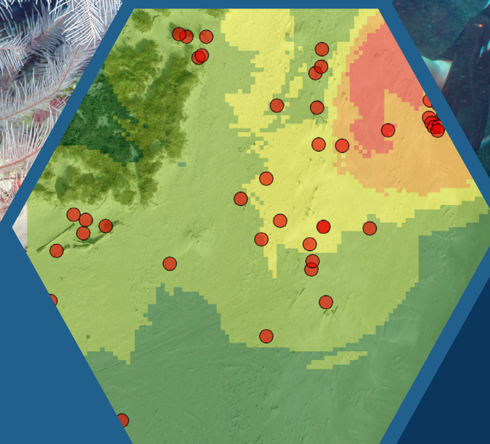

# Habitat Mapping Team
# **Strategic Plan 2021–2026**


March **2023**

NOS | NCCOS | MSE | Biogeography Branch

## Websites

**Habitat Mapping Team**
https://coastalscience.noaa.gov/science-areas/habitat-mapping-and-characterization/

**National Centers for Coastal Ocean Science (NCCOS)**
https://coastalscience.noaa.gov/

## Image and photography credits

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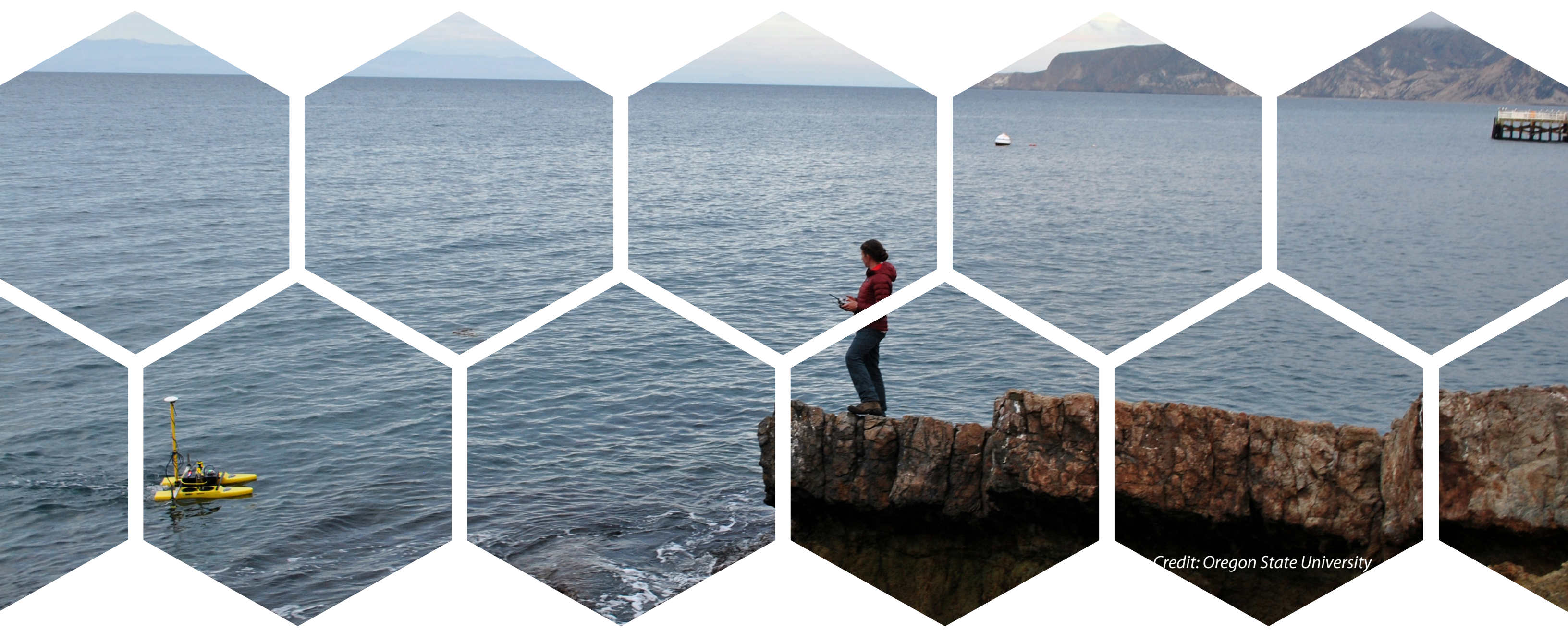
## Disclaimer

# Message from the Team Lead

This document describes ambitious  goals, investments, and practices the Habitat Mapping Team (HMT) intends to embrace over the next five years in order to affect and position us for the future. Our success towards meeting the mission of NOAA and our partners is predicated on our ability to remain agile in the rapidly evolving coastal intelligence community. Technological capabilities and coastal resource management issues continue to develop at increasingly shorter temporal scales therefore HMT must adopt strategic approaches to forecast, influence, and adapt to changing conditions so as to continue as effective leaders and geospatial pioneers of innovative applied science. HMT has self-identified to provide the role of serving the inter-niche (see introduction). In order to do so effectively, HMT must frequently evaluate its focal areas, workforce, competencies, partnerships, and commitments to continue to adapt itself so as to remain poised to best anticipate, lead and fulfill the coastal management challenges of the present and future.

# Contents





*Credit: Oregon State University*

# INTRODUCTION

Credit: Oregon State University

Coastal resource managers and many coastal and offshore industries like energy and shipping need high-quality and reliable map products to make smart management and business decisions. Understanding coastal, pelagic, and benthic habitats can allow industry, regulators, and special interest groups to come together to make more comprehensive planning decisions regarding, for example, the siting of offshore energy facilities, or navigation routes for ships that are safer for whales and beneficial to coastal tourism.

Federal agencies need NCCOS's habitat mapping products for management of living marine resources, monitoring and assessing conditions from the shore to the seabed over the short and long term, and assessing the effectiveness of federal or state management actions. NCCOS's efforts to map coastal, pelagic, and benthic habitats also support technology development, as we work with private industry and academia to push the boundaries of time-sensitive, efficient and integrated data collection and visualization.

## HMT Snapshot

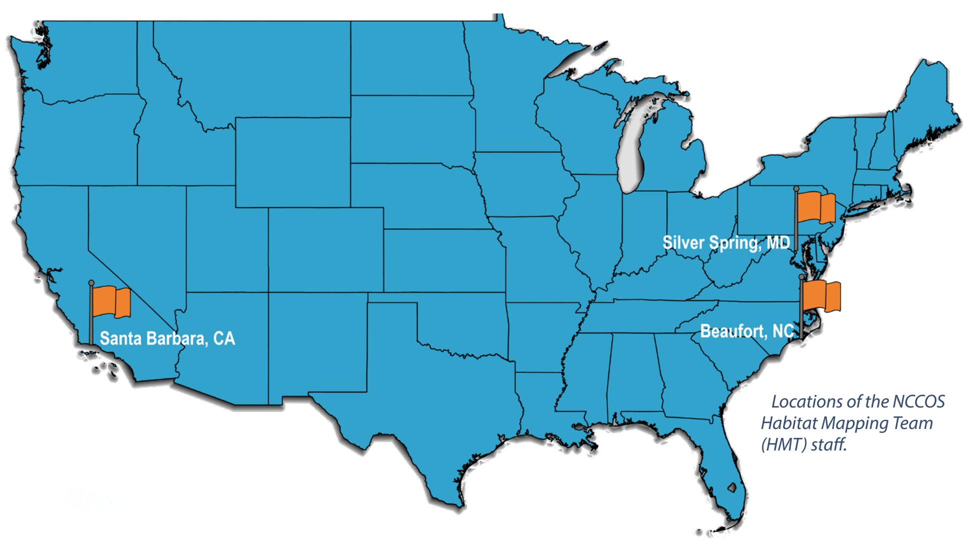
### Who We Are

The NCCOS Habitat Mapping Team (HMT) provides cutting-edge, high-quality, and reliable science-based habitat mapping products so their customers and partners can make smart management and business decisions to address evolving economic, environmental, and social pressures on our ocean and coasts. Our approach uses diverse and state-of-the-art technologies to map and characterize the seascape from the intertidal zone to the U.S. Exclusive Economic Zone (EEZ). This includes uncrewed aerial, surface, and underwater vehicles; ships; aircraft; remotely operated vehicles; and satellites; and a range of sensors associated with each. We innovate, develop, and produce interactive data models visualizations for managers to make informed decisions and to identify critical information gaps.

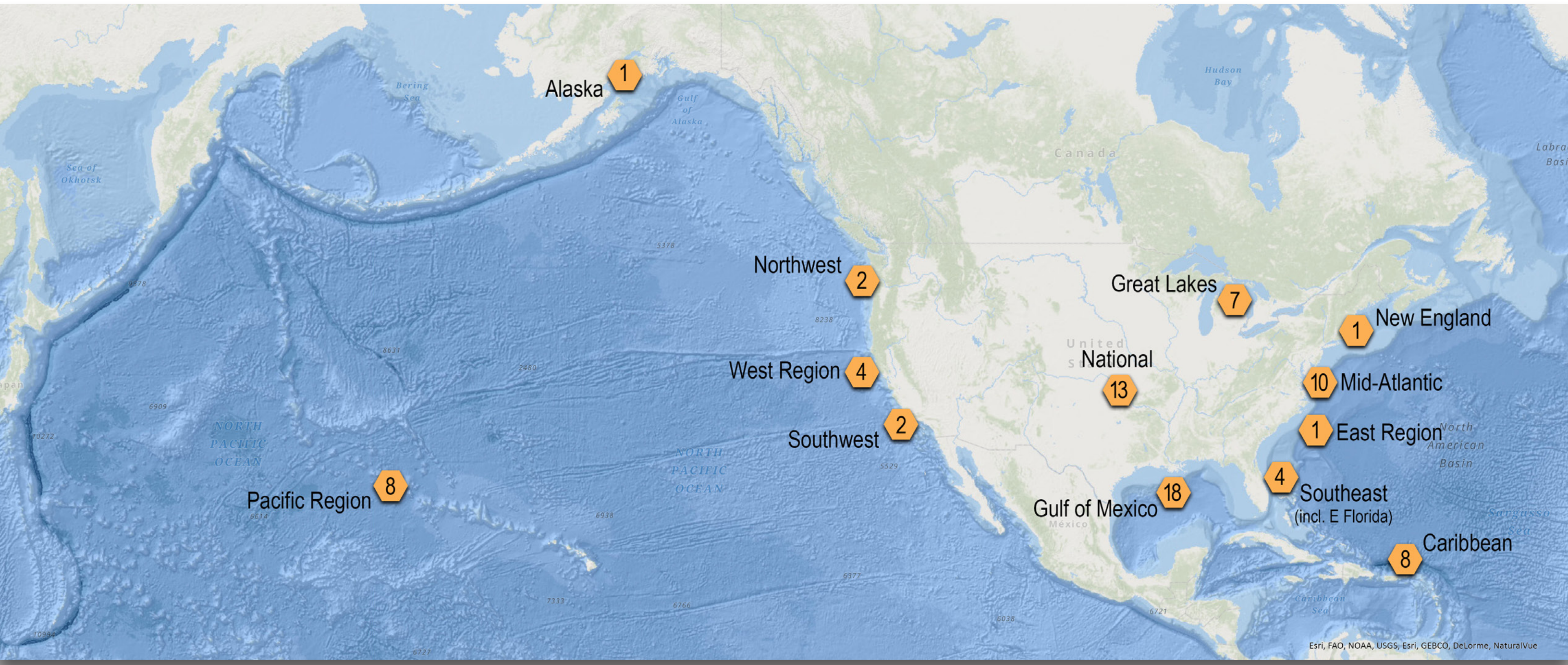
HMT is designed around the inter-niche concept, "filling and connecting" gaps created by other niches to provide integrated scientific solutions. The HMT inter-niche approach fills and connects gaps to provide end-to-end coastal, geospatial, and applied science solutions to resource managers using existing and enhanced technology, application development, and visualization tools. This inter-niche approach is utilized in a variety of mapping activities, such as coral conservation, renewable energy planning, and protection management.

### Where We Work

HMT is based out of NOAA's headquarters in Silver Spring, Maryland. However, HMT staff are located across the U.S.



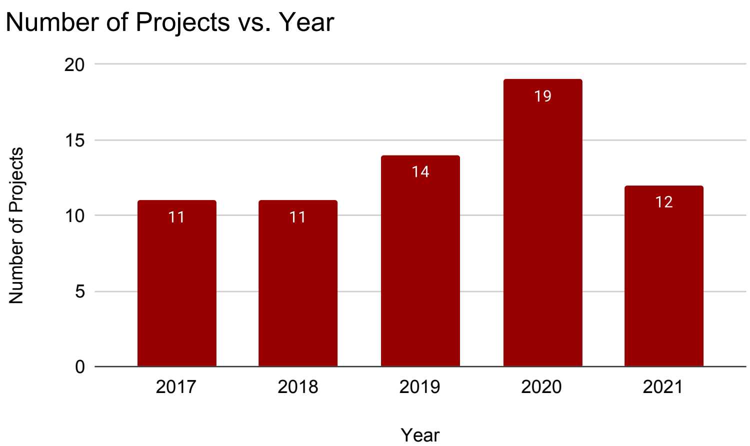

*Locations of the NCCOS Habitat Mapping Team (HMT) staff.*



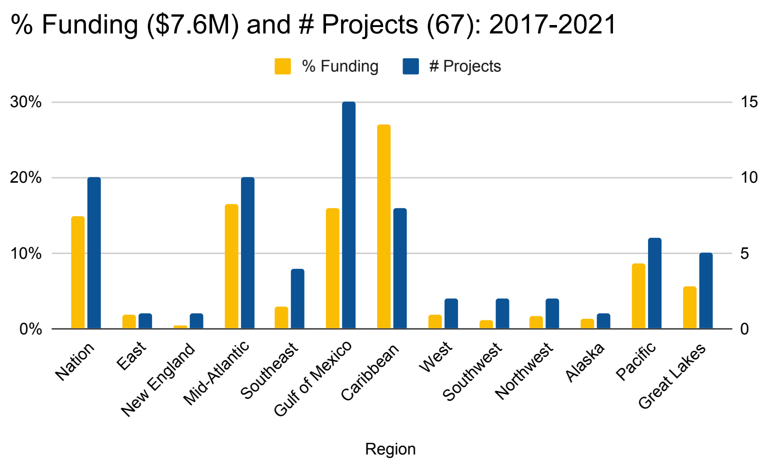

*Location of HMT projects from 2017–2021 (79 total).*

## Project Load & Budget

HMT science efforts are primarily supported through reimbursable funding (approximately 70%) received from other NOAA programs; external State, Federal and DoD organizations; and competitive proposal processes. From 2017–2021, HMT has conducted over 67 projects distributed across a wide-distribution of our Nation's coasts. The majority of non-NCCOS funded projects have a 2–3 year duration. A large percentage of our portfolio is focused on supporting science activities in the Caribbean and Gulf of Mexico. HMT's business model is principally based on cost recovery to support a complement of contractors, travel, equipment, and other direct costs associated with maintaining a robust program.




*Number of HMT projects by year from 2017–2021.*




*Number of projects (67 total) and percent funding ($7.6M total) by project location from 2017–2021.*

# FOCAL AREAS

Benthic habitat maps describe the spatial distribution and qualities of the seabed or lakebed physical structure (e.g., reef, sand, rock) and biological cover (e.g., live coral, seagrass, algae). HMT (Habitat Mapping Team) has a long history of developing benthic habitat maps using a variety of technologies, software programs, and map making techniques. The primary uses of these habitat maps are to inform marine management decisions, ranging from marine protected area design to offshore energy development.

HMT has instituted a multi-faceted approach to habitat mapping which incorporates key, inter-connected mapping activities and data visualization steps. This approach positions HMT as a unique, experienced, and technically advanced provider of science-based products to connect knowledge and fill information gaps within coastal and marine ecosystems. HMT concentrates on six focal areas, which enable the Team to provide cutting-edge planning, data collection, data processing, modeling, and visualizations to inform coastal and marine management decision-making.

These focal areas contribute to HMT's approach for habitat mapping and characterization. The ***Habitat Mapping*** and ***Habitat Characterization*** themes describe an end-to-end (i.e., collection to data archival) lifecycle approach that HMT takes in addressing coastal management needs, however each of these focal areas can also be performed independently.

## HABITAT MAPPING

**Focal Area 1:** Mapping Coordination & Spatial Prioritizations

**Focal Area 2:** Remote Sensing & Signal Processing

**Focal Area 3:** Uncrewed Systems for Mapping

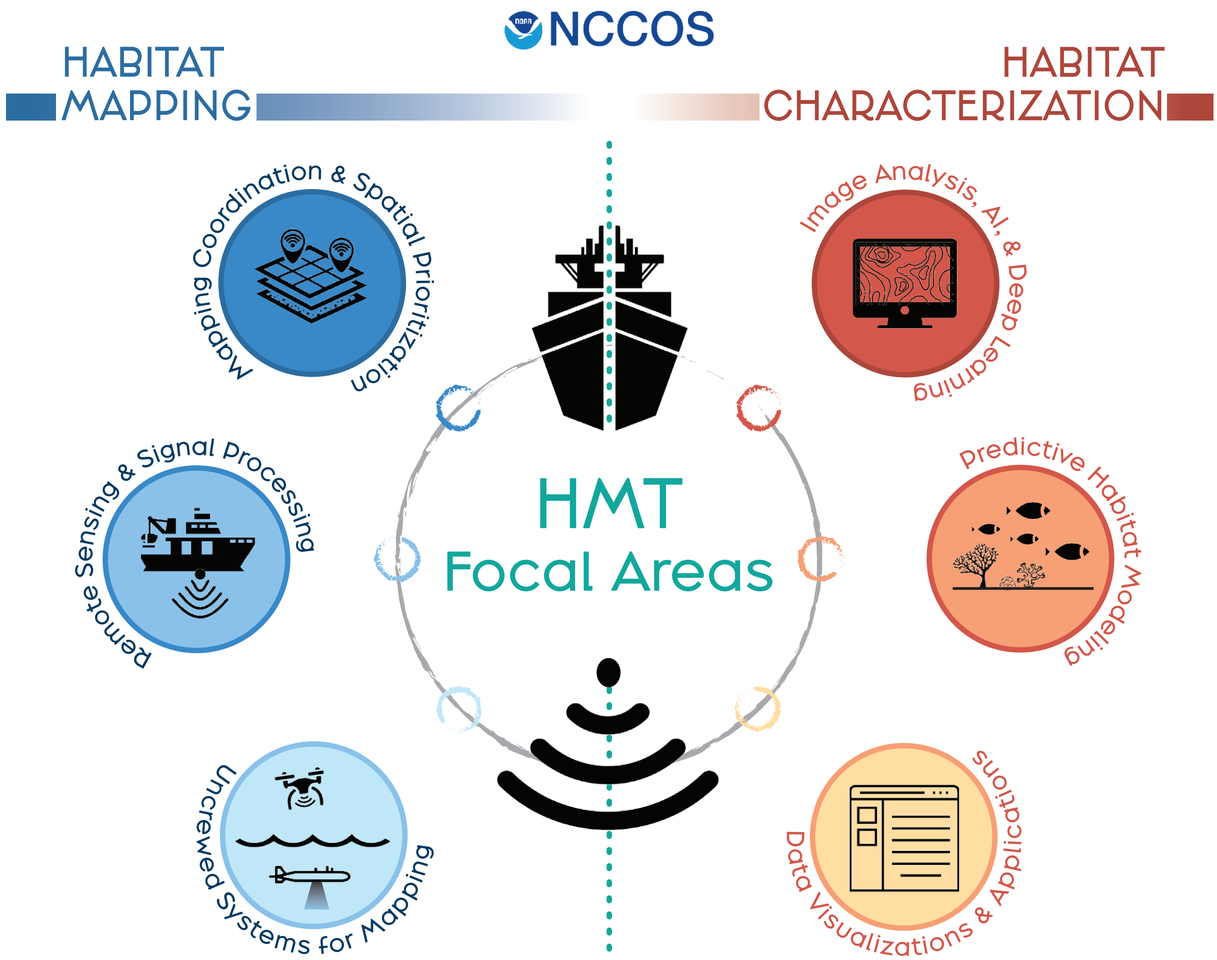
## HABITAT CHARACTERIZATION

**Focal Area 4:** Image Analysis, Artificial Intelligence, & Deep Learning

**Focal Area 5:** Predictive Habitat Mapping

**Focal Area 6:** Data Visualizations & Applications

HMT's diverse experience in these focal areas enables the team to focus and customize each product specifically to partners' and clients' needs. Multiple focal areas can be applied to provide an end to end solution, or specific focal areas can be executed for targeted applications.




## Mapping Coordination & Spatial Prioritization

HMT has designed a participatory spatial prioritization process to provide critical information on "where" and "why" mapping data are needed and promote mapping coordination, planning, and collaboration among multiple agencies.

## Remote Sensing & Signal Processing

HMT applies advanced signal processing to remotely sensed acoustic and optical data to provide comprehensive interpretations of bottom and water column habitats and features.

## Uncrewed Systems for Mapping (UxS)

HMT uses airborne, surface, and underwater UxS to enhance remote sensing for habitat mapping. UxS provide high resolution acoustic and optical imagery to augment crewed systems or in remote areas. Precise controls allow for long-endurance and repeatable surveys.

## Image Analysis, Artificial Intelligence, & Deep Learning

HMT is exploring further applications for machine learning in image analysis and its potential to assist in HMT's workflow. These automation techniques streamline data analytics, allowing for an increased focus on the critical steps of data interpretation and product development.

## Predictive Habitat Modeling

HMT uses predictive modeling approaches to create benthic habitat maps. These predictive maps are quantitative and can be used to understand habitat changes over time. This modeling framework can also be deployed in the cloud, allowing HMT to process large datasets more efficiently.

## Data Visualizations & Applications

HMT specializes in developing visualizations and immersive spatial data tools to support decision making, science communication and outreach.

SCIENCE SERVING COASTAL COMMUNITIES

*Illustration of HMT's focal areas.*

# Habitat Mapping

The focal areas described in this section address the stages of the Habitat Mapping theme such as needs assessments and prioritization, project scoping and planning, survey design, and defining the most appropriate specifications of sensors and platforms used to acquire observations.

## Focal Area 1: Mapping Coordination & Spatial Prioritizations

### *Background & Definition*

Providing accurate geospatial map products to clients is one of HMT's principal objectives, but doing so depends upon having a thorough understanding of mapping requirements and coordination among data providers and users. Seafloor mapping is a logistically intensive, time consuming, and costly enterprise. HMT has demonstrated expertise in building inventories and catalogs of existing mapping data to improve inter-agency coordination efforts; selecting and operating research vessels, platforms (see **Focal Area 3: Uncrewed Systems for Mapping**), and sensors (see **Focal Area 2: Remote Sensing and Signal Processing**); and collecting seafloor and water column data (see **Focal Area 5: Predictive Habitat Modeling**). HMT has developed a robust network of partners throughout the U.S. to provide expertise in understanding the uses, collection, and application of mapping data to support a variety of coastal management and conservation issues. To address these challenges, HMT has designed a participatory spatial prioritization process to provide critical information on "where" and "why" mapping data are needed and to promote mapping coordination, planning, and collaboration among multiple agencies. Planning between agencies and their partners will allow them to "map once, use many times", ultimately reducing redundant efforts and maximizing the efficient use of resources.

### *Applications*

Mapping Coordination

HMT has been on the forefront of coordinating regional mapping efforts. HMT partnerships with federal and non-federal organizations have enabled significant leveraging of resources to fill data gaps to address multiple organizational and management goals. Below are several examples of mapping coordination efforts that HMT has led and contributed to:

1. National Ocean Mapping, Exploration, and Characterization Council
2. Integrated Ocean and Coastal Mapping (IOCM) Standards for Ocean Mapping Protocols (SOMP)

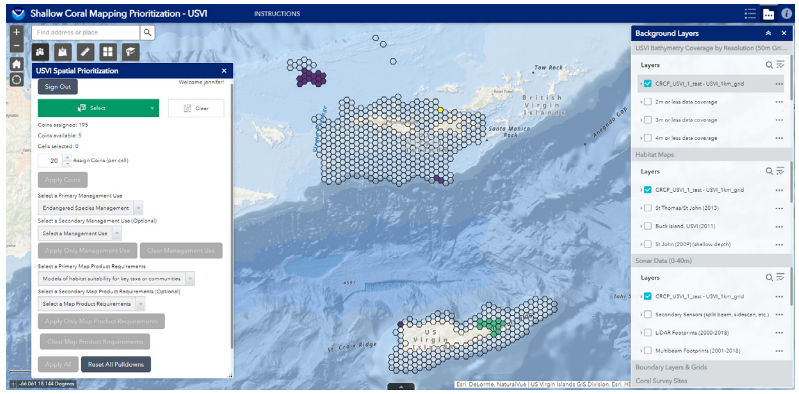
Credit: Cory Ames (CSS, Inc./NOAA NCCOS)

3. Deep-sea coral initiatives (e.g., West Coast, Alaska and Southeast Deep Sea Coral Initiatives and NRDA Mesophotic and Deep Benthic Communities [MDBC])
4. Regional mapping campaigns and initiatives (e.g., Expanding Pacific Research and Exploration of Submerged Systems [EXPRESS] campaign, Seascape Alaska Campaign, Southern California Mapping Initiative, U.S. Caribbean mapping campaign)

For example, HMT contributions to the EXPRESS campaign included conducting a spatial prioritization, supporting scientific data collection, and coordinating across Federal and academic partners to identify and map priority areas. In another example, HMT has collaborated with Florida Keys National Marine Sanctuary (FKNMS) to assemble an extensive inventory of available seafloor mapping data and benthic imagery along the Florida reef tract. Our efforts have precipitated strategic planning collaboration between HMT, FKNMS, NOAA's National Marine Fisheries Service (NMFS) and Office of Coast Survey (OCS), the National Park Service, and NOAA's Coral Reef Conservation Program (CRCP) to fill remaining gaps in data throughout the region. Similarly, on behalf of CRCP, HMT has been coordinating and mapping coral reef ecosystems from shallow to deeper margins in the U.S. Caribbean since 1999.

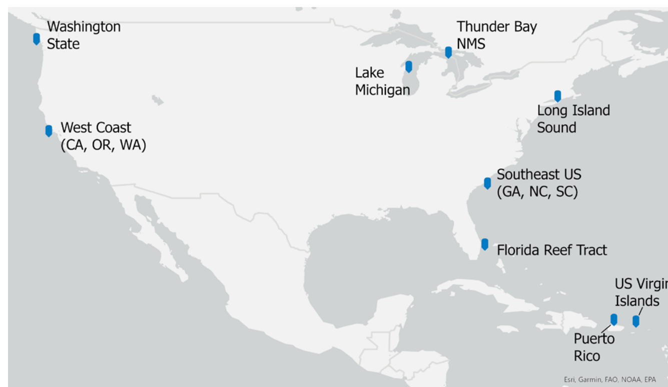
## Spatial Prioritization

HMT has developed a participatory Geographic Information System (pGIS) application called a Spatial Prioritization Widget. This application identifies common research priorities and locations shared among partner organizations, which can be used to help fill gaps in data and promote coordination across organizations. The Spatial Prioritization Widget is customizable and scalable to meet the specific needs of local or regional organizations. This approach is a quantitative and objective approach to efficiently and systematically gather input from multiple participants to quantify and define mapping priorities. Participants can convey where mapping data is needed, when the products are required, and what type of information is useful to their organization. This information is critical for planning and coordinating subsequent mapping efforts.

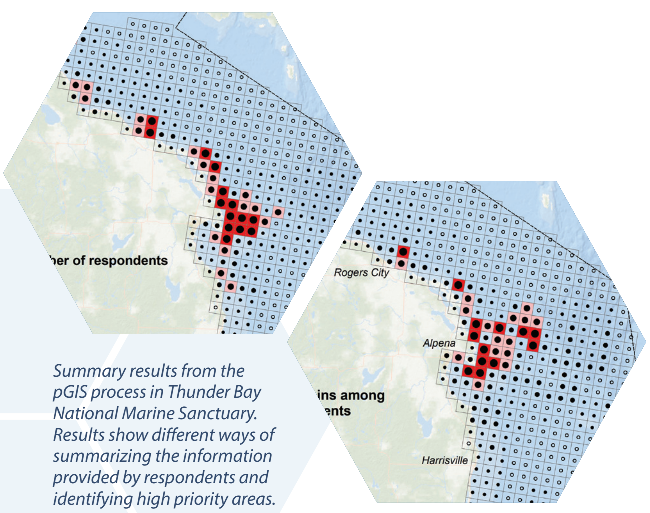



*An example of HMT's customizable pGIS interface. In this example, the application was used to identify mapping priorities of shallow coral reef areas in the U.S. Virgin Islands (USVI).*

HMT has executed regional prioritization efforts throughout the U.S. EEZ, and the widget was used to conduct the U.S. coral reef mapping, and National Ocean Mapping, Exploration and Characterization Strategy. A recent prioritization project for lakebed mapping in Thunder Bay National Marine Sanctuary in Lake Huron has been used to help researchers and managers to find mutually-shared priority locations (NCCOS News: August 2020).




*Select locations of mapping prioritization efforts conducted HMT.*




*Summary results from the pGIS process in Thunder Bay National Marine Sanctuary. Results show different ways of summarizing the information provided by respondents and identifying high priority areas.*

> **GOAL 1:**
> ***Pursue innovative ways to advance coordination between and among coastal managers and researchers***
> - Continue to develop and refine the pGIS application to incorporate new technological advances in web applications and data sharing.
> - Continue to identify additional agencies, partners, and regions that can benefit from prioritizations.
>
> **GOAL 2:**
> ***Increase HMT's recognition within NOAA and externally as a leading expert in planning, managing, and executing mapping campaigns at regional and local scales***
> - Develop new approaches to coordinate and strengthen mapping collaboration partnerships.
> - Develop a platform for centralizing and disseminating NOAA benthic habitat mapping information and data.
> - Execute prioritizations for all U.S. shallow coral reef ecosystem jurisdictions.
> - Enhance the efficiency of broad -scale mapping initiatives in the Gulf of Mexico through the NRDA MDBC restoration settlement.

## *Future Directions*

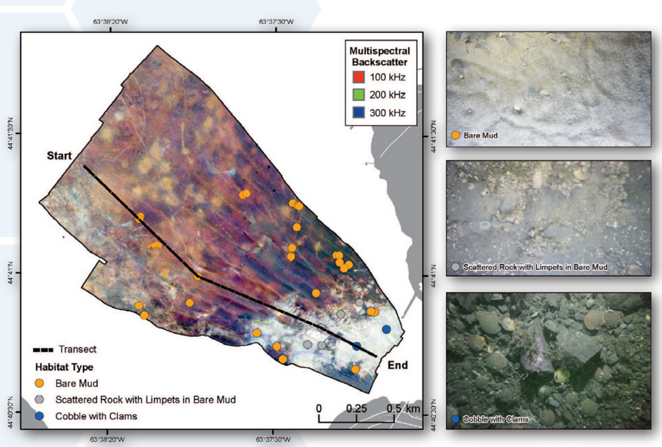
Advances in mapping technology and automated approaches to benthic habitat characterization have increased the demand for mapping data at ever broader extents and finer resolutions (see ***Focal Area 2: Remote Sensing and Signal Processing*** and ***Focal Area 3: Uncrewed Systems for Mapping***). Thus, there has been an urgent need to define requirements for habitat mapping products that meet multiple user needs and then identify the best sensors and interpretation methods to meet those requirements.

## Focal Area 2:
## Remote Sensing & Signal Processing

### *Background & Definition*

Maps showing the depth, shape, and texture of seabeds or lakebeds provide the first indicators of the geological types and biological composition of benthic habitats. HMT adopts NOAA and international standards for seabed and lakebed mapping to produce the highest possible resolution bathymetry maps to meet multiple user needs, including characterizing the shape and texture of the bottom. Characterizing benthic habitat over large areas makes use of many of the same technologies used by hydrographers to produce nautical charts, such as multibeam echosounders (MBES) and airborne lidar remote sensing systems. The team also conducts research and development in data processing from a suite of remote sensing technologies (e.g., satellites, echosounders and sonars, lidar, uncrewed systems [UxS] payloads) to extract valuable measures of acoustic backscatter and lidar intensity characteristics of the seabed, lakebed, and water column features.

To survey large areas, multiple sensors and survey platforms (see **Focal Area 3: Uncrewed Systems for Mapping**) are required. Integrating these different datasets can be challenging when the systems lack calibration to a common standard. HMT applies advanced signal processing, particularly in backscatter intensity, to standardize datasets into a comprehensive interpretation of the seabeds or lakebeds. New MBES are now able to collect bathymetry and backscatter at multiple frequencies, simultaneously, increasing the data available to discriminate features on the seabed or lakebed. Recent research by the team has shown that backscatter collected at multiple acoustic frequencies ("multispectral backscatter") can provide added insights in the characteristics of the benthic zone, especially soft sediment habitats. Multibeam and sidescan sonars can also be used to detect objects such as shipwrecks, artificial reefs, and marine debris like derelict fishing gear and traps.

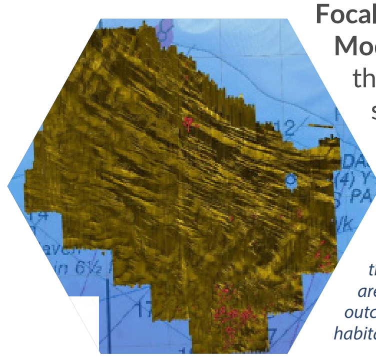



*A map from an experimental analysis of multispectral (multi-frequency) MBES backscatter presented as a 3-band RGB (red, green, blue) image and corresponding visual habitat characterizations of the seabed. Modified from source: https://doi.org/10.2112/JCOASTRES-D-18-00103.1*

### *Applications*

#### Mapping Seabeds and Lakebeds

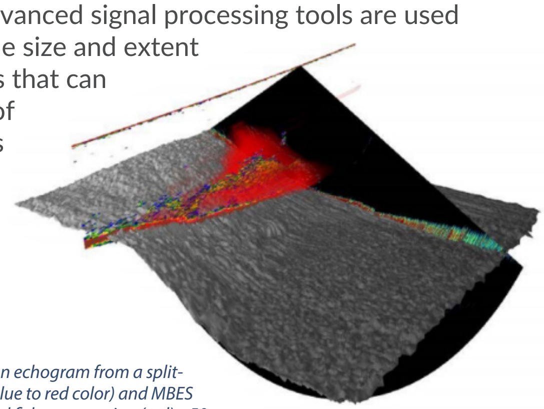
An ecological assessment of a wind energy planning area off Cape Fear, North Carolina, "Wilmington East", used MBES and sidescan sonars to provide initial bathymetry and backscatter for a large area covering over 400 km$^2$. The mapped area showed clusters of seabed features that represented emergent rock ledges and ridges that served as reef habitats for diverse fish communities. HMT acquired and interpreted sidescan sonar and multibeam backscatter during mapping surveys to provide ecological indicators from depth, roughness and hardness or sediment characteristics on the bottom. Backscatter provided indicators for the presence of shellfish beds that form habitats or are invasive species in the Great Lakes ecosystem. Optical imagery (see **Focal Area 4: Image Analysis, Artificial Intelligence, and Deep Learning**) and species distribution modeling (see **Focal Area 5: Predictive Habitat Modeling**) are used to enhance these interpretations of the seabed or lakebed.



*Sidescan sonar reflectivity of the seabed in the Wilmington East wind energy planning area. Red marks represent potential rocky outcrops and possible sensitive essential fish habitat.*

#### Mapping Water Column

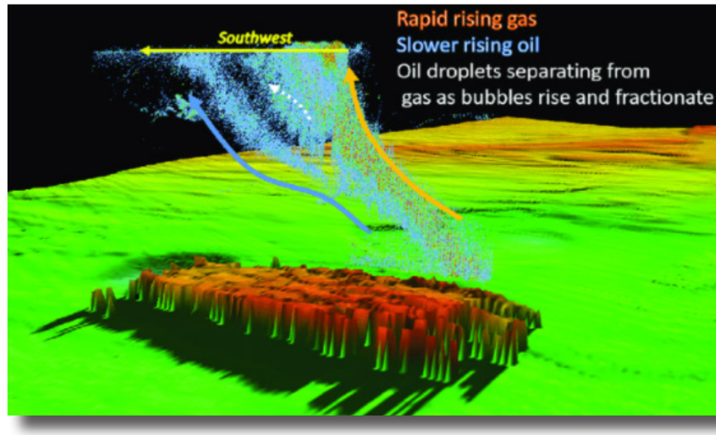
Simultaneously acquiring water column sonar data during seafloor mapping surveys allows for assessments of the distribution of fish communities and the relative ecological value of bottom habitats. HMT uses water column sonars to detect and map the distribution of fish and fish schools to relate to seafloor habitat characteristics. The team also exploits water column sonar data from MBES to extract measures of reef fish schools and spawning aggregations. The wide swath of the MBES increases the search volume and efficiency when searching for fish aggregations over very large reef areas. Advanced signal processing tools are used to estimate the size and extent of fish schools that can extend 100s of square meters over bottom habitats.



*Composite image of an echogram from a split-beam echosounder (blue to red color) and MBES beam fan and detected fish aggregation (red) >50 m wide and >200m long along a reef slope.*

## Mapping Oil Plumes & Gas Seeps

Gas bubbles and plumes from subsurface oil can be detected from water column sonar backscatter. Similar to fish, signal processing of calibrated split-beam and MBES allow for the estimation of the extent of subsurface oil and gas plumes as well as quantifying the flux of oil and gas through the water column. Gas bubbles can include methane seeps or other hydrocarbons where there is high contrast in the density of the gas and surrounding water. HMT conducted these types of surveys in 2018 at the Taylor Energy MC20 in the Gulf of Mexico to detect and measure continued output of hydrocarbons at this decommissioned site.



*Composite image of a gas (orange arrow) and oil plume (blue arrow) rising from a downed structure. The prevailing currents are pushing the gas and oil to the southwest.*

## *Future Directions*

The burgeoning growth in mapping survey data will demand increasingly automated approaches by HMT. Hydrographic mapping projects are now utilizing vessels and autonomous systems simultaneously to map areas more quickly and economically. Cloud-based machine learning identification techniques are in development and critical to assist with the analysis and extraction of features on the bottom and in the water column (see **Focal Area 4: Image Analysis, Artificial Intelligence, and Deep Learning** and **Focal Area 5: Predictive Habitat Modeling)**. Where habitat characterization is a goal, rapid processing of the bathymetry and water column backscatter will provide actionable intelligence to guide ground-truthing for production of habitat maps and other ecosystem characterizations.

**GOAL 1:**
***Deliver standard operating procedures for acquisition and quality control for data from seabed and lakebed acoustic backscatter and water column.***

- Lead NOAA's development of acoustic backscatter and water-column Standards for Ocean Mapping Protocols (SOMP) to achieve a core objective of the National Ocean Mapping Exploration and Characterization Strategy (NOMECS).

**GOAL 2:**
***Increase efficiency in data processing and interpreting bottom habitat.***

- Develop and implement artificial intelligence and machine learning tools to automate bottom and water column backscatter processing and deep learning tools.
- Publish and publicize standard operating procedures (SOPs) for methodologies and data processing workflows.
- Evaluate and modify workflows and procedures to significantly reduce processing times for large volumes of data, data collected by multiple concurrent platforms, and/or autonomous systems.
- Operationalize cloud-based processing and machine learning identification techniques for data analysis and feature extraction (see **Focal Area 4: Image Analysis, Artificial Intelligence, and Deep Learning** and **Focal Area 5: Predictive Habitat Modeling**).

**GOAL 3:**
***Develop strategies to continue research and development of novel sensors and signal processing, especially integrated on uncrewed systems (see Focal Area 3: Uncrewed Systems for Mapping).***

- Support and identify miniaturization of remote sensing systems to increase integration into UxS.
- Research and develop backscatter from multi-frequency echosounders and lidar waveforms for characterizing bottom habitats and water column communities.
- Continue identifying requirements across NOAA programs for characterizing bottom and water column habitats using UxS and novel sensors.

# Focal Area 3:
# Uncrewed Systems for Mapping


## *Background & Definition*

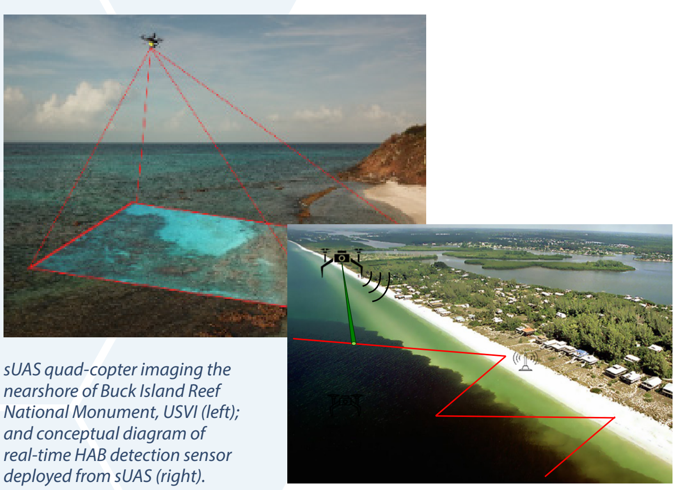
Uncrewed systems, or more commonly UxS, is a broad category encompassing a wide-array of vehicles—aerial, terrestrial, or marine (surface and underwater)—and associated elements, such as sensors and communications software, that can execute data-collection missions without human presence aboard. They are typically programmable, self-powered, untethered, and operate on a continuum from attended to fully autonomous. UxS provide an efficient, viable, and cost-effective means for HMT to meet science requirements and to augment the capabilities of traditional platforms such as aircraft, ship, and satellites.

UxS provide HMT a solution to meet the burgeoning demand by the scientific and management community for increased observational ability in the coastal zone (depths 0–100 m). Uncrewed systems can address several constraints of crewed vessels and planes. Examples of the limitations of crewed platforms include the spatial scale of data collected, responsiveness or frequency of revisits, or access limitations due to environmental challenges. Thus, UxS can greatly improve the extent to which high-resolution bathymetry, habitat ground-truthing, and animal observations can be obtained in the coastal zone.

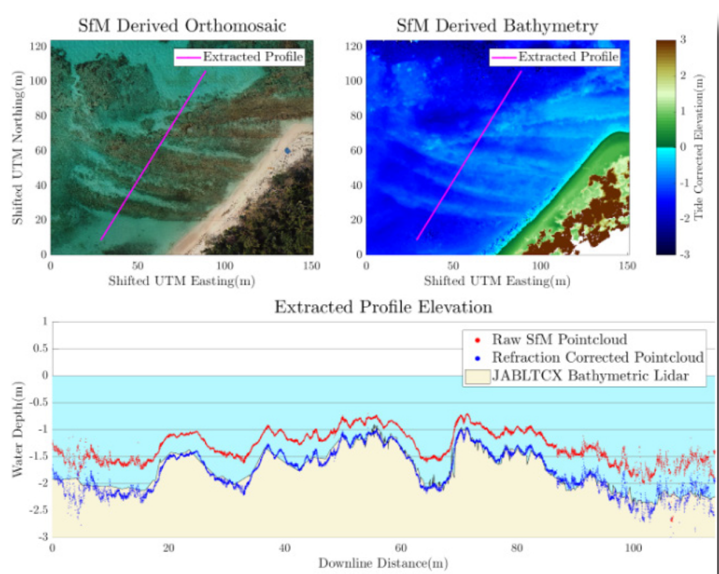
## *Applications*

### Shallow-water Mapping & Monitoring

sUAS (small Uncrewed Aircraft Systems) provide efficient and rapid access to coastal environments where traditional systems are costly to deploy or unable to navigate, particularly for remote locations. sUAS typically deploy optical camera payloads which can be used to construct highly detailed photomosaics and digital elevation models using Structure from Motion (SfM) software (see **Focal Area 6: Visualization, Communication, and Outreach**). HMT has developed guidelines to operationalize this approach and has led regional workshops to establish communities of practice. Additionally HMT is developing low-cost, easily deployed, and accurate harmful algal bloom (HAB) detection sensors to provide real-time information to shore-based scientists.



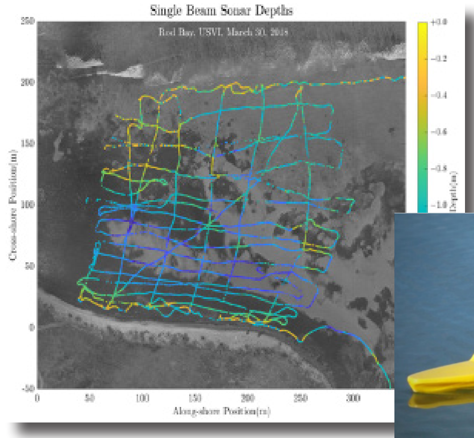
*sUAS quad-copter imaging the nearshore of Buck Island Reef National Monument, USVI (left); and conceptual diagram of real-time HAB detection sensor deployed from sUAS (right).*




*Photomosaics (top-left) and digital elevation models (DEMs; top-right) derived using Structure from Motion (SfM) acquired from sUAS can resolve seascape elevations in much greater detail than traditional sensors (bottom).*

## Acoustic Surveys From UxS

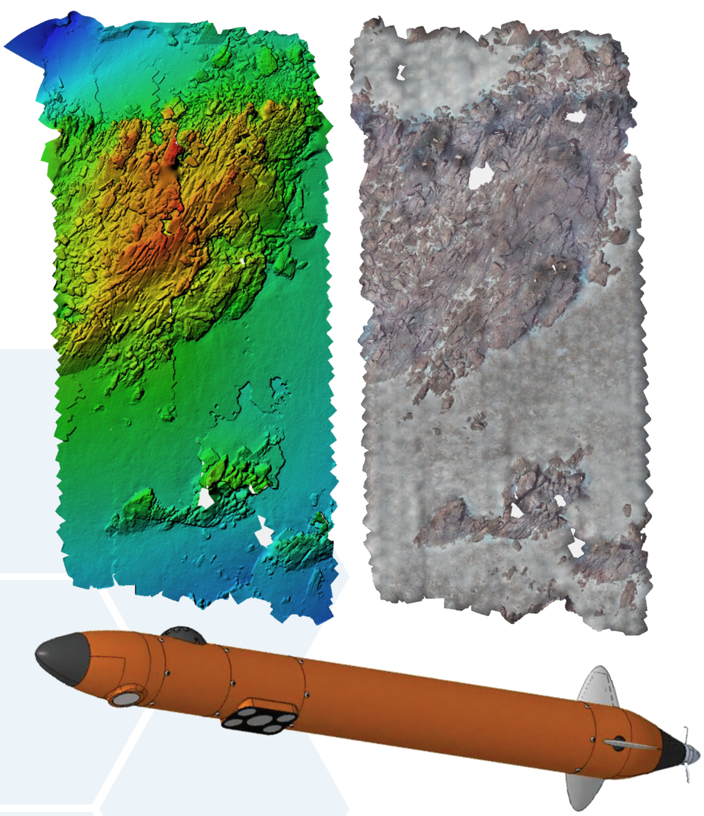
HMT uses surface and underwater UxS to survey water depths in shallow, navigationally challenging areas and also to conduct long endurance surveys along the coastal shelf. Active and passive acoustic sonars can be instrumented on these vehicles to map bottom habitats and topography; and track and quantify marine life abundance.




*Depth data collected using a single beam sonar mounted on a Hydrone USV in Prisoner's Harbor, Santa Cruz Island, CA; and used to independently validate the depths derived using SfM.*

## Seafloor Mapping

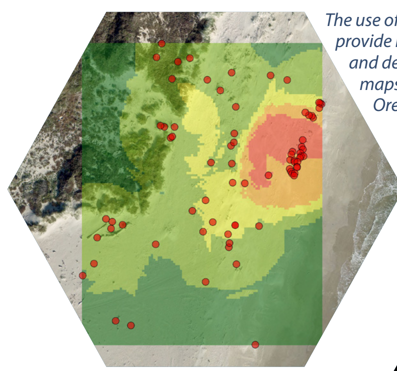
HMT utilizes micro-AUVs (unmanned underwater vehicles) with camera and ultra-short baseline (USBL) modules to conduct ground-truthing of benthic habitats. These UxS, which are depth rated to 300 m and six hour endurance, are used to conduct large area imaging of sites to produce digital elevation models (DEMs) and photomosaics. Small in size and easily shipped, the AUVs provide a rapid response ability that can be deployed from shore, small vessels and larger platforms to acquire detailed and rapidly framed images of the U.S. seafloor.



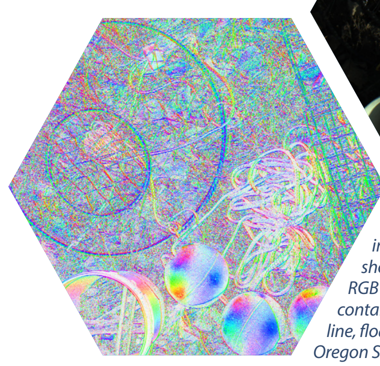
*Example DEMs (left) and photomosaics (right) derived using SfM acquired from AUVs (NWFSC Seabed) provide high resolution imagery of seafloor topography and habitats. BAE micro-AUV (Riptide, 25 lbs) with LED strobe lighting, Artic Ray 12 mp high framing color camera, and SeaTrac X150 ultra-short baseline (USBL; bottom).*

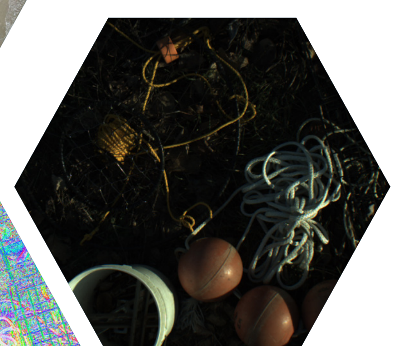
## Object & Animal Detection

HMT is also developing automated object detection and classification workflows for UAS imagery using artificial intelligence (AI; see **Focal Area 4: Image Analysis, Artificial Intelligence, and Deep Learning**). The objective is to develop and implement operationally-efficient workflows and deployable algorithms to provide rapid analysis and identification of objects such as habitat type, marine animals, or marine debris. Additionally, HMT and partners are investigating the utility of advanced sensor payloads, such as polarimetric cameras, to improve detection accuracies of object types.



*The use of sUAS and artificial intelligence (AI) to provide rapid, post-event acquisition of imagery and detection of marine debris to produce heat maps of object densities. Credit: NCCOS and Oregon State University.*





*HMT is developing innovative uses of polarimetric cameras for improving object detection. Test site shows polarimetric (left) and standard RGB camera (right) for a mixed scene containing common marine debris objects: line, floats, and plastic. Credit: NCCOS and Oregon State University.*

### *Future Directions*

In the last five years, HMT has made tremendous progress in developing and incorporating the use of UxS, but further growth and investment is necessary. We seek to enhance the development, adoption, and utilization of airborne, surface, and underwater systems in our program to better address science requirements of NCCOS and clients. Uncrewed systems are an NCCOS programmatic priority, and as such HMT has been researching, advancing, and operationalizing the use of UxS platforms to further these science capabilities. HMT will continue investment in UxS to provide enhanced and longer duration observational abilities, particularly in remote locales and in locations of the coastal zone challenged by safety or navigational access issues.

**GOAL 1:**
***Stay knowledgeable and current on UxS technological advancements***

- Proactively monitor developments by Department of Defense (DoD) research and develop (R&D) programs to identify potential developing dual-use technologies.
- Seek engagement in R&D opportunities including but not limited to Cooperative Research and Development Agreement (CRADA) and Small Business Innovation Research (SBIR) opportunities.
- Continue to engage the internal and external community through technical teams to develop workshops, protocols and recommendations.

**GOAL 2:**
***Increase investment in HMT UxS***

- Seek ways to increase and improve investments by NOAA, NOS, and NCCOS in ways which enhance HMT UxS capabilities.
- Actively seek funding and develop proposals to further support R&D efforts.
- Use reimbursable project funding, where appropriate, to jump-start and enhance integration and utilization of UxS and seek programmatic NCCOS funds to sustain routine UxS operations.
- Evaluate, define and seek the appropriate balance between owning, operating, and maintaining UxS in-house versus the use of non-NCCOS UxS expertise.

**GOAL 3:**
***Increase HMT's UxS utilization and deployment frequency***

- Improve partnership opportunities with groups that have pools of vehicles and operational expertise including academia, DoD, other science agencies, and private industry. This includes the development of contracts, agreements, and partnership arrangements.
- Actively seek to operationalize systems once R&D benefits have been demonstrated.
- Continue to develop using these UxS platforms to deploy innovative new sensor payloads for operational use.

*Credit: Oregon State University*

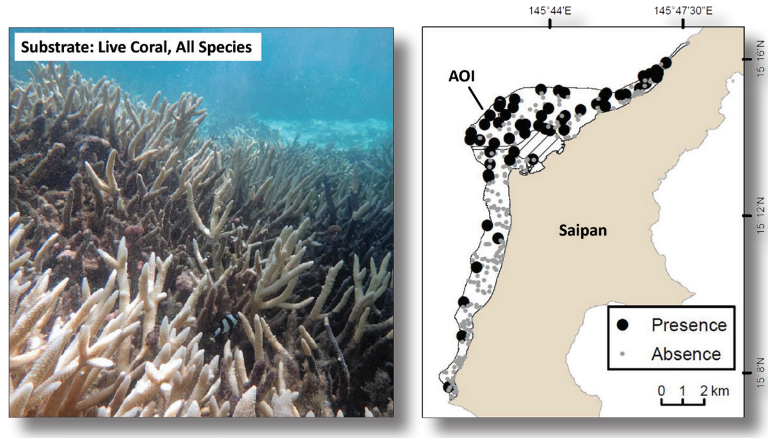
# Habitat Characterization

The focal areas described in this section address the stages of the Habitat Characterization theme. These focal areas generally follow the habitat mapping stage, and include analysis and interpretation of data, generation of geospatial products, as well as visual representation and outreach.

## Focal Area 4: Image Analysis, Artificial Intelligence, & Deep Learning

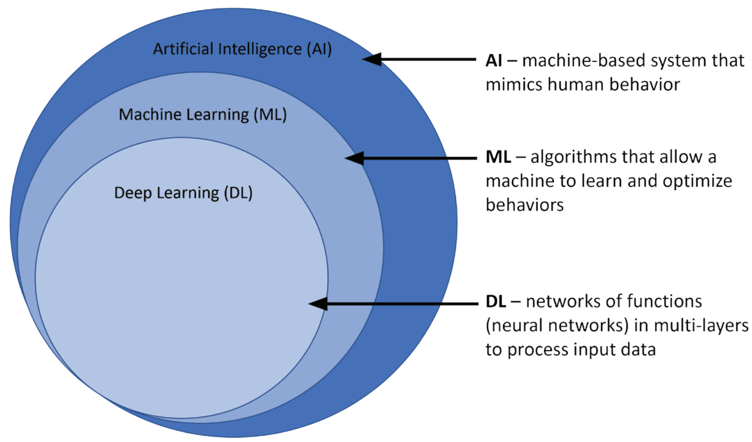
### *Background & Definition*

HMT analyzes imagery to characterize underwater habitats, from the species and substrate level, to the larger-scale, ecological community. Imagery may be collected from remote sensing platforms such as UxS payloads or satellites (see **Focal Area 2: Remote Sensing and Signal Processing** and **Focal Area 3: Uncrewed Systems for Mapping**) or in situ by dive operations.




*Ground validation (GV) underwater image (left) with map (right) showing characterization (presence vs. absence) of "Live Coral" substrate type for GV locations in 2016 Saipan Lagoon Area of Interest (AOI). Similar classifications were created for each biological cover and substrate type (see Saipan Lagoon Mapping for more details).*

Traditionally, analysts have manually interpreted the content of these imagery data sets to determine the types of benthic biological coverage (e.g., coral or seagrass) and substrate type (e.g., mud or sand), which is a time-intensive and subjective process. Advancements in computational processing, such as AI machine learning (ML) and deep learning (DL) techniques, show promise to be very effective and efficient tools in supporting a scalable solution for HMT workflow. ML is a type of AI that uses input data (e.g., about habitats and their environment) to develop predictions by learning iteratively how best to minimize error. The more input data that ML approaches are given, the better its predictions will become. The use of AI ML can: 1) reduce human annotation effort, 2) reduce human-induced errors and bias, 3) enhance reproducibility, transparency, and auditing, and 4) detect patterns unapparent through manual analysis.




By incorporating machine and deep learning annotation tools to update HMT workflow, automation techniques streamline the data analytics tasks which allows analysts to concentrate on the critical steps of data interpretation and product development (see **Focal Area 2: Remote Sensing and Signal Processing**; **Focal Area 3: Uncrewed Systems for Mapping**; and **Focal Area 5: Predictive Habitat Modeling**).

### *Applications*

#### Automated Marine Debris Detections

HMT's goal is to deploy a web-based application that can be used to automatically detect individual macro marine debris objects from imagery along beaches. HMT is operationalizing a deep learning-based object detection model that automates the analyses of images from a variety of sources (e.g., aerial, UAS, or satellite), locates, matches, and labels the detected marine debris to a series of categories. Debris density and distribution heat maps will be generated from detection model results to provide accurate, timely intelligence for debris impact incident assessments and removal response.

#### Enhancing Habitat Mapping Accuracy & Efficiency Using Artificial Intelligence

HMT is currently exploring further applications for machine learning in image analysis and its potential to assist in the habitat mapping workflow. For example, annotation and extraction of habitat information from underwater optical imagery is currently done manually by HMT. However, HMT is assessing several commercial off the shelf (COTS) AI solutions for underwater image and video classification and labeling. Each COTS platform has a slightly different use and capability for image classification, which will be part of the HPCC AI assessment.

### *Future Directions*

HMT is currently exploring further applications for machine learning in image analysis and its potential to assist in HMT workflow. Deep learning and other machine learning models show promise in image annotation and segmentation for ground validation (GV) imagery (in situ imagery used to ground-truth remote sensing data) and SfM large-area-imaging data.

**GOAL 1:**
***Standardize HMT's process to collect and annotate the GV imagery used in the habitat characterization process***

- Standardize the sampling design and process that HMT uses to collect GV imagery.
- Improve HMT abilities to collect large area imagery for GV data.

**GOAL 2:**
***Integrate AI ML into HMT data acquisition and processing***

- Increase utilization of AI ML to annotate GV and SfM imagery
- Determine most effective software solutions to integrate AI into the habitat characterization image analysis process.
- Create standard operating procedures for identifying abundance of physical structures and biological covers in benthic imagery.
- Participate in ML training relevant to image analysis techniques.
- Adopt AI ML for object detection from aerial, UxS, and/or satellite imagery.
- Implement AI algorithms for object detection.
- Quantify how AI minimizes observer bias and increases the performance of the habitat predictions and maps.

## Focal Area 5: Predictive Habitat Modeling

### *Background & Definition*

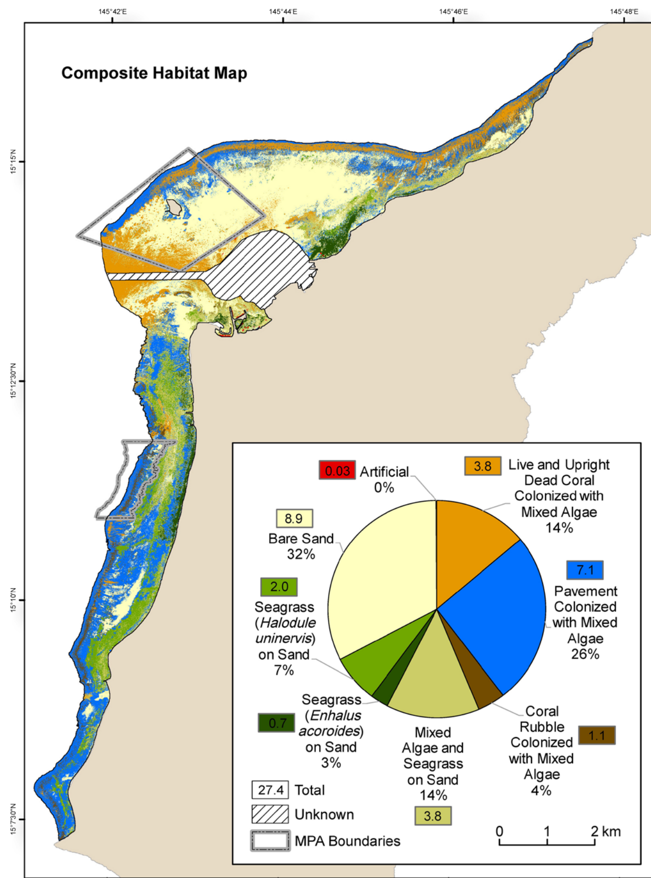
Historically, HMT experts hand digitized and classified habitats that were visible in remotely sensed imagery (e.g., aerial photographs). More recently, predictive modeling approaches have been implemented to semi-automate this habitat characterization and classification process, and to provide a framework to more efficiently process increasing volumes of data. Predictive habitat modeling is the process by which relationships are mathematically defined between habitats (e.g., sand with seagrass) and its associated environmental or geographic variables (e.g., depth, slope, distance the shoreline). These mathematical relationships are then applied to georeferenced imagery depicting these different variables, and used to predict the spatial distribution and abundance of benthic habitats across the seascape.

Recent advances in artificial intelligence (see **Focal Area 4: Image Analysis, Artificial Intelligence, and Deep Learning**) now make it easier to implement predictive modeling approaches, and to generate continuous predictive maps for benthic habitats. These approaches have been successfully implemented by HMT, enhancing our ability to characterize habitats in support of NCCOS science and the coastal and marine management community. They were implemented and refined in close collaboration with the NCCOS Biogeography Branch's Modeling Team (MT). Three predictive habitat modeling examples are described below in shallow (<30 m), moderate (50-150 m) and deep locations (>150 m) around the United States.

## *Applications*

### Shallow-water (<30m)

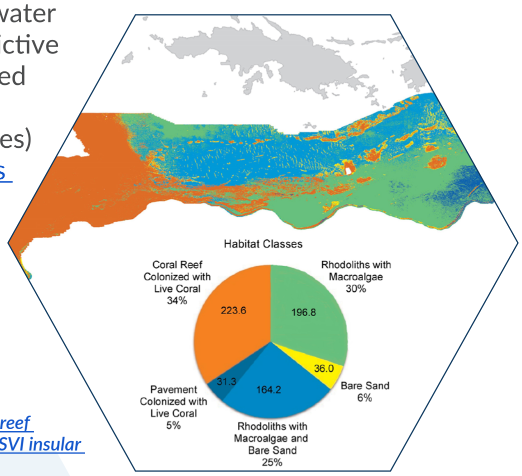
Over the last decade, natural and human-caused threats have changed the composition of shallow-water (<30m) [benthic habitats in Saipan Lagoon](), Commonwealth of the Northern Mariana Islands (CNMI). Local resource managers requested that new habitat maps be developed to better understand these changes. Consequently, HMT used satellite imagery, underwater photographs, and predictive modeling (boosted regression and classification trees) to produce updated benthic habitat maps originally produced by HMT in 2004.




*Map (2017) of shallow-water benthic habitats in Saipan Lagoon, Commonwealth of the Northern Mariana Islands (CNMI).*

### Mesophotic (30 to 150 m)

Mesophotic coral reef ecosystems (MCEs, 30–150m) provide many ecological and economic benefits to nearby islands, including supporting fisheries and enhancing shoreline protection. Like their shallow-water counterparts, MCEs are increasingly under threat from a variety of stressors and threats, especially in the U.S. Virgin Islands (USVI). To establish a baseline for managers in the USVI, HMT used existing MBES datasets, underwater videos and predictive modeling (boosted regression and classification trees) to [produce maps of MCEs on the USVI insular shelf]().

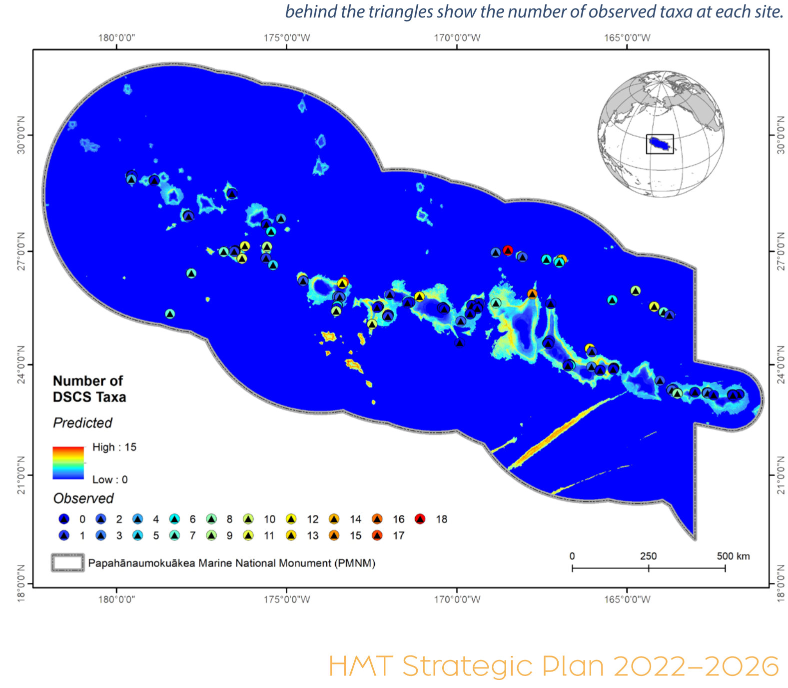



*Map of [mesophotic coral reef ecosystems (MCEs) on USVI insular shelf]().*

### Deep-sea (>150 m)

Deep-sea (>150 m) coral and sponge (DSCS) communities are also vulnerable to natural and human caused stressors and impacts. However, collecting data on DSCS communities is logistically challenging and cost prohibitive, especially in remote areas like Papahānaumokuākea Marine National Monument (PMNM). To fill this information gap for PMNM, the Biogeography Branch's Modeling and Habitat Mapping Teams collaborated to [produce maps of DSCS (100–3,500 m)]() in the PMNM. These maps show the probability of occurrence for a range of DSCS taxonomic groups, and were developed using existing environmental datasets, underwater videos and a range of predictive modeling techniques (i.e., boosted regression trees, generalized additive models, and maximum entropy).

*Map showing the predicted, relative taxonomic richness in Papahānaumokuākea Marine National Monument (PMNM). The black triangles denote the locations of in situ observations, and the colors behind the triangles show the number of observed taxa at each site.*



## Future Directions

In the last decade, HMT has worked closely with the Biogeography Branch's Modeling Team to make predictive modeling a core capability in the Branch's habitat characterization and classification process. This effort enables HMT to: (1) make habitat maps more objective, quantitative and probabilistic, and (2) operationalize HMT's habitat mapping and characterization processes, and ultimately (3) transition mapping to a monitoring tool, which could be used to detect and quantify changes in seafloor habitats over time.

**GOAL 1:**
***Standardize HMT's process across the team to collect and annotate the GV and accuracy assessment (AA) imagery used in the habitat characterization process.***

- Standardizing the sampling design, equipment and process that HMT uses to collect underwater imagery.
- Incorporate use of USBLs or DVLs to reduce the positional uncertainty associated with underwater imagery.
- Establish a joint HMT and Biogeography Modeling Team (MT) working group to develop, publish, and promote a GV and AA standardization strategy.

**GOAL 2:**
***Continue to strategically test, evaluate and employ a range of new predictive modeling approaches in our work, in close collaboration with the MT.***

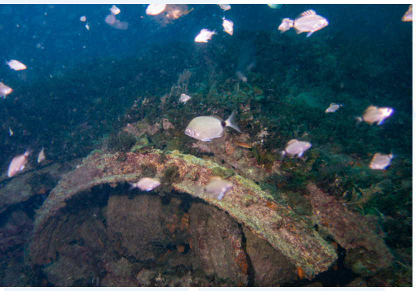
- Allocate time and resources to HMT staff to evaluate new, rapidly evolving predictive modeling and algorithms and approaches.
- Provide a dedicated time to review HMT and MT work plans and the joint pursuit of NCCOS funding/resources for this research and development.
- Identify members of each team to develop a more detailed strategy for comparing predictive modeling approaches.

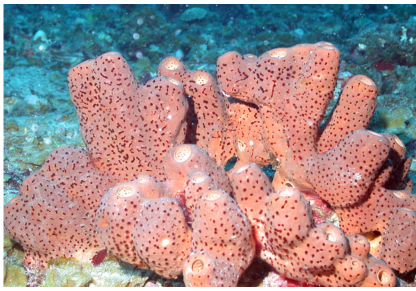
**GOAL 3:**
***Grow predictive habitat modeling capacity within HMT and the Biogeography Branch.***

- Review staff competencies and assess gaps in skills. Hire more staff or retrain existing staff with predictive modeling expertise as our modeling portfolio grows.
- Identify and increase staff sharing opportunities between HMT and MT to help further strengthen ties and coordination between the two teams. This goal could be accomplished through contractor or subcontractor hires, post doc positions and/or fellowships.

**GOAL 4:**
***Develop stronger ties with NOAA NMFS and academic modeling communities; as they have extensive predictive modeling capabilities, expertise and experience.***

- Strategically partner with these groups to enhance our partner network, technical abilities and visibility in the predictive modeling community. These collaborations would foster information sharing across experts, encourage the development of best practices for predictive habitat modeling, and advertise HMT's capabilities to new partner and client networks.
- Host dedicated workshops, like those completed for deep-sea corals and NRDA MDBC, to help engage with outside experts. These workshops should include tangible outcomes and a peer-reviewed publication.



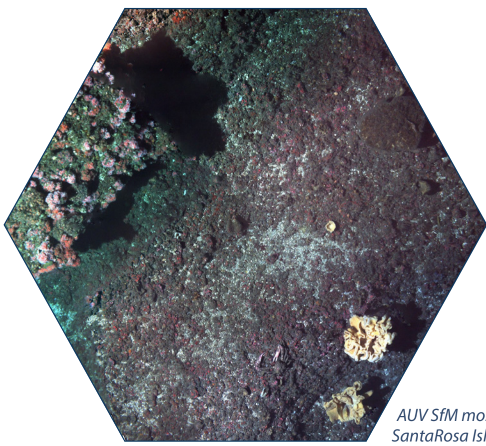


# Focal Area 6:
# Data Visualization & Applications

## *Background & Definition*

HMT specializes in developing multiple types of visualizations, ranging from static products to those that form interactive, cross-cutting tools. Static products like maps, figures, or infographics synthesize information into discrete, understandable, and easily shareable formats. Visually appealing moving products, such as video fly-throughs of habitat mapping data or interactive SfM models, help display information in more immersive and dynamic formats. To increase availability and usability of visualizations, HMT also generates online tools, such as data portals, data atlases, and interactive decision-support tools, that represent the next frontier in data translation and communication.

*A benthic habitat map (center panel) of the Cordillera Coral Reef Natural Reserve on display in Fajardo, Puerto Rico is an example of a static visualization product developed by HMT. Such infographics can help inform stakeholders and raise awareness for resource management decisions.*

*AUV SfM mosaic south of SantaRosa Island.*

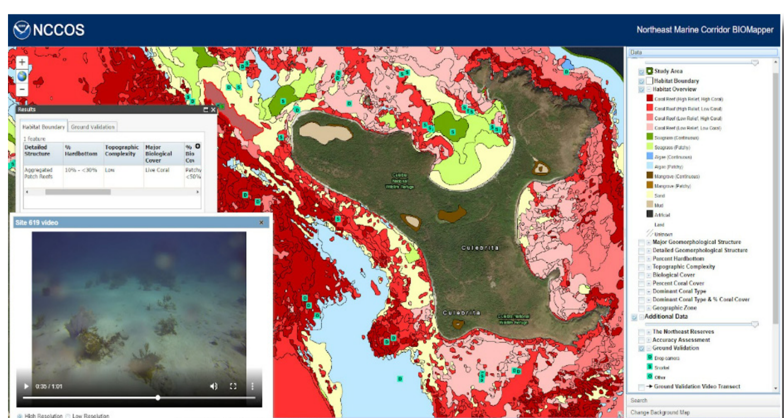
HMT focuses on providing effective visualizations for science communication and outreach. The tools can simplify the display of complex data and patterns so that a broad range of users can more easily understand their meaning. By Implementing an approach where visualizations are considered a core component of all projects, HMT can better communicate and highlight the capabilities of HMT to map and characterize habitats and associated biota using advanced technologies and quantitative approaches.

## *Applications*

Three key examples described below highlight how HMT visualizations help support decision-making and also foster stakeholder engagement and outreach initiatives.

### Online Maps

Web mapping services, such as BIOmapper, facilitate the exploration of habitat mapping data in marine and freshwater ecosystems. The tool currently features habitat maps generated from 20 geographic areas, including several federal marine protected areas in the Pacific and Caribbean, and a recently designated national marine sanctuary in the Great Lakes. BIOmapper displays mapping data from remote sensing and predictive models and in-water site videos. Users can freely and easily interact with these data in an online environment to explore underwater data, discern spatial patterns, and examine habitat distributions, which can collectively support resource management decisions. The BIOmapper allows users to toggle between the habitat map and several other spatial layers that represent biological cover or the geomorphological complexities, then watch the underwater videos to learn more about the ecosystems.




*A BIOmapper displaying a benthic habitat map and a GV video from the Northeast Marine Corridor, Puerto Rico.*

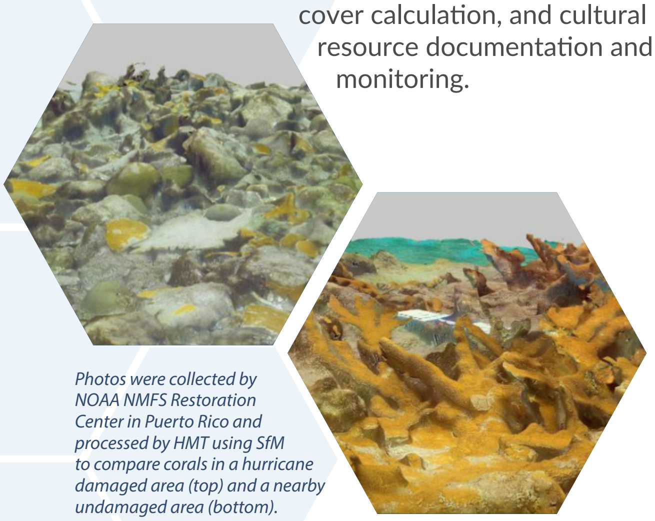
## Mapping Platforms

3D Mapping Platforms, such as Living Shipwrecks 3D, are freely available online and allow diverse audiences to directly engage with remote sensing data coupled with photographs and videos. The website, which was a product from a collaboration between HMT and the Monitor National Marine Sanctuary, has been used primarily to support stakeholder engagement and outreach efforts ahead of a proposed sanctuary expansion.


*Living Shipwrecks 3D is an online interactive tool that displays habitat mapping data collected from acoustic surveys over shipwrecks, as well as photographs and videos. The tool combines bathymetry maps with maps of fish (white circles) detected with echosounders.*

## Photogrammetry Models

Photogrammetry, such as Structure from Motion, or more commonly SfM, uses computer vision and a series of overlapping images to produce accurate and detailed three dimensional models of seafloor shape and habitats. HMT develops visualization products created from SfM such as interactive 3D models, photomosaics, and digital elevation models. Online interactive models can be very compelling, allowing users to spin and zoom them and use built in tools for measuring features. HMT's SfM models can be used for a wide variety of applications including damage and recovery assessment, change detection, coral percent cover calculation, and cultural resource documentation and monitoring.



*Photos were collected by NOAA NMFS Restoration Center in Puerto Rico and processed by HMT using SfM to compare corals in a hurricane damaged area (top) and a nearby undamaged area (bottom).*

## *Future Directions*

HMT will remain at the forefront of visualization development and pioneer new approaches towards data representation.

**GOAL 1:**
***Explicitly plan for and incorporate visualization in future HMT projects.***

- Incorporate visualizations into project proposals not only as deliverables, but also as leverage for translating project findings to key audiences and partners
- Develop concrete and deliberate plan for visualizations with project partners, using approaches including storyboarding and tailored workshops
- Harness visualizations, in partnership with the NCCOS communications branch, for use in presentations, websites, social media, media interviews, and other avenues to facilitate stakeholder engagement and outreach initiatives

**GOAL 2:**
***Build capacity in, develop infrastructure for, and pursue training in visualization techniques.***

- Establish a working group, think tank, or "visualization lab" (e.g., "HabViz Lab") dedicated to supporting visualization innovation for projects across HMT
- Formalize partnerships with visualization labs and software developers to stay on the cutting edge
- Funnel resources towards maintaining expertise by deliberately learning and dedicating time to pursuing or pioneering new visualization approaches (e.g., capacity building, infrastructure development, and training)
- Enhance graphic design expertise of HMT to develop infographics and conceptual diagrams that help illustrate the mapping process and findings

**GOAL 3:**
***Generate visualization standards and pursue advances in visualization.***

- Create standards and formal guidance for visualization development and associated communication to help endorse use and guide others
- Pursue multi-platform (e.g., computer, tablet, mobile) visualizations to reach broader audiences
- Advance capabilities for seamlessly integrating and displaying data from multiple mapping and characterization sensors into a common and accurate spatial framework (e.g., co-registry of multi-modal and multi-scalar mapping)

# WORKFORCE FRAMEWORK

## Competencies & Capabilities

HMT workforce model is based on a hybrid mix of federal employees and contractors. This model allows HMT to staff a permanent core group of federal employees with a mix of contractors. Contractor personnel allows HMT to add technical capabilities to fill needed gaps or adjust skills as necessary, and meet project staffing requirements. However, there are negative aspects to this model as well as it has high dependency on external or competitive “soft” funding to support the contractor workforce, which generally lacks annual stability for multi-year forward planning. Federal positions lost to attrition or retirement are difficult and slow to fill.

In general, HMT federal employees are often: experienced project managers and senior subject matter experts, proficient at building new partnerships, identifying and pursuing new sources of funding, and identifying future research efforts. HMT contractors are primarily technical and field support staff, analysts with specialties in many technical disciplines needed to support the success of our projects.

Multi-year funding uncertainties contribute to workforce staffing challenges. Subsequently, HMT has limited capacity to support or engage in new projects. Most employees are fully tasked, so the ability to add additional projects or support new program priorities is extremely challenging and requires careful balancing. As such under current conditions, evaluating HMT carrying capacity and potential new starts requires careful and frequent evaluation and balancing of funding needed, personnel and project delivery commitments.

In 2021, the current composition of HMT is four federal, one NOAA Corps officer, and eight contractors. 48% of HMT budget is allocated to support contractor labor (based on 2019 funding analysis). In the last five years, two federal employees have retired.

## Skillset Gaps

HMT continually explores opportunities to increase and diversify skills and expertise amongst it’s staff, resulting in a more adaptable and flexible approach to the needs of partners and projects. In an effort to discern the current level and variety of expertise and skills within HMT, an assessment of competencies and capabilities was conducted.

Credit: Oregon State University

Each member of HMT conducted a self-evaluation to report their respective proficiency levels (expert, moderate, beginner, none) for 22 detailed competencies organized into three categories: core technical, core professional, and specialty competencies. The three competency categories are defined as:

*Core Professional Competency*
Critical area of expertise that includes "soft skills" or universal skills sets that relate to staff members' abilities to conduct, communicate, work as a team, support continued learning, or other functions that serve as a cross cut of the staff members' specific area of expertise and the larger HMT mission.

*Core Technical Competency*
Critical area of expertise that forms a "must have" for any staff member working within the mission space of HMT. This covers the technical aspects of the job to include methodologies, procedures, use of equipment, or other capabilities that form the backbone of the HMT mission function .

*Specialty Competency*
Area of expertise that separates an overall average to slightly above average employee to one that may excel in the mission area (e.g., machine learning, average staff members may have computational skills but someone proficient in machine learning would provide higher value in this mission area).

The exercise was conducted to identify and define core competencies needed to achieve HMTs objectives (see Focal Areas) and to gauge HMT’s current level of proficiency for each competency.

*The proficiency levels were define as:*

**Expert**
I'm known as a subject matter expert or lead in this competency

**Moderate**
I do this with minimal oversight.

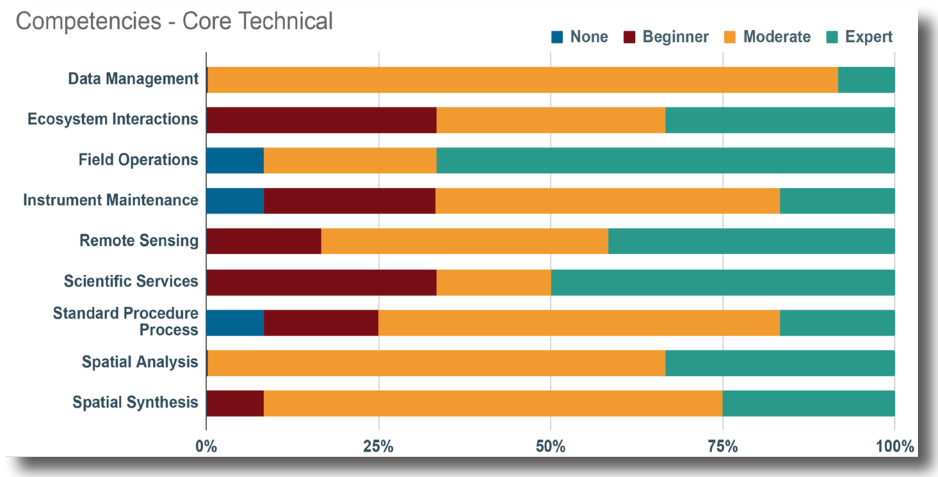
**Beginner**
I do this with moderate oversight.

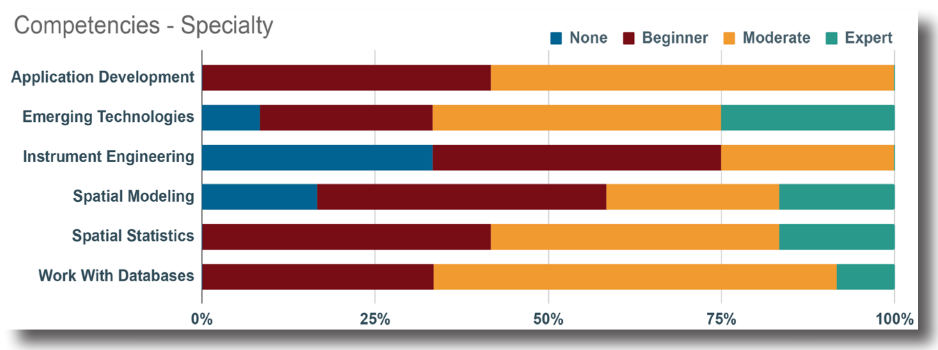
**None**
I have lots of great competencies, and this isn't one of them!

The results of the self-evaluation highlighted the diverse competency skills of HMT personnel, promoting the capabilities in providing multi-faceted approaches to habitat mapping. However, the process was intended to identify "where are our gaps" to help inform professional and training opportunities, as well as, to use this information to prioritize future hiring needs. The competency analysis identified some clear deficiencies and gaps in our current HMT workforce.

The results specifically identified competency gaps at expert level proficiency in "Core Technical" and "Specialty" categories for: Data Management, Instrument Maintenance, Database Operations, Instrument Engineering, Application Development, Spatial Statistics, and Spatial Modeling. However, Data Management is currently being addressed at the MSE level with one additional hire expected. It is anticipated these positions and skills will provide expertise which permutates to the project level. Application development, which includes the design and implementation of applications and web mapping services, is currently being provided at the Branch level. However, web mapping services and visualization are a growing technical need and capability within the Team.

HMT continues to invest in the expansion or increased utilization of uncrewed systems and vehicle and sensor payloads, which require expertise in procuring, testing, engineering, integration, operation, and maintenance. Furthermore, there were bi-modal results for Project Management and Research Proposals in the "Core Professional" category, identifying high proficiency of these two competencies, but for only a few individuals.



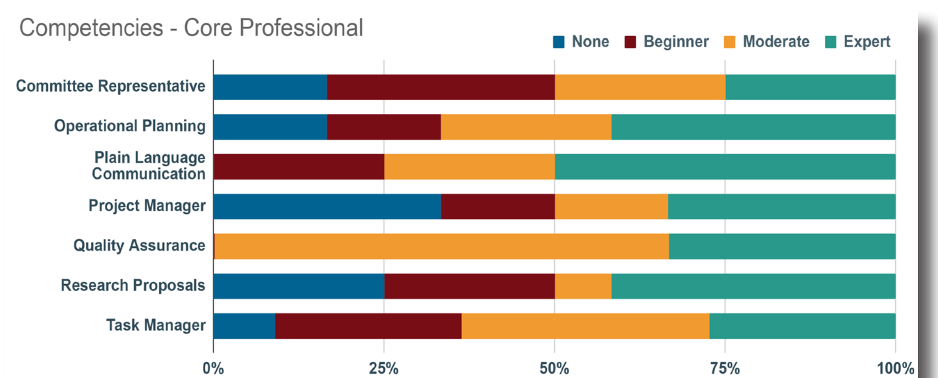



*Table of competency and proficiency definitions*

| Competency | Definition |
|---|---|
| ***Core Professional*** | |
| Committee Representative | Able to represent NOAA as an expert committee member |
| Operational Planning | Ability to conduct field effort costing, planning, contracting, equipment purchase, methodology design, risk assessment, and environmental compliance towards the successful execution of complex field campaigns. |
| Plain Language Communication | Ability to communicate scientific and technical concepts in oral and written form to audiences ranging from layperson to expert. Includes briefings, web-site content, technical reports, and peer-reviewed journal articles. |
| Project Manager | Able to develop new proposals including scoping, costing, personnel needed, project and deliverable scheduling; ability to manage a team, meet deliverable schedules, quality control products, execute expenditures within budget, and communicate results effectively orally and in writing. Ability to foster and develop new partner relationships. |
| Quality Assurance | Programs of systematic proactive sampling methods and standards development that work to improve quality, minimize defects, assure confidence and product integrity. |
| Research proposals | Able to write research proposals. |
| Task Manager | Able to manage a small team of personnel; develop technical approaches; quality control products; communicate results orally and in writing; and track task budget and scheduling as part of a larger project. |
| ***Core Technical*** | |
| Data Management | Able to design, organize, and manage large data streams with diversity of file type and sizes to optimize storage, retrieval, dissemination, and archival. |
| Ecosystem Interactions | Able to assess the relationship among the physical, chemical, and biological interactions of various aquatic (marine and freshwater) ecosystems with living marine resources. |
| Field Operations | Ability to safely execute the collection of in situ field data from a variety of platforms, in various weather conditions, and using a variety of sensor/sample collection techniques. Requires familiarity with safe operations in remote conditions, operations risk assessment, and familiarity with operation of sample/sensor instruments or apparatus. |
| Instrument Maintenance | Evaluates, configures, and troubleshoots existing scientific instrumentation systems. |
| Remote Sensing | The acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on-site observation, especially the Earth. Remote sensing is used in numerous fields, such as geography, land surveying and most earth science disciplines; it also has military, intelligence, commercial, economic, planning, and humanitarian applications. In current usage, the term "remote sensing" generally refers to the use of ship-, UxS-, satellite- or aircraft-based sensor technologies to detect and classify objects on Earth. |
| Scientific Services | Ability to apply scientific investigation design, practical problem solving, and statistical/analytical skills towards applied research efforts. Query partners to determine scientific research and product needs and communicate complex science to a broad range of stakeholders. |
| Spatial Analysis | Compilation, processing, and analysis of remote sensing data in support of mapping programs; vertical and horizontal positioning, sound speed corrections, optical imagery corrections, data processing, image analysis, analytical aerotriangulation, digital cartographic data compilation, composition of data structures for GIS application, and completion of associated graphic, textual, and digital products required to meet program requirements. |
| Spatial Synthesis | The integration of existing and new data into synthesized, co-registered, and spatially compatible geodatabases. Includes a range and variety of source types and file formats. |
| Standardized Procedure Process | Able to develop, maintain, and distribute standardized procedures |
| ***Specialty*** | |
| Application Development | Ability to design, code, and support custom GIS or web mapping applications for analyzing data and disseminating mapping products. |
| Emerging Technologies | Knowledge of emerging technologies (e.g., applications, hardware, software, and telecommunication), and their applications and the implementation of information systems to meet organizational requirements. |
| Instrument Engineering | Designs, tests, builds, and optimizes new and existing scientific instrumentation to meet requirements identified for scientific measurements. |
| Spatial Modeling | The use of machine learning, artificial intelligence, deep learning on high performance machines, or cloud networking to conduct complex, computationally intensive analysis. Able to develop, code, validate, evaluate, and operate predictive spatial models to map the spatial and temporal distribution of physical, oceanographic, and geological aspects of marine habitat, and secondarily species distributions, and/or marine wildlife survey data. |
| Spatial Statistics | Apply spatial temporal statistical methods to aggregate and classify abiotic and biotic objects and phenomena from multiple sources. Apply statistical principles and methods to analyze data and solve problems, including automating data analysis using machine learning, characterize existing and new observation data sources, and develop new and improve data analysis techniques. |
| Work with databases | Able to develop and use complex multivariate environmental databases |

## Future Directions

The competency exercise helped to identify several challenges HMT needs to address and improve workforce readiness and the continued development of individual employees. Over the next five years, HMT seeks to address these gaps through the following workforce initiatives:

- Seek to recruit and hire the most qualified and diverse workforce.
- Seek ways to advance the professional and technical growth of the team.
- Seek ways to recruit, mentor, and/or provide opportunities through internships and fellowships to support young professional scientists.
- Identify partnerships, cooperative agreements, and other mechanisms to address needed skills or capabilities as an alternative to building this capacity internally.
- Conduct annual competency assessment to identify workforce technical gaps and update hiring assessments and needs per five year focal area projections.
- Develop competency assessment for future HMT hiring and position recruitment.
- Seek ways to achieve and promote optimum work life balance.
- Develop and implement procedures for contractor reviews synchronized with the federal review schedule.
- Develop and implement procedures for contractor project and task work plans, oversight procedures, and protocols for adjustments when needed synchronized with the federal work plan development schedule.

In order for us to maintain the current project commitment trajectory or to grow our portfolio these are the competencies of greatest need which will be used for developing future federal and contractor position description announcements and recruitments:

- Senior scientists able to provide project management, budget planning, scoping and execution
- Additional spatial analysis scientists who are able to execute advanced data synthesis.
- Spatial modelers to formulate innovative new techniques, predictive modeling, further cloud-based processing, and advance AI and machine learning techniques.
- Instrument and platform design, engineering, and maintenance to support the growth of an increasing sensor, payload, and platform capability within HMT.

# RELATIONSHIPS

## Importance of Partners & Relationships

Establishing and maintaining collaborative relationships with federal and non-federal partners is crucial to the Habitat Mapping Team's core mission. Important partnerships include, but are not limited to, state and territorial agencies, academic and cooperative institutes, centers of excellence, industry, programs across NOAA, non-NOAA federal agencies, non-governmental agencies, and defense. These partnerships are critical because: (1) they ensure HMT's benthic habitat maps and associated products are accurate, timely and tailored to meet the specific needs of marine researchers, managers and end users in the region; (2) they allow HMT to leverage the existing and extensive local knowledge in the region and incorporate that local perspective and expertise into our products, (3) they establish open lines of communication between technical experts and non-technical end users, which is essential to optimize the development and use of our habitat products, and (4) collaborate with partners to provide support in workforce staffing needs and gaps (See Workforce Framework chapter), research and development, and technical innovation.

## Current Relationships

HMT's current partnerships range broadly in terms of geography, disciplines (see Focal Area chapter), and organizations. At any one point in time, the mix of organizations, geographies and disciplines varies, and largely depends on the list of active projects at the HMT. Historically, our team's geographic footprint has spanned the U.S. EEZ, and we support partners with all coastal states and territories from the U.S. Caribbean to the Commonwealth of the Northern Mariana Islands, and from Alaska to American Samoa. In each geographic location, HMT invests substantial time and effort to establish relationships with local organizations, stakeholders and experts to understand the unique issues, challenges and needs of the region. These organizations have included federal, state, local, territorial and tribal agencies and government entities, as well as academic institutions, non-governmental organizations and key members of industry. Our work is also often multidisciplinary, partnering and collaborating with experts in fisheries, energy, charting, ocean policy and conservation, among others. Overall, HMT is focused on collaborating and building relationships that improve the utility and applicability of our habitat products.

## Relationship Opportunities

While collaborating is essential to the HMT, the team is constantly exploring new opportunities, enhancing existing relationships, and advancing ways to build partnerships. For example, we strive to enhance existing relationships by encouraging marine managers to incorporate HMT project support and scoping discussion earlier in the decision making processes. Broadly in marine science, there is often a disconnect between technical experts and managers, which are the end users. This disconnect results in lost opportunities for the technical experts to help answer real-world, marine management questions, and lost opportunities for managers to have the best available information. At HMT, our projects and involvement frequently ends when decision making processes begin. However, both managers and HMT would benefit from our continued involvement, helping managers better understand how to apply our products and helping the HMT better understand how our products could be improved to support these decision making processes. Looking forward, HMT should budget programmatic time and resources to work side by side with managers to apply our products in their decision making processes. On the management side, non-technical users could help forecast what technical needs, levels of capacity, and milestones are needed for decision-making processes so HMT can better plan for and address future needs. Over the long term, closer partnerships and better communication will lead to better products from HMT, more informed decisions by managers and more favorable marine conservation outcomes for the region.

In addition to enhancing existing partnerships with managers, HMT should look for opportunities to work with new partners focused on climate change, resiliency, and restoration related issues. Climate change is negatively impacting benthic habitats in the United States at multiple spatial scales. The loss of key habitats, like live coral reefs or mangroves, is negatively impacting the safety, the economy and the resilience of coastal communities. HMT is uniquely positioned to help coastal communities and management agencies not only quantify, understand and visualize these habitat losses over time, but also work with partners to design forward looking solutions to reverse these losses. As a team, we should pivot from tracking habitat declines to working with partners to innovate solutions that will help ocean and coastal communities adapt to their changing environments. Examples of those types of efforts include HMT's involvement in supporting habitat restoration efforts such as Mission:Iconic Reefs and NRDA MDBC projects. Our team should also work with partners to quantify the effectiveness of these solutions, helping managers and communities better prioritize how to use their limited resources. Overall, HMT knowledge, skills and tools will be increasingly relevant and needed to help solve complex, multidisciplinary and fast moving problems in our ocean and coasts.

## Future/Expanding Relationships & Collaborations

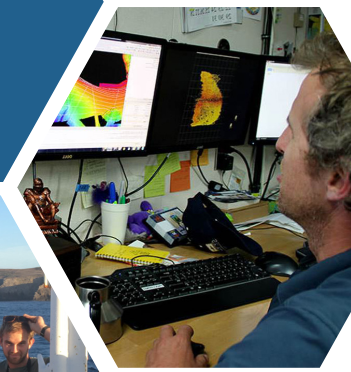
Looking ahead five years, the Team should pursue the following goals related to partnerships and relationships:

**GOAL 1:**
***Allocate programmatic time and funding for HMT staff to work closely with marine managers and end users to apply our products during their decision making processes.***

However, traditional HMT efforts have been challenged by the lack of flexibility to continue the relationships and support with marine managers beyond the final product delivery date, and the lack of access to sustained funding sources to enable holistic and longer duration support efforts. However, the new NCCOS Programmatic Approach to funding should (to be implemented in FY2023), in theory, empower and provide the mechanism for project managers to work closely with end users to define an end to end process, and develop multi-year collaborative projects.

**GOAL 2:**
***Diversify HMT's partnership network, focusing on collaborations that not only quantify, but also address climate change and restoration efforts towards benthic habitats, marine resources, and coastal communities.***

Currently, HMT routinely develops products that quantify habitats and their decline due a range of factors, including climate change and natural disasters. However, HMT is uniquely positioned to help coastal communities, managers and researchers not only quantify and visualize these habitat losses over time, but also work with partners (e.g., FEMA, DOD, NOAA , NOAA Restoration Center) to design forward looking solutions to reverse these losses. Overall, HMT knowledge, skills and tools will be increasingly relevant and needed to help solve complex, multidisciplinary and fast moving problems in our ocean and coasts, including climate change and habitat restoration, into the future.



**GOAL 3:**
***Strengthen HMT's partnership and collaboration network to enable a hybrid workforce model and enhance our recruitment capabilities.***

HMT's business model requires core technical and professional competencies to support its mission requirements (See ***Workforce Framework***) which can be difficult to adequately predict and staff given changes in annual project commitments. Furthermore, HMT is often challenged to identify and adopt emerging technologies and workflows. Instituting HMT workforce agility (i.e, competencies and personnel numbers) is key to success. Strong partnerships with academic institutions, industry, and defense agencies are critical solutions to addressing HMT challenges. HMT must enhance its use of external partnerships to address surges in personnel needs; furthering research and development efforts; and providing technical services and expertise which are beyond the core scope of the Team.

# LOOKING AHEAD

HMT and several of our key collaborators undertook this strategic planning effort in order to better understand and define our present-selves. But also to forecast who we want to be in the future, and identify steps to reach those goals. A strategic plan is unusual for a group of our size. And admittedly, HMT is atypical for marine resource organizations given the geographic and technical breadth of our focus. But HMT takes great pride in being different and also the goal of accomplishing great science.

HMT, collectively, coined a new term which best describes how we work and how we see ourselves benefiting the partners that we support. Inter-niche, the concept of "filling and connecting" gaps created by other niches to provide integrated scientific solutions.

HMT strives to be the glue that binds disparate pieces of information together into a meaningful and applicable geospatial intelligence solution. We can also provide value added synthesis that combines and enhances other discrete efforts into a powerful, new, and integrated science medley.

HMT is unique, and also very ambitious. This plan is not intended to be a static snapshot, but rather guidance that we will revisit annually as a roadmap and scorecard, and is intended to identify the stretch goals HMT will strive to accomplish in the next five years.

Credit: Cory Ames (CSS, Inc./NOAA NCCOS)

The mission of the National Centers for Coastal Ocean Science is to provide managers with scientific information and tools needed to balance society's environmental, social and economic goals. For more information, visit: http://www.coastalscience.noaa.gov/.