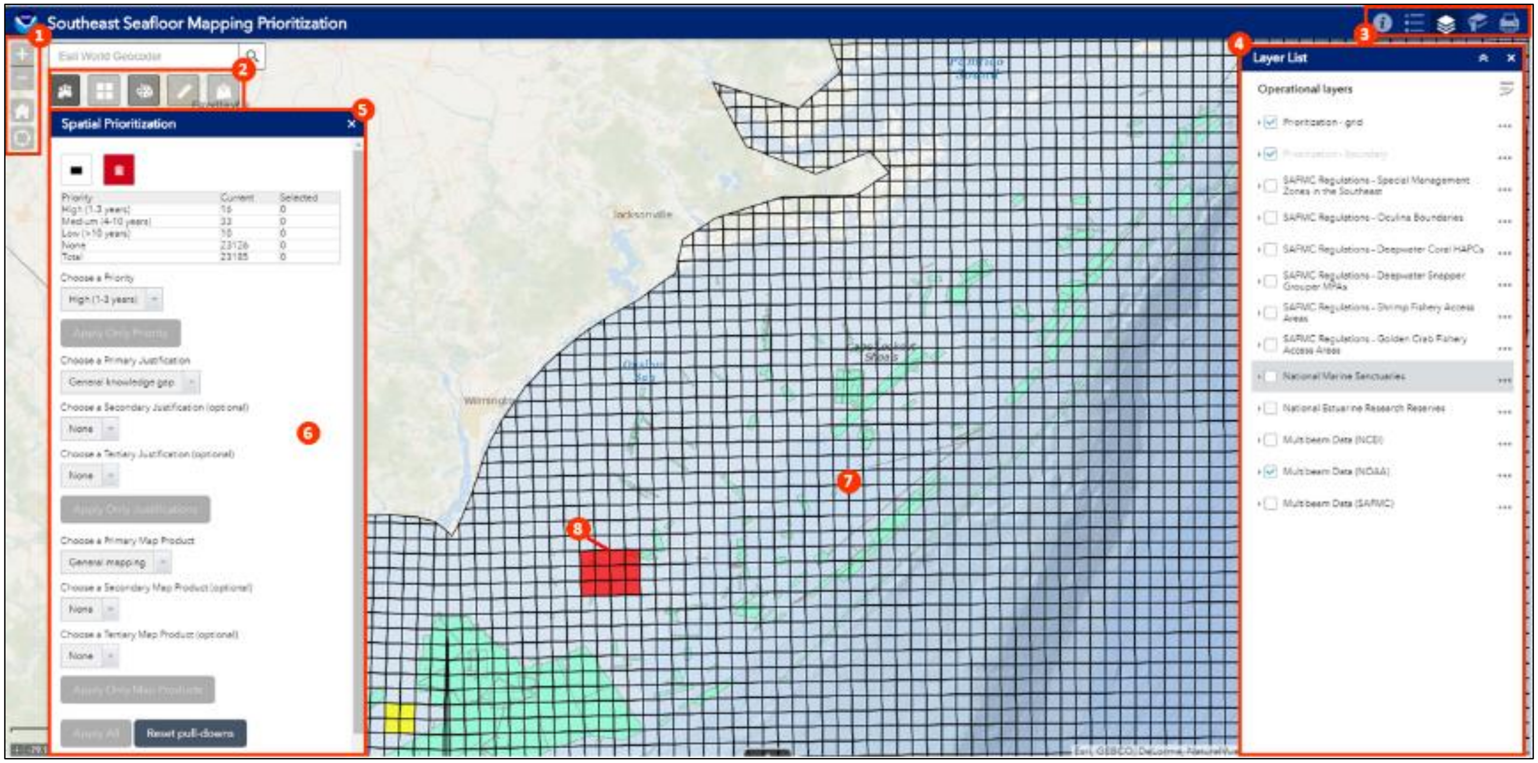

Figure 4-6. The Southeast Seafloor Mapping Prioritization online tool components:

(1) Navigation toolbar: zoom in (-), zoom out (+), or go back to the home extent of the map
(2) Left hand toolbar: includes (from the left) Spatial Prioritization, Basemap Gallery, Draw, Measure, and Add Data tools
(3) Right hand toolbar: includes (from the left) About, Legend, Layer List, Bookmark, and Print tools
(4) Layer list: includes data layers available for adding to the web map
(5) Spatial prioritization: the prioritization tool panel for drawing priority areas and assigning attributes on the grid
(6) Priority attributes: the parameters for prioritization including Priority Level, Justification(s), and Map Product(s)
(7) Prioritization grid: each user designates their priority areas on their own grid
(8) Priority area: once the tool is used, priority areas will be shown on the map, highlighted in colors according to priority level

In addition to visualizing data, there are various tools for navigating the map, drawing priority areas, and sharing findings with colleagues. The tools will be more specifically outlined in the User Guide distributed to agency respondents and are listed in the graphic in Figure 4-6.

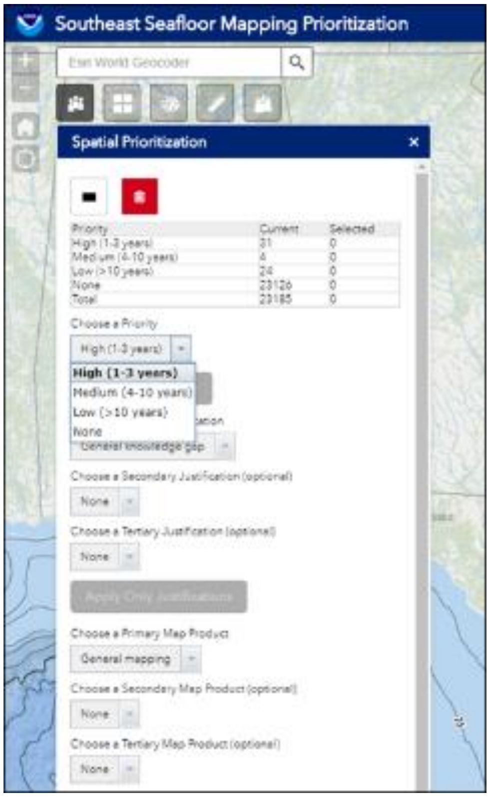

Figure 4-7. The Spatial Prioritization tool panel within the SE Seafloor Mapping Prioritization tool. The tool allows the user to draw an area on the map and designate attributes to describe the priority area.

The Spatial Prioritization tool is integrated into the web application and allows the user to draw priority mapping areas on a prioritization grid, assigning attributes to describe the priority areas (see Figure 4-7). The prioritization grid is adapted from the Outer Continental Shelf (OCS) lease blocks to include state waters, so each grid cell is approximately 3 square miles. Each user of the tool has their own grid that is not viewable to other users, so users will not see priority areas submitted by other participants.

For any given priority area, there are constraints by priority level on how large the priority area can be. These constraints are based off typical coverage for an offshore survey to create priority areas on a practical and implementable size and scale (see Table 4-2).

In addition to spatially designating priority areas on a grid, the user assigns certain attributes to the area to describe when the data are needed, why the data are needed, and what kind of data and associated data products are needed. Table 4-2, Table 4-3, and Table 4-4 provide lists of the parameters included in the tool. Priority Level is based on the timeline of when the data are needed (see Table 4-2). These priority timeline ranges were adjusted after receiving feedback during the 2018 workshop to include shorter timelines for each of the priority levels. Justification (Table 4-3) relates to why the data are needed, and the list covers commercial uses, managed resources, and research and scientific study. Finally, the Map Product parameter relates to what kind of data are needed (Table 4-4). During the workshop, a survey was distributed to participants, requesting feedback on these attributes. The survey feedback will be integrated into the updated version of the tool before implementation.

Table 4-2. Priority Level parameter list used in prioritization tool to depict priority level based on a timeline for when the data are needed. Also provided are the maximum number of grid cells a user can specify by the designated priority level.

Priority Level	**Maximum grid cells per area**
High (1 – 2 years)	Up to 25 grid cells
Medium (3 – 5 years)	Up to 35 grid cells
Low (> 5 years)	Up to 50 grid cells

Table 4-3. Justification parameter list used in prioritization tool to depict why the data are needed. User can choose up to three justifications or reasons for each priority area.

Justification(s)
General knowledge gap
Coastal inundation and natural coastal hazards
Commercial fishing (e.g. commercial fishing areas)
Cultural/historical resources (e.g. shipwrecks, debris fields)
Defense and homeland security activity
Diving (e.g. recreational dive sites such as shipwrecks)
Important biota/natural area (e.g. rock outcrop, spawning/nursery area, living resources management)
Infrastructure (e.g. existing or potential cable, pipeline, outfall, offshore energy development)
Managed area (e.g. trawling zone, parks, designated use area)
Monitoring (e.g. key location for bottom samples, mussel growth)
Pollution (e.g. marine debris, oil spill response)
Recreational boating (e.g. sailing, cruising, or other activities from private boats)
Safety and navigation (e.g. shipping lanes, port facilities, marinas)
Scientific research
Sediment movement and management (e.g. longshore drift, erosion, depositional area, dredging/spoil, sand mining)
Sport fishing (e.g. areas for sport fishing from shore, private boats, or chartered boats)
Not specified

Table 4-4. Map Product parameter list used in prioritization tool to depict what kind of data are needed. User can choose up to three map products for each priority area.

Map Product(s)
General mapping (e.g. use of various collection methods to map the spatial distribution of features)
Bathymetry/Digital Elevation Model (e.g. multibeam, lidar, interferometric sonar)
Ferrous object detection/magnetic anomalies (e.g. magnetometer)
Ground-truth data (e.g. imagery or physical samples such as grabs or cores)
Color (e.g. multispectral satellite sensors, aerial photography)
Surface type, hardness/smoothness/slope (e.g. side scan or backscatter from multibeam sonar)
Sub-bottom geology (e.g. sub-bottom profiler)
Not specified

A more thorough guide to using the prioritization tool will be distributed to agency respondents, but the main steps to using the tool involve:

- Finding the area of interest for seafloor mapping using data available in the viewer, user’s own data, and feedback from colleagues within user’s agency or organization
- Drawing the priority area on the grid using the Spatial Prioritization tool panel (Figure 4-8).
- Assigning associated attributes to the area, including (1) Priority level, (2) Justification(s), and (3) Map Products

- Reviewing and submitting priority areas within the Southeast Seafloor Mapping Prioritization web application (Figure 4-9).

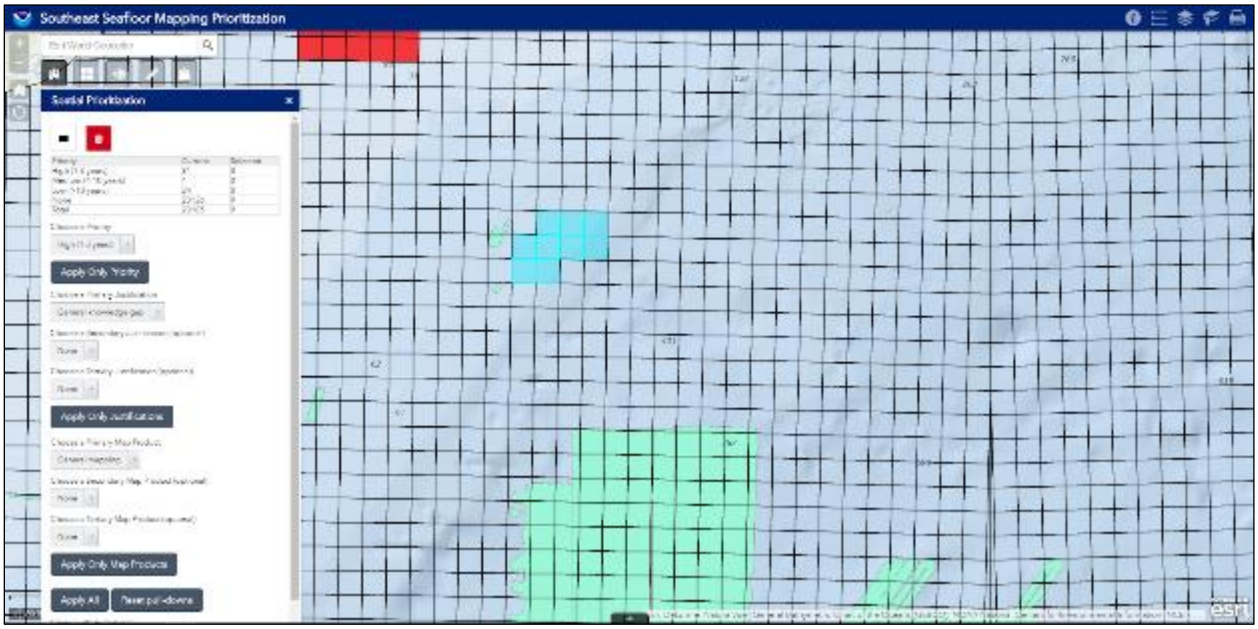

Figure 4-8. A screenshot of the process of drawing a priority area on the grid using the Spatial Prioritization tool panel.

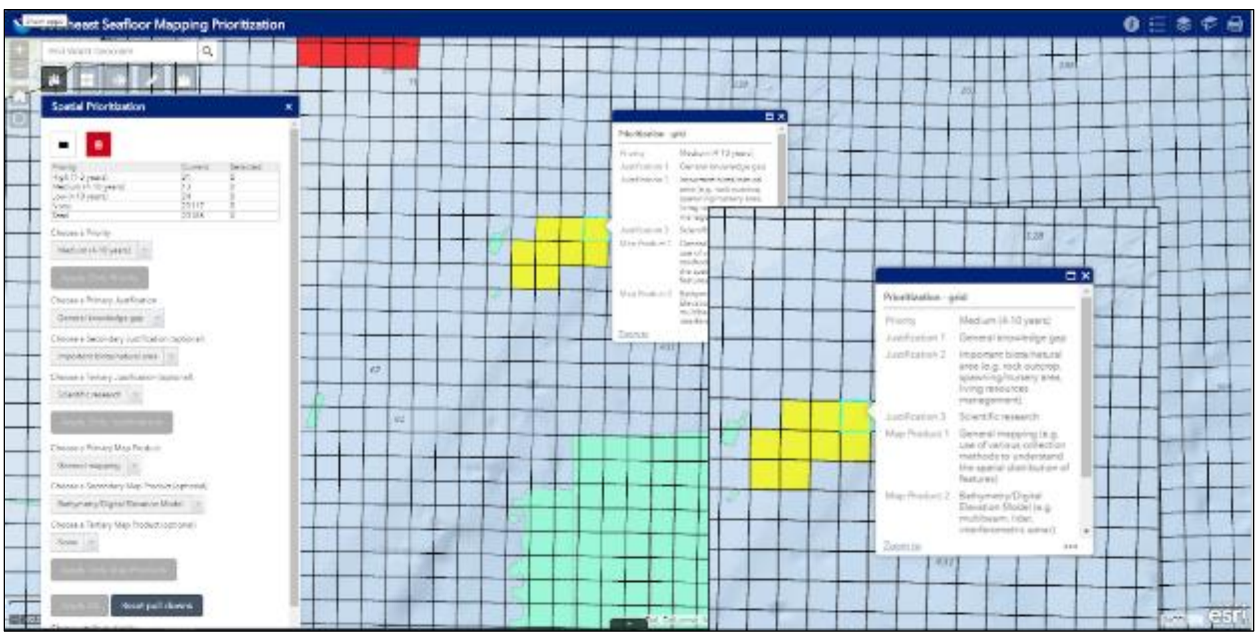

Figure 4-9. A screenshot of what the priority area will look like once submitted, and the associated pop-up window that displays the assigned attributes for any given grid cell.

All of the user's responses will be saved on their personal grid as a spatial representation of priority mapping areas for their organization. After agency respondents have submitted their priority areas, all of the grids can be aggregated and analyzed in a manner similar to that described in Chapter 4.2.

During the 2018 workshop, some questions were discussed on how to most effectively execute this tool in our region, including:

Scaling the tool to such a large geographic region

Previous iterations of the prioritization web applications through NCCOS have been implemented in much smaller geographic regions, such as Washington state waters or Lake Michigan. The Southeast Atlantic, including both state and federal waters, is a vast area, requiring some adaptations of the tool to work within such a large region. For example, applying the concept of "tokens" is more complicated when you have such a big area and stakeholder agencies working within different portions of the region. During the workshop, participants agreed to implement the tool without restricting overall number of "tokens" or grid cells for prioritization under a beta testing of the tool, including a small number of stakeholders present at the workshop.

Engaging stakeholders to facilitate broad participation across agencies

During the workshop, the strategy for implementation and engagement with key stakeholders was discussed. While developing a functional and effective tool is key, getting stakeholders to participate and use the tool is just as important. A technical working committee was created during the workshop and the members of this committee will participate in a beta testing of the tool prior to full implementation. The SECART is continuing to gather feedback on what stakeholders to engage with and how to effectively gain participation from stakeholder agencies. Beyond figuring out what stakeholders to involve, the question was proposed during the workshop of what level within agencies to receive input. For example, within any given state or federal agency, there are several different departments that could provide mapping prioritization feedback. Conclusions from the workshop included (1) getting feedback from different divisions within stakeholder agencies and (2) making sure to convey that these priority areas by no means need to be formal submissions that are authoritative and representative of an entire agency or organization. The outcome from the prioritization exercise does not imply availability of resources.

Coordinating with previous prioritization efforts

Not only is the SECART considering how to most effectively engage stakeholders, but also the question arose during the workshop of how to integrate previous prioritization efforts into the Southeast Seafloor Mapping Prioritization exercise. For example, SeaSketch has become a hub for agencies to coordinate mapping efforts within and across agencies. Some of the participants at the workshop have already used SeaSketch for priority mapping. A strategy is being developed to build upon the information already available through applications like SeaSketch, while integrating the new features of the Southeast Seafloor Mapping Prioritization tool.

How to factor in mission-based mapping

Another factor important in considering the implementation of the tool is whether or not to integrate mission-based seafloor mapping efforts, such as the scheduled projects executed by US Army Corps of Engineers (USACE) districts. At the workshop, the consensus seemed to be that this information should be integrated into the application, as it can help inform need-based mapping across other agencies.

Timeline for implementation

Originally the SECART aimed to implement a full version of the tool by Summer 2018. Workshop participants offered valuable and constructive feedback on modifications to the tool and concerns related to the implementation of the tool, as discussed above. Now, the team plans to execute a beta version of the tool to the technical working group by Summer 2019. A timeline for full implementation of the tool to the broader group of stakeholders is yet to be determined.

Next steps for the tool include answering any remaining questions from the topics discussed above, developing a strategy for gathering key stakeholders for participation, identifying agency respondents for each organization, and implementing the tool in a multi-tiered approach.

The results from the prioritization exercise will be similar to the results outlined in the previous section, Chapter 4.2: An approach to participatory prioritization for seafloor mapping. Submitted priority areas will be aggregated, analyzed, and interpreted into hot spots for high priority mapping in the future.

5 Interpreting habitat maps using remotely sensed elevation surfaces and predictive modeling

Habitat maps are created from bathymetric data using several approaches with the aim of identifying characteristics related to the seafloor, such as coral reefs, habitat features, fish spawning aggregations, sand resources, and areas of archaeological significance. There are many different approaches that can be used to create predictive habitat maps. During the workshop, Laura Kracker, with NOAA NCCOS Habitat Mapping Team, outlined two approaches to habitat predictive modeling that can be used across these areas of categorization. These approaches can be broken into two main groups *(see Table 5.1)*: (1) Pixel-based predictive modeling (BRTs) and (2) Delineation and segmentation of seafloor features (segmentation by polygons).

Table 5-1. Habitat predictive modeling approaches, including pixel-based predictive modeling (BRTs) and delineation of features (polygons). Source: Laura Kracker, NOAA

Approach	Technique	Resolution (Grain Size)	Flexibility
Pixel-based predictive modeling (BRTs)	Machine learning assigns a probability of occurrence to each pixel	Based on the 'best attainable' resolution of the original data and the error associated with position of GV (ROV, camera) data. (ie. 11x11m)	Pixel resolution up to any merged or thresholded scale
Delineation of features (polygons)	Classify the sonar response into like pixels (PCA), segment, and label polygons	Minimum mapping unit (ie. 100 - 1000+ m^2)	Static. Can only scale up / simplify

Pixel-based predictive modeling is the newer approach that integrates machine learning and offers higher resolution habitat maps. The result of this technique is pixel-level probability of occurrence with a variance coefficient. The maps are based on the "best attainable" resolution, whereas the older method of creating habitat maps using the delineation of features creates coarser habitat maps, because of scaling up or simplifying the data in the process of analysis. Using the delineation method, the sonar responses from the bathymetric data are classified into similar pixels and then merged into polygons representing different habitat classifications. The difference in the products of these two techniques can be seen in the two maps in *Figure 5.1*.

Ground validation (GV) and accuracy asssessments (AA) are completed in both modeling approaches using methods such as:

- Taking pictures of the seafloor at GV and AA sites
- Reviewing videos from sites and annotating substrate and cover type (presence/absence)
- Extracting seafloor metrics at each GV site, including bathymetric, oceanographic, and geographic attributes
- Running the BRT model many times to create (1) predictive surface of probability of occurrence and (2) coefficient of variation surface rasters

The model runs for each substrate and cover type and creates these prediction and variance surfaces for each type. The final result is a composite benthic habitat map. Next steps for this modeling process including continuing to evolve the modeling approach, as well as looking at moving the model processing to the Cloud.

Workshop participants engaged in a discussion of approaches to interpreting remotely sensed seafloor imagery to habitats. The US Army Corp of Engineers raised the specific challenge of interpreting sand and grain size from sonar imagery and the improvements that can be made using multi-spectral backscatter, or acoustic reflectivity from multiple simultaneous ensonifications of the seafloor with a sonar. Another challenging seafloor habitat type was the delineation of flat pavement or other very low relief rocky hardbottom that may have thin sand veneer from very low relief sand bodies.

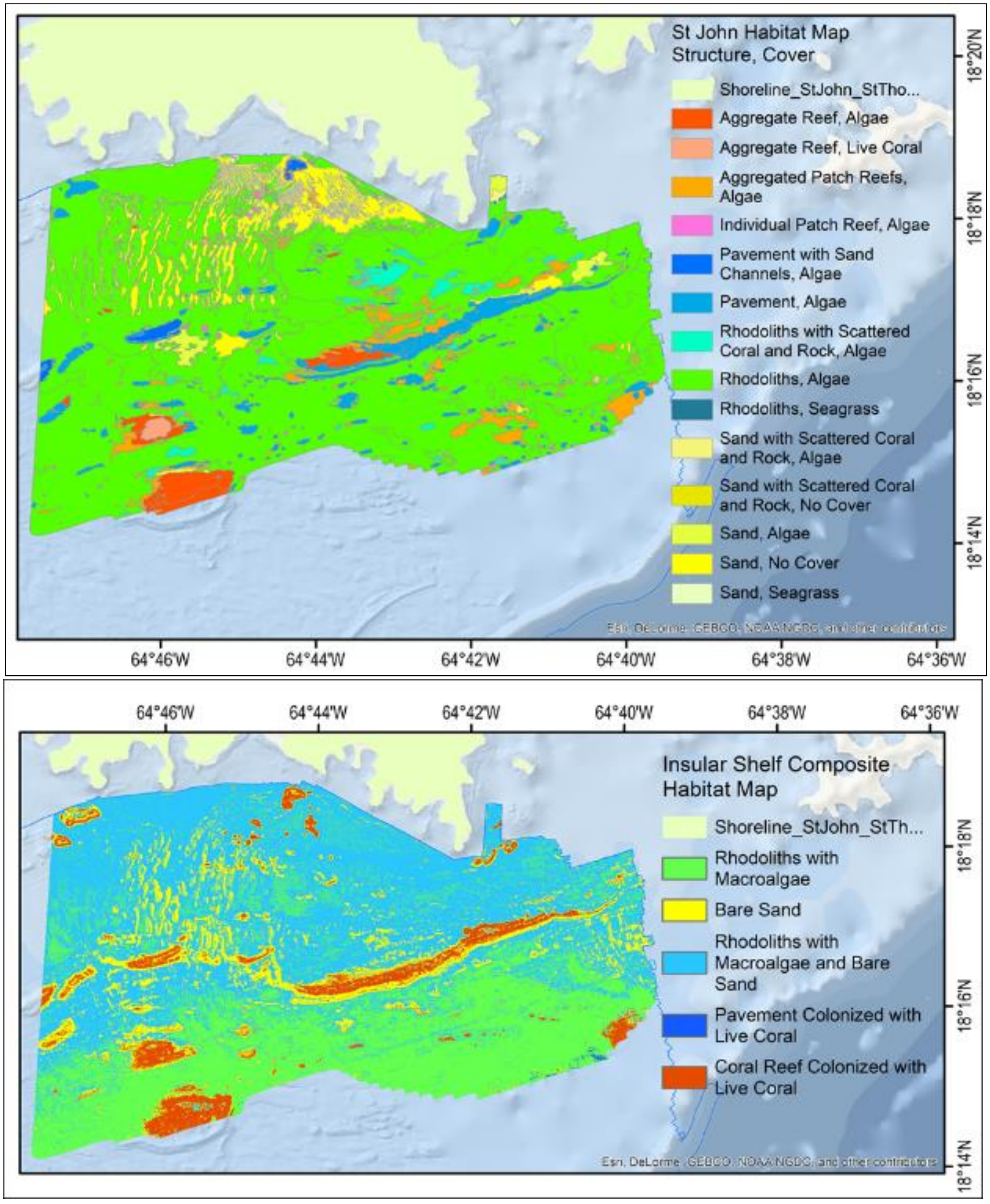

Figure 5-1. Approaches to habitat mapping: Delineation of polygons (top) and Pixel-based predictive modeling (bottom). Source: Laura Kracker, NOAA

6 Defining management drivers, requirements and best practices for seafloor mapping

During the 2018 workshop, breakout sessions were divided among three habitat types identified by 2016 workshop participants as focus areas for the region that have unique management drivers and stakeholder user-groups:

- Shallow estuarine habitats (Section 7) – inshore bays, sounds and tidal rivers within state boundaries
- Nearshore sand shoals and sediment resources (Section 8) – from the surf-zone and primarily focused on nearshore coastal ocean (e.g. targeted for mining to restore beaches), but including unconsolidated sediments on the outer continental shelf
- Offshore rocky and deep coral reefs (Section 9), including cultural resources such as shipwrecks – sensitive habitats and areas on the outer continental shelf through the shelf slope and including canyons and deep plateaus

The goal of this exercise was to better define the requirements for habitat maps that are needed to make management decisions and match the appropriate and state-of-the-science sensor and technique to the expectations and requirements in terms of extent, spatial resolution, and level of detail in the habitat characterization. Groups were provided a set of trigger questions to guide the discussion:

Part 1. Customers, Users and Requirements

1. Who are the primary customers for seafloor habitats maps in your habitat focus area?
2. What are the primary management drivers requiring seafloor mapping and related data?
3. What resolution and extent are required for decision making or management actions?
4. How do you receive habitat mapping information? Examples include:
    a. Online-interactive resources
    b. Digital data shared by owner or acquisition source
    c. Paper maps and printed reports

Part 2. Matching State of Science to Requirements

1. What technical standards or operating procedures exist for mapping your habitat area?
2. What remote sensors are most often used to map your habitat area?
    a. List sensor types and platforms used (satellite, airborne, ship, small boats)
    b. Provide ranges for resolution (e.g., meter x meter, by depth) or other coverage metrics for sensors as well as resolution for interpreted maps
3. What classification schemes or standards are used in your habitat area?
4. What ground validation methods are used to interpret remotely sensed data?
5. Are accuracy assessments expected by end-users?
6. Are there monitoring or change detection programs in place for your habitat area?

Each group had expert leads who were practitioners in the field of seafloor mapping or remote sensing. Facilitators were present to maintain progress through the questions. Each group progressed in different ways through the trigger questions guided by expertise with the varied stakeholders and management drivers within the habitat focus areas.

7 Shallow estuarine habitats

The Southeast US Atlantic coast is a mosaic of water systems where coastal rivers or bays interface with the coastal ocean. This includes a wide variety of habitats from the shallow expansive lagoonal estuaries bounded by the Outer Banks of North Carolina, the vast salt marsh bounded estuaries of South Carolina and Georgia, and the sub-tropical seagrass and mangrove resources of the shallow waters of Florida (Figure 7-1). Human populations surrounding these areas can range from the very low populations of Core Sound, NC, to the high population densities in Coastal Florida. Due to its location in the narrow zone between terrestrial landscapes and the open ocean these habitats are highly vulnerable to anthropogenic and natural activities and events, such as coastal development, navigation, storms, and eutrophication due to nutrient runoff. Although wide varieties of natural habitats occur in this zone, in practice seagrass meadows, shellfish beds, salt marshes, and mangrove forests are usually the priority of coastal managers and researchers. Macro-algae is occasionally of interest although most often in the context of controlling nuisance blooms. Given the wide variety of habitats and surrounding human development, there is a large number of customers and management drivers for shallow estuarine habitat maps. This complex landscape requires a variety of methods and technologies to create those maps.

7.1 How is this habitat mapped? Why are there gaps?

The dominant shallow estuarine habitats exist along an elevation gradient ranging from salt marshes and mangroves with extensive emergent biomass to sub-tidal shellfish beds at depth in turbid water. This, along with the fact that these habitats can co-occur at small spatial scales, make mapping them a difficult process. The result often being that more than one mapping technology is required. Compounding these challenges are the influence of environmental conditions, such as water turbidity, and the spatial complexity of the landscape. High-resolution remote sensing data is universally required for these areas. Temporal considerations, such as tidal stage, sun angle, and seasonal phenology, can play a major role in the success of a mapping effort. The remote sensing tools most often used for mapping in this area consist of multi-spectral imagery collected from satellites or aerial platforms, LIDAR point clouds collected with airborne sensors, and acoustic backscatter/bathymetry or bottom character collected using small manned or autonomous boats. Each of these technologies has its own environmental and/or technical limitations.

Multi-spectral imagery
High-resolution (<1 meter) imagery in the visible and near-infrared spectrum acquired from an airborne or satellite platform is a preferred data source for mapping mangroves, salt marshes, intertidal shellfish beds, and seagrass meadows. The fact that mangroves and emergent marsh grasses present strong signatures above the water surface makes them easier to identify and map. Atmospheric (clouds and haze) and seasonal conditions need to be considered, but these can usually be addressed with planning and with satellite revisit capability, good source imagery can be collected in most cases. Shellfish beds and seagrasses are more challenging to map with multi-spectral imagery. Even shellfish beds exposed at low tides usually have a subtidal portion that can be difficult to map with optical sensors. Seagrasses are primarily sub-tidal and the clarity and condition of the water can greatly limit the ability to map these resources. Both shellfish beds and seagrasses have spectral signatures that can be confused with other features so field validation is required.

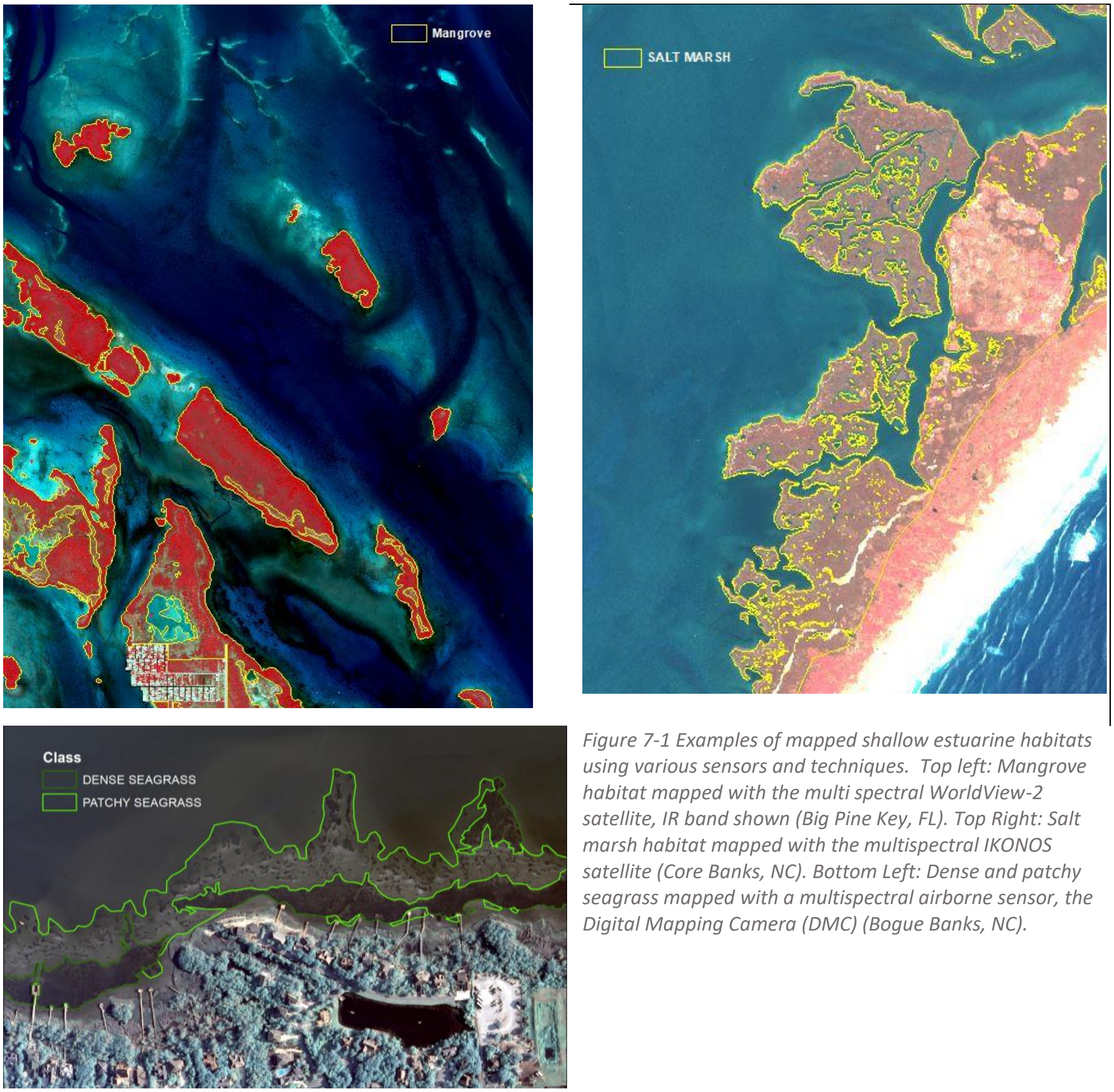

Figure 7-1 Examples of mapped shallow estuarine habitats using various sensors and techniques. Top left: Mangrove habitat mapped with the multi spectral WorldView-2 satellite, IR band shown (Big Pine Key, FL). Top Right: Salt marsh habitat mapped with the multispectral IKONOS satellite (Core Banks, NC). Bottom Left: Dense and patchy seagrass mapped with a multispectral airborne sensor, the Digital Mapping Camera (DMC) (Bogue Banks, NC).

LIDAR

Light Detection and Ranging (LIDAR) systems (most commonly mounted on aircraft) are remote sensing instruments that use light in the form of individual laser pulses to measure distance to the ground. LIDAR point clouds capture precise elevation measurements, often at high densities (multiple points per square meter). A reflected intensity value is also captured (usually at a single wavelength). This provides a detailed and highly precise vertical profile over and area that can be used to detect mangrove and salt marsh canopies. The reflectance may be useful for characterizing the target as well. Occasionally LIDAR can be collected using green wavelength light to assess submerged habitats such as seagrasses or other SAV. LIDAR typically penetrates the water column to a greater depth than passive imagery (up to 50 m deep) but is also vulnerable to water clarity and conditions. There have been limited applications of LIDAR to shellfish mapping, although the rugosity of shellfish beds may provide enough of a unique signature that it could be detected using LIDAR. One limitation of the technique is that LIDAR must be collected at low altitudes, therefore the swath width is narrow and several flight-lines may be needed to cover an area. This can drive up the time needed to acquire the data and hence drive up cost.

Swath acoustic sensing

Multibeam Echosounders (MBES) collect bathymetry data in a fan like swath beneath the vessel (mounted on vessels from small shallow draft boats to ocean going ships) and simultaneously capture the intensity of the returning echo as backscatter imagery that provides information on benthic texture and hardness. Side Scan sonars operate in a similar manner and produce similar products but propagate the sound in outward looking oblique pulses, however, they do not collect bathymetry data. Both systems can be used for a variety of shallow water mapping applications and can be mounted on small boats to map channels in shallow estuarine areas. With MBES the bathymetry data in conjunction with the backscatter can be processed to produce benthic habitat maps. Higher frequency sonars (> 200 kHz and up to 900 kHz) are most useful in shallow estuaries as they provide higher levels of detail, are capable of working in turbid water, and the typically shallow depths of these areas are within the sensing range of these systems. Spatial resolutions required are usually at the 1-meter level. Since these systems only function in subaqueous settings, they have no value for salt marshes or mangroves, but since shellfish beds and seagrasses have strong acoustic returns this technology is very useful for mapping those habitats. In waters that are deep enough, vessels can navigate back and forth patterns that overlap the swath of the sonar coverage creating a complete 3 dimensional coverage of the bottom. However, in shallow coastal environments, the sonar swath is often too narrow to allow for complete bottom coverage. In those cases, the lines of data can be interpolated to create a surface. Validation is required for this type of mapping as other features on the bottom can produce similar signatures.

Single-beam acoustic sensing

Single-beam sensors collect depth and bottom character information (through signal processing) as a series of points along a vessel track. If the transects are arranged in a tight pattern it is possible to confidently interpolate between lines and create something like a comprehensive map. Appropriate frequencies of these systems for estuary work are comparable to multi-beam and side-scan sensors and they can provide detailed bathymetry, as well as information on the presence of biota and the hardness of the bottom. They have proven utility in detecting shellfish beds and seagrass meadows. Depending on how the signal is processed, information about the vegetation canopy can be obtained as well. A limiting factor is the point nature of the data.

Data and information gaps

Simply knowing the distribution and extent of inshore habitats and how they change over time is one of the most crucial needs for coastal managers. Unfortunately, these data can be expensive and difficult to obtain. The environmental and technical challenges associated with mapping shallow estuarine habitats are at the root of the many data gaps that exist in this geography. Environmental and tidal windows limit the opportunities to collect data. Take for example seagrasses. They are extremely abundant benthic habitats in Florida and North Carolina. They have been mapped with aerial imagery for decades, first with hardcopy film cameras, now mostly with digital cameras. However the list of environmental variables that must be met for successful acquisitions is long. Cloud cover and associated cloud shadows obscures seagrass beds and must be kept to a minimum. Winds must be low; wind speeds above 10 mph cause whitecaps that impede visualization. Tides must be low as possible. For seagrasses that have seasonal variation in biomass, the time periods of highest biomass should be targeted. Sun angle to reduce glint in the images must also be considered. In some estuaries micro-algal (brown tide) blooms can preclude aerial surveys for weeks at a time.

Projects often require the use of multiple sensing technologies (optical and acoustic) to produce comprehensive maps as well as extensive field time to achieve desired accuracies. Unfortunately the expertise to apply the various mapping technologies usually resides among different organizations and companies. For example, an accurate oyster reef map of a typical estuary may require both aerial overflights at low tide and shallow acoustic surveys during high water. With many areas being inaccessible much of the time.

The complex geographies and shallow waters require closely spaced acoustic survey tracks along narrow navigation corridors. The net result is that mapping inter- and subtidal habitats is technically difficult and, as a result, an expensive endeavor. A common approach to addressing these mapping gaps is to establish a field monitoring program that provides information during periods between the difficult mapping efforts, although this too has logistical demands.

Long-term data and information gaps persist among the following habitats and in the following geographies:

- The deep-water edge of seagrass meadows in all systems
- Seagrass meadow distributions on time-frames of less than 5 years
- Subtidal shellfish beds in turbid estuaries
- Ecological condition “health” of seagrasses, shellfish beds, salt marshes, and mangroves
- Reliable status and trend information

Table 7-1. Management drivers and expected qualities for seafloor habitat maps in shallow estuarine systems. Abbreviations include: Coastal and Marine Ecological Classification Standard (CMECS), Hyper-Spectral Sensing (HSS), National Marine Sanctuary Program (NMSP), Multi-Beam Sonar Bathymetry (MB), Real-time Kinematic Global Positioning System (RTK GPS), Submerged Aquatic Vegetation (SAV), Single-Beam Sonar Bathymetry (SB), Satellite-Derived Bathy (SDB), Side Scan Sonar Backscatter (SS), Topo-Bathy LIDAR (TBL)

Level of activity/ decision/ regulatory decision	**Level of scale, detail, resolution, biological (Bio) / geological (Geo) level required**	**Preferred sensors used and standards for data collection**	**Appropriate attributes or classification scheme required**	**Type of validation used (visual, camera, other)**
Dredging for beach renourishment sand and maintenance of navigation channels	Geo: 1m res, temporal	MB, SB (for elevation); SDB	Sediment grain size	multi-sensor
Fisheries Habitat Management	Bio: submeter res (1ft), otherwise validation needed	SS, MB, SB, TBL, satellite and aerial imagery, chlorophyll, HSS, sediment profile imaging for benthic habitat mgmt; SDB	CMECS State/Academic classifications nest	visual, camera, grab samples; RTK GPS
	Geo: elevation is an indicator; temporal resolution is also important -- how often recollections are needed (cuts across)			
Aquaculture siting and permitting	Bio: submeter res (1ft), otherwise validation needed	SS, MB, TBL, satellite and aerial imagery, chlorophyll, HSS, sediment profile imaging for benthic habitat mgmt; SDB		
	Geo: elevation is an indicator; temporal resolution is also important -- how often recollections are needed (cuts across)			
Cultural Resource Managements: object identification* (*may need NMSP and state cult resource input*)	Geo: 1m resolution	magnetometer, SS, MB, subbottom profiles	May need classification based on protection status	

Level of activity/ decision/ regulatory decision	Level of scale, detail, resolution, biological (Bio) / geological (Geo) level required	Preferred sensors used and standards for data collection	Appropriate attributes or classification scheme required	Type of validation used (visual, camera, other)
Hazards Resilience Planning: community and ecosystem response	Geo: variable parcel 2m to sub 1m; rugosity, elev, SAV/grasses/mangrove density/height	SS, MB/SB, TBL, Satellite, aerial imagery, chlorophyll, HSS, sediment profile imaging for benthic hab mgmt; SDB magnetometer, sub-bottom profiles		
Risk/Vulnerability Assessment: natural and cultural sensitivity indices	Bio: 1m res; simple shoreline characterization (vulnerability, oppy for marsh to retreat)	Satellite and aerial imagery, TBL		
	Geo: 1m res; simple shoreline characterization (vulnerability, oppy for marsh to retreat)			
Navigation	Bio: submeter res (1ft), otherwise validation needed	SS, MB, TBL, SDB		
Coastal Infrastructure: docks, etc. Siting, permitting, and any mitigation necessary	Site specific, submeter, or best available; time element bec habs are dynamic	Satellite and aerial imagery, TBL		
Shoreline Management (shoreline hardening, beach renourishment,)	High res. elevation	Satellite and aerial imagery, TBL		RTK GPS
Inundation Modeling	High res. elevation	TBL		RTK GPS
Ocean Acidication: vulnerable habitat distributions (SAV, shellfish, etc.)		SS, MB, TBL, satellite and aerial imagery		
Restoration	Bio: submeter res (1ft), otherwise validation needed	SS, MB, TBL, satellite and aerial imagery, chlorophyll, HSS, sediment profile imaging for benthic hab mgmt; SDB		

7.2 Management drivers and Stakeholders

Customers and stakeholders range from local governments with small area applications to the Federal Government with a broad spectrum of needs such as data on channel depths and shoaling as it relates to navigation and seagrass and marsh monitoring as it relates to EFH (Table 7-1). Local governments need habitat maps for a variety of planning and development needs. State governments need to know the distribution and extent of resources such as saltmarsh, seagrass and mangrove for land conservation and fisheries management applications. Maps, and the image sources from which they are derived, are important tools for state and federal entities that review permits for everything from dock placement to channel dredging. Academic institutions need habitat and bathymetry data for everything for planning experimental study site locations to complex sea level rise modeling.

Management drivers calling for habitat information are mostly closely connected to coastal development and mitigation or restoration. In most cases, managers desire the best spatial resolution source data possible, preferably sub-meter resolved, to be able to detect small patches of habitat. This resolution is also desired by managers dealing with shoreline management, shellfish/aquaculture siting, mitigation and other drivers. Given the importance, sensitivity, and proximity to human activities, shallow estuarine habitats are relevant to many management policies and affected by several statutory jurisdictions. In recognition of the economic and ecosystem services these habitats provide many of the management drivers revolve around the need to conserve these habitats, restore habitats to former extents, compensate for losses to human impact, or encourage their long-term viability. In the case of shellfish where there is a direct economic value, management drivers exist to maintain a sustainable supply for harvest.

Most management implementation strategies involve permitting to regulate human activity affecting these habitats. For example Departments of Transportation (DOT) in all coastal states have to apply for permits to be reviewed by NOAA if their projects impact Essential Fish Habitat (EFH). Therefore they need accurate habitat maps to determine the distribution and extent of impacted habitats, and if mitigation is called for, they need habitat maps, and perhaps bathymetry or elevation data to locate potential mitigation sites. In recent years, declining stocks of commercial fin and shellfish have led to increased applications for aquaculture facilities, and again the permits require habitat information at the potential site.

In the following sections we will describe example habitat and specific management driver linkages.

Seagrass meadows

Seagrasses are considered wetlands and as such are protected from fill activities by section 404 of the federal Clean Water Act. Additionally, many state laws prohibit destruction of seagrass and actively encourage expansion of seagrass to help improve fisheries nursery habitat and maintain a healthy ecosystem.

Shellfish beds

Shellfish beds are managed for their role as important ecosystem constituents. State natural resource agencies often oversee this aspect. They also have food and economic value which is often handled by state departments of health. The goals of these efforts are primarily to maintain the resource for human consumption, although preserving their ecosystem services is also a goal.

Salt marshes

Like seagrasses, emergent salt marshes are protected from fill under the Clean Water Act. Management drivers for these areas are generally focused on preserving marshes for their intrinsic habitat value as well as their role in buffering storm surge and protecting coastal infrastructure.

Mangrove forests

As with the other shallow vegetation habitats, mangroves enjoy protection under the Clean Water Act. It should be noted that the CWA does not protect against altering water regimes that may negatively affect marshes and mangroves.

8 Nearshore sand shoals and sand resources

On the Southeast Atlantic Outer Continental Shelf (SE OCS), shoal features can be characterized as Holocene or Pleistocene-aged sedimentary deposits (ridges, banks, or bars) dominated by sand, gravel, or shell hash. They typically exhibit bathymetric relief, and are morphologically dynamic (Rutecki et al., 2015), and they can be isolated, or interconnected through shoal complexes or fields. Nearshore sand shoals and sand resources offshore of the Southeastern Atlantic coast of the United States are important from a variety of economic, cultural, and habitat-related reasons. For the purposes of the workshop, the resources discussed were geographically focused on the nearshore coastal ocean (e.g. targeted for mining to restore beaches), but also included unconsolidated sediments on the OCS. Thicknesses of surficial sand units vary significantly across the shelf, from a thin veneer offshore of northern South Carolina to meters in thickness moving south towards and off the coast of Georgia (Barnhardt, 2009). While prior study has found that shoreface-attached sand ridges on the inner continental shelf appear to function as important habitat for many fish species, and may have higher species abundance and richness than other areas of the inner continental shelf (Vasslides and Able, 2008), studies specific to the Southeastern Atlantic are rare and generally, more is known about invertebrate community assemblages than fish species. Historically, focus in the Southeast has been placed on mapping and sampling hard bottom locations as habitat, and the spatial extent of these areas is better understood (SEAMAP-SA, 2001).

Figure 8-1. Examples of nearshore sand shoals and sand resources. Clockwise from top left: Emergent sand shoals at Frying Pan Shoal, NC; submerged sand waves spanning approximately 2km; example of a container ship requiring deep shipping channgels to coastal ports; and sand deposition as part of a beach renourishment project.

When considering only geological origin and physical processes impacting the formation and subsequent changes in morphology, shoals fall into several broad categories: relict Holocene or Pleistocene sedimentary deposits, cape-associated shoals, and sorted bedforms (Rutecki et al., 2015). It is also important to understand that these features exist on a continuum of scale ranging from shoal fields to ripples. Discussion of mapping standards necessary to meet the needs of managers is therefore dependent on the nature of the study or scope of interest, in addition to the type of shoal under consideration. With this in mind, the level of scale and resolution associated with each activity involving sand shoals is identified as broad, geological framework or process study, versus detailed, site-specific needs that may also involve studying local wave and current patterns.

1. Relict Holocene or Pleistocene Deposit Shoals and Shoal Fields/Complexes: Also known as 'banks', isolated inner shelf shoals are generally associated with relict coastal sedimentary landforms and/or shoreline positions. Some isolated inner shelf shoals can also be formed by the re-working of barrier island complexes, eroded by ravinement following the end of the Last Glacial Maximum (LGM). Shoal fields, or complexes, are usually formed from proximally exposed deposits and consist of discrete sand bodies. Following with a BOEM literature synthesis (Rutecki et al., 2015), this discussion groups shoals that have been referred to in the past as 'shelf retreat massifs' into this category as well as relict cape associated shoals, depending on their morphology.
2. Cape-associated shoals: Active sedimentary systems that form from the convergence of two alongshore sediment transport pathways, cape-associated shoals extend from cuspate foreland promontories that are formed by two barrier islands or beach ridges joined at right

angles (Rutecki et al., 2015). Their morphology can be influenced by the underlying framework geology, and they can extend for kilometers following the same orientation as the present shoreline (Thieler and Ashton, 2011).

3. Sorted Bedforms: Along the Southeastern coast of the United States, sorted bedforms, a more generic term encompassing features originally termed 'rippled scour depressions' (Caccione et al., 1984) are shore-perpendicular seafloor features typically identified in the nearshore environment, and are known to occur in sediment-starved areas and active ravinement surfaces. Typically floored with coarse shell hash and/or quartz gravel, sorted bedforms are characterized by moderate (<1 m) relief and crests, or ripples, that are oriented shore parallel and transverse to the mean direction of water flow (Thieler et al., 2001; Coco et al., 2007). In the South Atlantic, sorted bedform features have been characterized offshore of Wrightsville Beach, NC (Thieler et al., 2001), Folly Beach, SC (Harris et al., 2005), and offshore of Dewees and Capers Islands, SC (Luciano, 2010). Owing to their compositional makeup of coarse shell hash and gravel, sorted bedforms can be identified in sidescan sonar data by their high acoustic reflectivity, bounded by areas of lower reflectivity sand or mud (Thieler et al., 2001). These shoal features are compositionally not an ideal source for beach renourishment sand, but they may provide important habitat for benthic marine organisms and fish species. They exist along a continuum of seafloor features that develop into sand ridges where sediment is more readily available (Thieler et al., 2014).

8.1 How is this habitat mapped? Why are there gaps?

Sand shoal habitat is ideally mapped with a suite of sensors (high-resolution bathymetry, magnetometer, backscatter, and seismic), with interpretations validated by vibracores, surficial sediment grabs, and visual (still and video). In many areas where these sand habitats occur, mapping is conducted on a project scale (i.e. for dredging related to navigation or renourishment). In certain areas, such as the nearshore off of Folly Beach, SC, or the navigation channel of Charleston Harbor, repeated surveys provide valuable interval data that can give insight into how sediment and sedimentary deposits move over time.

The level of scale and resolution required to best meet the needs of managers ranges from a broad, geological framework scale to detailed, sub- to 10's of meters resolution. With many uses of these data, there are also many scales of data that are acceptable, from the resolution provided by existing coastal relief elevation models (about 90 m x 90 m) to high-resolution multibeam echosounder and seismic surveys. In terms of standard protocols, the US ACE uses a 3ft x 3ft grid for dredging operations, which can be refined to 1ft x 1ft if needed. Challenges can exist for converting needs in English units to those collected in metric, and vice versa. Scales depend on horizontal and vertical resolutions, depending on map view (e.g. multibeam footprints) or profile view (e.g. subbottom profiling). In some cases, depending on the level of resolution needed, point measurements are extrapolated between spaced lines, such as with magnetometer or seismic data. For these users, relevant habitat mapping data are generally accessed online, via internal databases, or obtained from the source.

Data and information gaps

Sand shoals are themselves not always well defined, and can exhibit a wide range of variability in terms of their internal geology and surficial extent and expression, as well as the depths at which they form (McBride and Moslow, 1991). Efforts to assess the location and extent of shoals are often project-specific and their low vertical relief can make them difficult to map without high-resolution geophysical survey methods. Bathymetric data can be used to understand a shoal's origin or connection to other seafloor features, but seismic profiling and coring are necessary to better understand the stratigraphy and internal geology of these features. Additionally, gaps exist because of the project-scale focus of many of these projects, the large area of the SE OCS itself, a historic focus on hard bottom habitat for fisheries management, and the nearshore focus of many beach renourishment reconnaissance surveys.

Table 8-1. Management drivers (subsections highlighted in grey) and expected requirements for mapping sand shoals in the nearshore coastal ocean. Abbreviations include: Coastal and marine ecological classification standard (CMECS), Remotely operated vehicle (ROV).

Level of activity/ decision/regulatory decision	Level of scale, detail, resolution, biological / geological level required	Preferred sensors used and standards for data collection	Appropriate attributes or classification scheme required	Type of validation used (visual, camera, other)
Planning and siting of offshore infrastructure				
Planning for area suitability	Broad, geological framework scale	Large-scale sidescan or multibeam bathymetry coverage	Hard/rocky versus soft bottom	vibracore, bottom grabs, visual (still and video), SCUBA
Physical installation of structures (i.e. wind turbines)	Detailed, sub-meter to 10's of meters	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic		
Installing transmission cables or pipelines	Detailed, sub-meter to 10's of meters	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic		
Mapping and understanding ecologically sensitive areas				
Sanctuaries	Broad, geological framework scale	Large-scale sidescan or multibeam bathymetry coverage	Hard/rocky versus soft bottom	ROV, visual (still and drop camera), SCUBA, sidescan sonar
Fisheries Management				
Commercial	Broad, geological framework scale	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic, water column fish sonar	Hard/rocky versus soft bottom	visual (still and video), SCUBA, trapping
Recreational	Broad, geological framework scale	Large-scale sidescan or multibeam bathymetry coverage, water column fish sonar		

Level of activity/ decision/regulatory decision	Level of scale, detail, resolution, biological / geological level required	Preferred sensors used and standards for data collection	Appropriate attributes or classification scheme required	Type of validation used (visual, camera, other)
Fisheries Management (continued)				
Artificial Reefs	Detailed, sub-meter to 10's of meters	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic		
Classification of Essential Fish Habitat	Detailed, sub-meter	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic	Benthic habitats classified by geoform and biological cover, CMECS	ROV, visual (still and drop camera), sidescan sonar
Mapping and understanding culturally sensitive areas				
Historic (shipwrecks, ordinance, etc.)	Detailed, decimeter to photogrammetry	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic		visual (still and video), SCUBA
Pre-historic (paleolandscapes)	Broad, geological framework scale, to photogrammetry	Large-scale sidescan or multibeam bathymetry coverage	Hard/rocky versus soft bottom; presences/absence of paleochannels and paleoincisions	vibracore, bottom grabs, visual (still and video), SCUBA
Navigation and Shipping Areas				
Channels	sub-meter	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic	Hard/rocky versus soft bottom	vibracore, bottom grabs, visual (still and video), SCUBA
Anchorage	sub-meter	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic		
Specialty Areas (dredging areas, historical sites, etc.)	sub-meter	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic		

Level of activity/ decision/regulatory decision	Level of scale, detail, resolution, biological / geological level required	Preferred sensors used and standards for data collection	Appropriate attributes or classification scheme required	Type of validation used (visual, camera, other)
Dredging and renourishment needs				
Identification beach-quality sand sources	broad to detailed	Large-scale sidescan or multibeam bathymetry coverage	Beach-specific grain size classification standards	vibracore, bottom grabs, visual (still and video)
Removal for navigation	sub-meter	Suite of high-resolution bathy, magnetometer, backscatter, high-resolution seismic	US Army Corp of Engineers (USACE) classification standards	
Removal for renourishment	broad to detailed	Large-scale sidescan or multibeam bathymetry coverage	Beach-specific grain size classification standards	
Hazards mitigation and response	broad to detailed	Large-scale sidescan or multibeam bathymetry coverage		
Proper survey design based on scale	broad to detailed	Large-scale sidescan or multibeam bathymetry coverage	Hard/rocky versus soft bottom; presence/absence of surficial sand	

8.2 Management drivers and Stakeholders

The management of nearshore sand shoals can be broadly categorized as focusing on either mapping and understanding the distribution of surficial sediments for ecological and cultural considerations (fisheries management, Paleoamerican sites), or planning and siting for uses such as infrastructure, navigation and shipping, and beach renourishment. For this exercise, these two categories were further refined into the following six (Table 8-1) to better describe requirements relevant for each driver: 1) planning and siting of offshore infrastructure, 2) mapping and understanding ecologically sensitive area, 3) fisheries management, 4) mapping and understanding culturally sensitive area, 5) navigation and shipping, and 6) dredging and renourishment needs. These drivers, technical considerations, and best practices are described in more detail below.

Customers and stakeholders requiring habitat maps to understand and manage nearshore sand shoals and sand resources are diverse (Table 8-1). They include fisheries management councils such as the NOAA National Marine Fisheries Service, archaeologists and preservationists, coastal communities that rely on offshore sand resources for beach renourishment materials, and federal agencies including United States Army Corps of Engineers (US ACE) as well as the Bureau of Ocean Energy Management (BOEM), whose Marine Minerals Program (MMP) is charged with the leasing and management of sand and gravel mineral resources on the OCS outside of state waters. Understanding the offshore distribution of potential beach-compatible renourishment sands also impacts onshore coastal resiliency managers. Stakeholders are further explored below as they relate to each management driver.

Driver 1: Planning and siting of offshore infrastructure

As interest in developing offshore renewable energy has grown, BOEM has worked in collaboration with state-level cooperators in the SE to better understand where suitable areas are located in order to establish Call Areas for further consideration. While a number of conflicting use issues restrict where renewable energy projects can be physically located, offshore shoals can function as an ideal location due to favorable bathymetric conditions (Rutecki et al., 2015). Planning for potential offshore renewable wind energy facilities on the SE OCS has necessitated an understanding of both broad-scale and detailed seafloor habitat distributions and surficial geologic features. Installing large structures and transmission cables in the marine environment, at depth, requires high-resolution, sub-meter to 10's of meters suite of multibeam echosounder, backscatter, magnetometer, and seismic data; while a more general planning effort might be accomplished with either sidescan sonar or multibeam coverage on a broad geological framework scale. Requirements and guidelines are provided by BOEM that instruct wind energy developers to define and delineate shipwrecks and essential fish habitat and exclude those areas from construction (Survey Guidelines for Renewable Energy Development - https://www.boem.gov/survey-guidelines).

Driver 2: Mapping and understanding ecologically sensitive areas

Within the SE Atlantic OCS, Gray's Reef National Marine Sanctuary (NMS), which supports nearly 200 fish species as well as the endangered Loggerhead sea turtle and North Atlantic right whale, is the only offshore marine area with specific protections. The 56 km^2 sanctuary, situated in depths ranging from 18 to 22 m, is primarily composed of unconsolidated sand sediments (75%) interspersed with patchy live bottom and hard bottom ledges. Unconsolidated sediments on the shelf, like those found within Gray's reef, are significant to a variety of species at different life stages. The interconnectedness between these unconsolidated sand sediments and other habitats (i.e. rocky offshore) is believed to be important for fish species as many reef associated species migrate out over sediment to feed, usually at night (Walsh et al., 2006).

Effectively mapping these areas requires both a broad, geological framework-scale approach as well as similar parameters as those applied to classifying Essential Fish Habitat (EFH): obtaining submeter resolution using sidescan, multibeam or single beam sonar supplemented by water column fish sonar, drop cameras, and trapping or ROVs.

Driver 3: Fisheries Management

Offshore sand resources play an important role in fisheries habitat and management, with ridge and swale and cape-associated shoal complexes identified by NOAA Fisheries as Essential Fish Habitat (EFH) for federally-managed species, or Habitat Areas of Particular Concern (HAPCs), which a region considers to have special characteristics or value important for maintaining sustainable fisheries. Cape Lookout, Cape Fear, and Cape Hatteras (NC) as well as the Charleston Bump, SC, are all considered HAPCs for the coastal migratory pelagic species group, which includes dolphin, wahoo, and the snapper-grouper complex because of their structure, which allows for interaction with the Gulf Stream to produce local upwelling. Diverse fish species use shoals and shoal complexes, which may function as important habitat during certain life stages. They are considered ecotones, or habitat transition zones, and use may vary across the same shoal or shoal complex (Rutecki et al., 2015). In the SE US, fisheries managers have historically focused mapping and research efforts on understanding the offshore distribution of hard bottom reef habitats, since these areas represent EFH for a variety of economically and recreationally important species (SEAMAP-SA, 2001). Through the use of sidescan sonar data, video, and diver observations in addition to traps and bottom fish trawls, areas were mapped on one-minute grid cells.

Within fisheries management, there are multiple areas of focus for different stakeholders: commercial and recreational fisheries management (broad, geological framework scale), mapping of artificial reefs (detailed, sub-meter to 10's of meters), and information needed for the classification of EFH (detailed, sub-meter). For commercial and recreational fisheries management, large-scale coastal relief elevation models and NOAA Coast Survey nautical charts provide information about the spatial locations and distributions of sand shoal resources. Mapping artificial reef habitats can be accomplished using high-frequency sidescan sonar verified through diver observations. For EFH classification requirements, submeter resolution using sidescan, multibeam or single beam sonar supplemented by water column fish sonar, drop cameras, and trapping or ROVs is desirable. The continued use of trawls is also being combined with other sampling methods to provide direct observations of habitat utilization, such as ROV surveys or trap-mounted cameras.

Driver 4: Mapping and understanding culturally sensitive areas

The submerged continental margin of the SE US retains surficial evidence of the paleolandscapes that have evolved in step with human habitation on the North American continent. Along the current shelf edge, conditions would have provided vantage points and estuarine resources for a period of nearly 6,000 years following the close of the Last Glacial Maximum ~18,000 ybp. Archaeological sites offshore are often located on former high ground (a few meters above sea level at the time of formation), associated with narrow interfluves between estuaries (Harris et al., 2013). On the inner shelf, sand resources can be associated with the many paleoincisions that cut into pre-Quaternary rock and marl (Harris et al., 2005). Further out on the shelf edge between the 50m ledges and the 60m isobath, the Geneva Delta, a ~40 km^2 lobate feature formed at or near sea level during MIS-3, contains an estimated

1.2 km^2 of sediment and is comprised of composite MIS-3 deposits possibly overlying 5d and 5b lowstand deposits. The mapping and delineation required to investigate this and other possible archaeological sites requires high-resolution bathymetric and subsurface surveys (Harris et al., 2013). Historic shipwrecks and ordnance offshore are another aspect of cultural resource mapping that should be taken into consideration. Multibeam bathymetry surveys in combination with magnetometer, sidescan sonar mosaics, high-resolution seismic data, with differential and real-time kinematic GPS and ground-truthing are necessary in order to appropriately map areas of interest. The level of resolution required varies depending on the objective of the project. Multibeam or sidescan sonar can be used at courser resolutions for mapping broad, geographic-scale paleolandscapes and detecting seafloor objects such as historical shipwrecks or ordnance. Higher resolution mapping of these areas can then be accomplished on a scale that is more detailed, with decimeter to photogrammetry scale for specific archaeological sites, shipwrecks, or ordnance through the use of ROVs or laser scanning.

Driver 5: Navigation and shipping areas

Nearshore areas, particularly around larger ports such as Savannah or Charleston, require frequent monitoring and dredging for navigation and shipping channels, as well as anchorages. Nautical charts created by the NOAA Office of Coast Survey are necessary for safe navigation and require seafloor mapping data related to the location of shoals in order to upgrade charts. With the US Army Corps of Engineers and NOAA Coast Survey as the primary managers for navigation and shipping areas, habitat mapping requirements should seek to meet or exceed US ACE mapping standards of 3ft x 3ft grids (either single beam or multibeam) for dredging, with the capacity to increase resolution to 1ft x 1ft, as well as full bottom multibeam coverage with 20% overlap, which is a requirement for Coast Survey nautical charts. Specifications for these mapping operations are based in part on the International Hydrographic Organization's Standards for Hydrographic Surveys for Order 1a surveys, which are intended for harbors, harbor approach channels, recommended tracks, inland navigation channels, and coastal areas of high commercial traffic density, typically in shallow areas less than 100 m depth (NOAA NOS, 2018). Repeatability of surveys is also key for this particular management driver; since surficial sand deposits can move, understanding where they are in terms for dredging or navigation purposes is significant.

Driver 6: Dredging and renourishment needs

Planning for offshore dredging related to renourishment necessitates an understanding not only of the surficial distribution of sediment resources, but also the shallow stratigraphy, thickness, and associated volume of potentially compatible bodies of sand. Using a combination of single or multibeam bathymetry, sidescan sonar, and chirp subbottom profiler is ideal. Ground-truthing interpretations through vibracores and surficial sediment grabs is also necessary. For dredging, pre-and post-dredge rasters with 5 m resolution are useful for understanding changes to sand resources. The level of detail required for surveys varies depending on the immediate need for the resource and the level of confidence in the presence or absence of sand at a particular location. For example, in 2014, the Bureau of Ocean Energy Management (BOEM) contracted with CB&I to conduct a large-scale geophysical survey aimed at inventorying potential beach renourishment and coastal restoration sand sources on the Atlantic OCS, between 3 and 8 nautical miles offshore. Seventy-five percent of the survey was conducted at a reconnaissance level, aimed at broader-scale resource determination, versus the twenty-five percent of the survey that was design-level.

In North Carolina, South Carolina, and Georgia, where reconnaissance-level data were collected, spacing between tracklines varied from ~0.5 to 5 km. In this instance, the absence of data in many areas of the OCS makes reconnaissance-level resolution valuable for targeting areas for future study. In regions offshore of the Mid-Atlantic and New England, where OCS sand resources are used more often for renourishment needs, design-level surveys with closer trackline spacing and additional ground-truthing through vibracores and surficial sediment grabs were needed for improved accuracy and finer detail. Regardless of the trackline spacing, a best practice for geophysical survey design is to include lines that are oriented the opposite direction ("tie" lines) in the survey so that the orientation and morphology of 3-dimensional features including shoals and paleochannels are better mapped and understood. Temporal resolution between surveys is also important for understanding how surficial sediment deposits move over time, and how borrow sites recover after use. Sand removal operations related to dredging and renourishment pose potential long and short-term physical and biological impacts, including but not limited to: alteration of physical shoal characteristics (sediment grain size, bedforms, and overall shoal dimensions), elevated turbidity, and the alteration of benthic infauna (Crowe et al., 2016; Rutecki et al., 2015; Drucker et al., 2004). High-resolution mapping supplemented by ground-truthing can be used to understand these impacts.

9 Offshore rocky reef, deep coral

Scattered among the abundant beds of sand and unconsolidated sediments, emergent bedrock and deep coral reefs on the SE US outer continental shelf support fisheries, recreational diving and related ecosystem services. Shipwrecks and purpose-sunk artificial reefs also contribute to structured habitats on the seafloor of the outer shelf in the region. The form and arrangement of hard rocky or artificial habitats on the shelf are linked to the dynamics of geological processes: rising and falling sea levels and shifting sands on the shelf that expose bedrock. For the purposes of this workshop, we defined the geographic and depth boundaries for offshore rocky reef and deep coral habitats (as well as shipwrecks and artificial reefs) from 15 meters to the maximum depth of the EEZ, from Cape Hatteras to south Florida. The rocky reefs, deep corals and shipwrecks are found across the depths of the shelf with various geological formations, extents and changes in vertical relief. Simplified, emergent rock can be as flat as pavement with little to no noticeable change in elevation, to rubble and boulders surrounded by sand, and as high relief linear ledges and ridges greater than 10 meters high. On the rock surface, benthic organisms such as sponges, corals, tunicates and algae can attach creating biological structure as habitat and shelter as well as food for small fishes. Deep corals on the outer continental and shelf slope are biogenic communities accreting over thousands of years. Additional deep water habitats are associated with submerged canyons and seafloor vent communities.

9.1 How is this habitat mapped? Why are there gaps?

Due in part to the large area of the SE outer continental shelf (over 100,000 square nautical miles), over 80% of the continental shelf remains unsurveyed using modern hydrographic methods to provide relatively high resolution (<20 x 20 m) elevation surfaces. Given the depths and generally poor water clarity in the coastal ocean in the region, hydrographic echosounders or sonars are the only means to provide information on the elevation and topography/complexity of the seafloor. Reflectivity from sidescan sonars can provide indicators of seafloor hardness or roughness or shadows caused by changes in elevation attributed to emergent rocks. Multibeam echosounders or swath sonar provide high resolution elevation.

9.2 Management drivers and Stakeholders

Customers and stakeholders using habitat maps including rocky reefs, deep corals and include fisheries management councils for designating managed areas, essential fish habitat legislated by the Magnuson-Stevens Fisheries Act. Other regulatory agencies include states fisheries and coastal zone managers in state water jurisdictions. The Bureau of Ocean Energy Management (BOEM) are charged with leasing and managing the use of the seafloor on the outer continental shelf, required by the National Environmental Protection Act to minimize where possible negative impacts to seafloor habitats and biota. The US Army Corps of Engineers regulates and manages the maintenance of coastal waterways including dredging activities that also support offshore sand mining for beach and shoreline restoration. Research groups also use habitat maps for studying the ecological function of benthic organisms, and use of habitat by fishery species.

Management drivers that are concerned with offshore rocky reefs can be categorized into two broad categories: 1) resource assessments and management and 2) offshore uses of the seafloor such as oil and gas extraction and renewable energy. Table 9-1 lists categories of management activities that include reef and shipwreck areas. Both of these management areas use different levels of spatial extent and detail to make decisions that could be categorized as “planning” and “siting”. The planning level requires information at relatively coarse resolution – 10s of meters to kilometers – to identify broad areas for activities that target structured habitats or attempt to exclude reef or shipwreck areas to minimize impacts from other ocean activities and uses. Siting requires information at much finer level of detail – meters to 10s of meters. Siting involves direct observations of the habitat and organisms that use it or bottom disrupting activities such as mining, dredging that may directly impact the rock reef habitats. Each of these levels of detail call for different data resolution and detail from sensors and techniques for interpreting the remotely sensed seafloor imagery.

Table 9-1. Management drivers and requirements for rocky reef, deep coral and deep vent communities, and shipwrecks/artificial reefs. Sensors and classification attributes matched to drivers and requirements by numbered categories. Abbreviations include: Remotely operated vehicle (ROV)

Level of activity/ decision/ regulatory decision	**Level of scale, detail, resolution, biological / geological level required**	**Preferred sensors used and standards for data collection**	**Appropriate attributes or classification scheme required**	**Type of validation used (visual, camera, other)**
Fisheries Management				
1. Identify/manage spawning aggregations 2. Assessment survey design 3. Habitat-based models of fish abundance	1. Elevation relief models, geomorphology/ manual feature identification 2. Predictive model of rocky reefs 3. High-resolution 2-4m elevation, backscatter, interpreted habitat types, Fish distribution/density	1. Coastal relief elevation models 2. Historical multibeam or sidescan sonar 3. High-resolution IHO multibeam surveys	1. Large geoform identification 2. Hard/rocky vs. soft / sediment 3. Benthic habitats classified by geoform and biological cover	1. Multibeam or sidescan 2. ROV, drop camera, subbottom 3. Drop camera, Trap/video surveys
Offshore energy infrastructure				
1. Planning for area suitability 2. Siting infrastructure and establishing buffers from sensitive seafloor habitats	1. Large scale, rocky outcrop or target identification 2. Delineated essential fish habitat or confirmed targets/shipwrecks	1. Mid-frequency sidescan sonar or multibeam sonar 2. Multibeam echosounder with backscatter/ reflectivity	1. Detected targets, rock outcrops or ledges, geoform features	1. Drop camera, Trap/video surveys, scuba
Research and conservation of sensitive deep sea habitats and shipwrecks				
1. Exploration for features or shipwreck targets 2. Defining areas for characterization and conservation	1. Large scale, rocky outcrop or target identification 2. Highest- resolution bathymetry, Delineated essential fish habitat or confirmed targets/shipwrecks	1. Mid-frequency sidescan sonar or multibeam sonar 2. Multibeam echosounder with backscatter/ reflectivity	1. Presence/absence of coral suitability or shipwreck targets 2. Fully delineated highest resolution delineation of coral mounds or vents, defined shape and structure of shipwrecks	2. Drop camera, Trap/video surveys, scuba

Driver 1. Fisheries assessments

Federally managed species in the snapper grouper complex use structured seafloor features like rocky reefs as essential fish habitat. To monitor trends in the status of fish stocks, the National Marine Fisheries Service and partners conduct a stratified sampling survey using underwater video and traps set at rocky reefs. There are two scales where knowledge of habitats could inform reef fish assessments and management. Statistical estimates of population trends rely upon stratification of the survey, which is improved with better maps of the relative distribution of rocky reef habitats on the continental shelf. Relative coverage of rocky reefs may vary by latitude. Large scale digital elevation models (DEMs) such as the U.S. Coastal Relief Model Vol.2 (NGDC 1999) 90 meter resolution can be analyzed for roughness and slope and provide an indication or likelihood of rocky reef distribution and identify possible gradients over depth and latitude (Dunn and Halpin 2009). These coarse elevation models will likely miss low relief features or ledges and outcrops that are less than 90 meters in size and would not allow for finer level classification of habitat types.

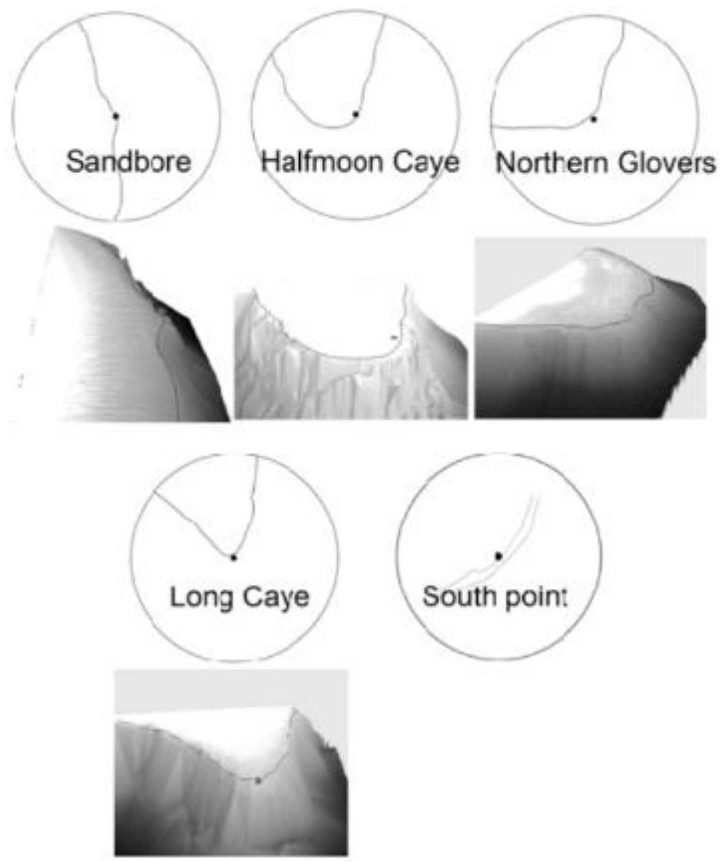

Figure 9-1. Location of spawning aggregations in the Caribbean Sea in the vicinity of shelf edge promontories shown as 3D models from coarse digital elevation models of the ocean (gray shaded for depth, from Kobara 2009).

Some members of the snapper-grouper fishery management complex aggregate during discrete times of the year to spawn. Several studies have documented spawning aggregation sites related to large scale geomorphological features such as promontories, or points of relief that jut outward from the continental shelf (Kobara et al. 2013; Farmer et al. 2017). The features can be kilometers in size and readily visible using relatively coarse coastal digital elevation models (Figure 9-1).

At a finer resolution, interpretation of seafloor habitat types can be made from remotely sensed data from multibeam hydrographic surveys. Fishery assessments utilize detailed maps of the precise location and type of rocky reef and surrounding unconsolidated sediments to select sampling locations for traps and cameras for enumerating species. Here, differentiating “soft sediments” from “hard rocky reefs” is the most useful intelligence to place sampling gear to assess managed fishery species in the snapper-grouper complex. Rock features can be delineated manually by visual inspecdtion of the elevation surface from multibeam seafloor surveys (Figure 9-2). To achieve higher level of habitat interpretation, hydrographic multibeam surveys are used to ensonify 100% of the seafloor in an area and produce elevation surfaces at resolutions of 1 to 8 meters depending on the type of multibeam used, the frequency of the multibeam sonar, and the depth of the seafloor (Table 9-2).

Rocky reef habitats are exemplified by varying levels of relief and complexity of the elevation surface. Measures of rugosity, variance of depth and slope provide indications of complexity and rapid changes in elevation such as emergent rocks or ledges. As presented above by L. Kracker and colleagues (reproduced from Costa et al. 2018, measures of complexity can be indicators of habitat types including geoform and biological cover. Rocky reefs can also be very low relief pavement, with very little change in elevation. In this case, measures of the reflectivity or "backscatter" can provide an indication of the hardness of the seafloor where pavement is harder with higher reflectivity, whereas soft sediments will have lower reflectivity (Figure 9-2). Many multibeam systems automatically collect backscatter data along with elevation. Expertise in conducting hydrographic multibeam surveys can ensure the highest quality of backscatter that reduces noise and artifacts. Even small artifacts in multibeam elevation surfaces due to motion of the survey vessel can cause significant difficulties accurately interpreting the seafloor, especially in low relief (<1m elevation change) areas.

Table 9-2. Expected cell resolution for multibeam surveys taking into account water depth and frequency that determines footprint of each beam and transmission rates

Water Depth (meters)	Expected Resolution (m x m cell size)
100	1
300	3
500	4
1000	9
2000	17
3000	26
4000	35

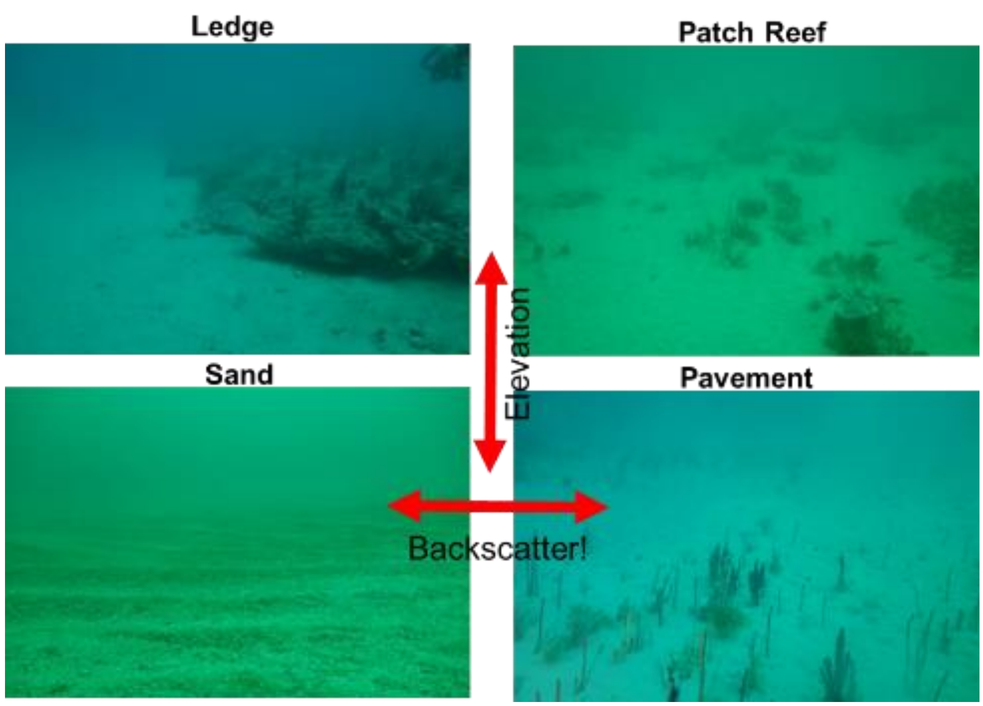

Figure 9-2. Example of outer shelf seafloor habitats and remote sensing parameters used to interpret imagery to habitats.

It is likely that reef fish species have a preference for rocky reef habitat types and possibly other factors like benthic biological cover such as algae, soft corals or sponges. Understanding the association and abundance of managed species with specific habitat types is critical for using assessment surveys to scale up counts and densities at selected stations to estimates of abundance for the species over a region. In coral reef ecosystems, there has been positive correlations between complexity and relief and measures of diversity and abundance (Pittman et al. 2011). Patterns of biomass and diversity over temperate rocky reefs is less defined (Paxton et al. 2018). To better constrain the relationship and our understanding between fish community metrics or biomass and habitat characteristics, the highest resolution multibeam surveys that provide elevation and backscatter intensity are required. Classifying remote sensed imagery to habitat types involves techniques from manual delineation of similar imagery types or statistical analysis and grouping of similarly complex seafloor types. Interpreting those seafloor classes to habitat types require ground validation usually in the form of direct visual observations by drop camera, remotely operated vehicle or diver observations. A presentation by L. Kracker earlier in this report summarizes two objective approaches for classifying and interpreting seafloor habitats like rocky reefs from hydrographic multibeam surveys resulting in a few to many seafloor geoform and habitat classes.

Driver 2: Planning and siting offshore energy infrastructure

Increased interest in developing renewable wind energy systems in the offshore environment has required information on the distribution of reefs, shipwrecks and other regulated essential fish habitat to minimize impacts to these natural resources. In the SE US, the Bureau of Ocean Energy Management has worked with the states to determine areas suitable for establishing renewable energy infrastructure in federal waters adjacent to state waters. Determining the location of sensitive and managed seafloor habitats are an important component to the planning. The planning areas can include several hundred square miles of seafloor. By example, BOEM worked with NOAA to assess the presence of rocky reefs and shipwrecks in a wind energy planning area near Cape Fear, North Carolina. Covering the 420 square kilometer area with 100% ensonification using multibeam would be cost prohibitive. Instead, NOAA proposed to conduct the survey with sidescan sonar, with line spacing 300m apart, cutting the effort and cost by a third (Taylor et al. 2015). A sidescan mosaic was created using the original 1 meter resolved imagery. Indications of rocky ledges and artificial targets were identified but the features and targets required further validation. Many features were in relatively close proximity in clusters and were then reexamined using >100% coverage high-resolution multibeam and validated with scuba divers and drop cameras. The new map of sensitive rocky reef habitat was used to refine wind energy planning area off Cape Fear, NC that excluded a large part of the original planning area that contained rocky reefs. Requirements and guidelines are provided by BOEM that instruct wind energy developers to define and delineate shipwrecks and essential fish habitat and exclude those areas from construction activities (Survey Guidelines for Renewable Energy Development: https://www.boem.gov/survey-guidelines/).

Driver 3: Ecologically and culturally sensitive areas on the seafloor

Deep coral, canyon and seafloor vent habitats provide important ecological foundation communities on the continental shelf slope. Due in part to the great depths of these communities, many remain undiscovered and poorly understood. Underwater optical methods provide the most valuable means to characterize and survey deep sea habitats. But ROVs and scuba divers are expensive to deploy, so require the best intelligence to guide cost-efficient surveys. Locating collections of these communities can be aided by large scale, relatively coarse digital elevation models of the seafloor, providing predictions or suitability of an area based on oceanography and geomorphology of the outer continental shelf and slope. High suitability can suggest locations for further exploration, typically accomplished with ship-based multibeam systems that can define high-relief areas likely representing the mounds and gardens of corals or vent communities.

Historically significant shipwrecks scatter the seafloor on the continental shelf and serve as habitats for fishery important species and time-capsules for the rich maritime and war history that has occurred off the SE coastal ocean. Locating these seafloor features is challenged by great depths and vast expanse of the continental shelf. Research into the history and ecological function of these areas requires accurate positioning to target detailed observations by underwater video systems on remotely operated or autonomous underwater vehicles or even scuba divers. Large scale multibeam or sidescan sonar can be used to detect objects on the seafloor at resolutions of about 10 meters. Once objects are detected, surface multibeam systems may not provide sufficient resolution to create useful models for shape and positive identification. Multibeam systems on autonomous underwater vehicles (AUVs) brings high-frequency multibeams with limited range closer to the seafloor for much higher resolution digital models than would be possible using ship-based multibeam echosounders. Ideally, photogrammetry mosaics or structure from motion models can be collected using ROVs or scuba divers. Laser line scanning systems provide additional means to produce sub-meter resolution models of the shipwreck to understand condition and uncover further mysteries on the reason for sinking.

10 Conclusion

SEABED 2030 established international goals to map the entirety of the ocean seafloor within the next decade. As of publication of this report, less than 15% of the southeast US Atlantic outer continental shelf has been mapped. The Southeast and Caribbean Regional Team (SECART) along with the National Centers for Coastal Ocean Science and Office for Coastal Management hosted two workshops to improve coordination among agencies in mapping seafloor habitats in the southeastern US coast and outer continental shelf. Spanning from North Carolina to Florida, over 40 participants for each workshop represented a broad swath of government agencies, academic institutions and non-governmental organizations.

The two workshops achieved the goals of bringing representatives from various government agencies and academic organizations together to contribute to a regional approach to seafloor habitat mapping in the southeast US region. In-person workshops such as these encourage open lines of communication that can facilitate data discovery, improved data sharing and ensure efficiency and economic savings in data collection for resource management. Sharing of information through these gatherings results in a better understanding of where habitats have been mapped, and where mapping needs to occur to achieve ecosystem management and conservation goals.

One of the most valuable outcomes from the workshops was the discovery of data available in government agencies archives that may not have been broadly accessible to potential users. The workshops also encouraged dialogue with agencies whose charge is mapping the seafloor, but may not require classification to habitat types. Participation by members of the US Department of Defense from the Navy and Army Corp of Engineers was particularly valuable. DoD participants gained a better appreciation for the types of and requirements of seafloor maps that could be used to classify habitats. The resolution and extent of these base maps may not be at the level that would be considered national security concern. After clarifying data needs for habitat mapping, a very large area of coverage was released off Florida that had been mapped for national defense strategic interests. The data provided to NOAA was in a high priority area and saved NOAA and the US Government over $1mill in future costs.

Defining priorities for where new habitat mapping data should be acquired is challenging considering the extremely large geographic extent of the southeast continental shelf and the number of management, resource use and research interests in the region. Participatory mapping tools have shown promise in improving understanding of resource mapping needs across management drivers. In the second workshop, participants learned about a new tool developed by NCCOS that will be evaluated in the southeast region. The seafloor mapping prioritization tool includes a comprehensive inventory of seafloor mapping data that already exists in archives or available through data sharing between organizations. Developing a robust inventory could take significant time, but is critical to understand where data exists to avoid unnecessary duplication and waste of resources. Lessons learned from previous seafloor mapping prioritization exercises found that restricting the amount of area that any one participating agency could select forces a strategic assignment of priorities, data needs and timelines. Transparent participatory mapping also shows intersections of common interests.

The final goal of the first two workshops was to help connect management drivers and requirements for habitat maps with the state of the science in mapping methods. Everyone wants the sub-meter resolved map of the entire domain, classified to fine geoforms and detailed taxonomy, but limited resources generally prohibit collection of these data. Careful review of management and decision-making or regulatory requirements helped elucidate the expectations for mapping products so the appropriate sensor, resolution and extent is used. Clearly stating the management question can help the practitioner best understand the expectation of the decision-maker and define the best practice and state of the art technology to achieve the goals. Sometimes, coming to this common understanding can only happen with in-person workshops like the ones described here.

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12 Appendices

Workshop materials are added as appendices in a companion document available alongside this report and include:

Terms and Agendas for 2016 and 2018 workshops

Participant Lists from 2016 and 2018 workshops

Presentation from 2018 workshop