NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 1

Program History, Evolution and Ethos

Mark E. Monaco, Ph.D.
Chief, NCCOS Marine Spatial Ecology Division

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NCCOS Priorities

- **Marine spatial ecology**
- **Coastal change: vulnerability, mitigation, and restoration**
- **Social science**
- **Stressor impacts and mitigation**

Oxford Lab

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

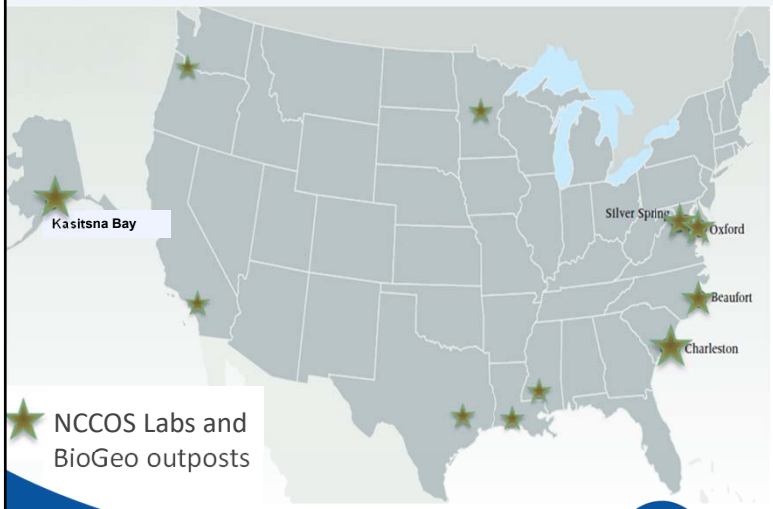
we deliver ecosystem science solutions to sustain thriving coastal communities and economies

Kasitsna Lab

- *Ecological and biogeographic assessments*
- *Habitat mapping*
- *Social science*
- **Regional ecosystem research to support EBM**
- **Coastal aquaculture siting and sustainability**
- **Coastal Change: vulnerability, mitigation, and restoration**

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

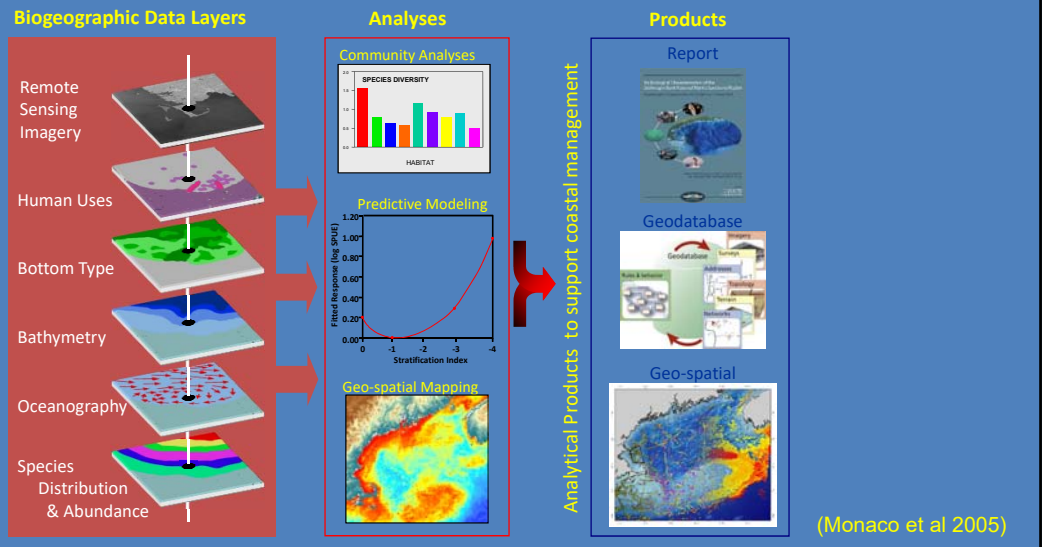


Key Events that shaped BioGeo!

- 1980's Strategic Assessments LMRs
- 1983 Nation Estuarine Inventory
- 1985 ELMR initial underpinnings of BioGeo
- 1991 ESRI's ArcView Released
- 1993 BioGeo created in SEA Division
- 1999 NCCOS created: from NMFS labs and BioGeo
- 2001 CRCP/USCRTF Map US Coral Reefs
- 2003 BioGeo Assessment Plan: Marine Sanctuaries
- 2004 Committed to "Field Studies" to enable spatial analysis/modeling
- 2004 Public version of habitat digitizer was created
- 2004-07 Foster Multi-beam and Fish Acoustics
- 2005 Hawaii Mapping
- 2009 Made commitment to build social science capability
- 2010 Completed Nation's Coral Reef Ecosystem Maps
- 2011 BOEM Environmental Studies Program-Wind Energy
- 2011 Deep Coral Mapping & Research, NCRMP, BioGeo Assessments, BOEM Modeling
- 2017 NCCOS re-alignment: Beaufort, Oxford, Kasitsna Bay
- 2018 Public version of the participatory GIS tool was created
- 2019 DWH Open Ocean, BOEM, DOD Mapping, Fish Acoustics

Biogeographic Assessment Framework

Biogeography: study of the spatial and temporal distributions of organisms, associated habitats, and the historical, biological, physical drivers of distributions (including humans)

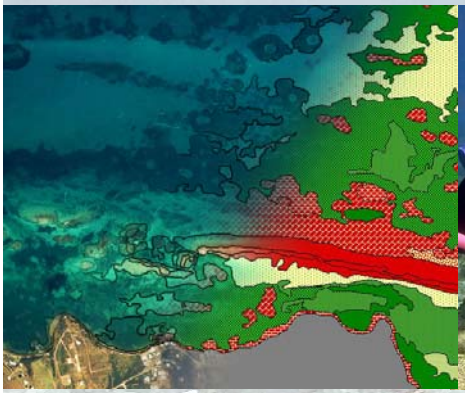


(Monaco et al 2005)

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

Integration of Mapping, Monitoring and Assessments



Habitat maps

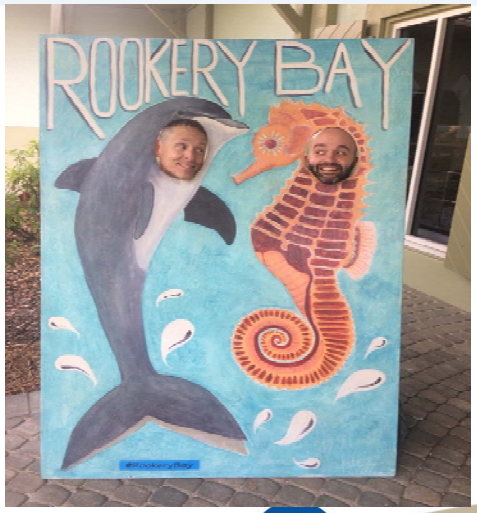
Divers collecting benthic habitat, fish size, and abundance data along a transect.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

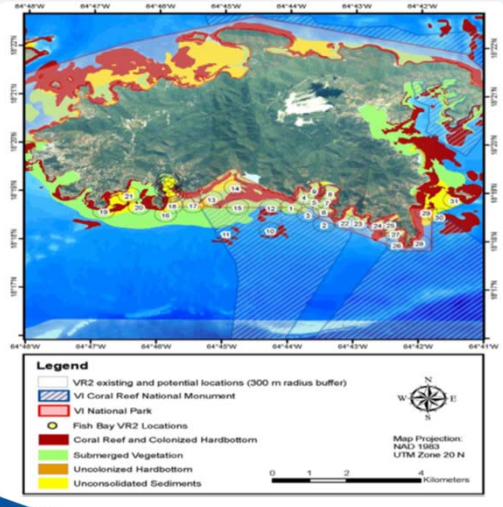


NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

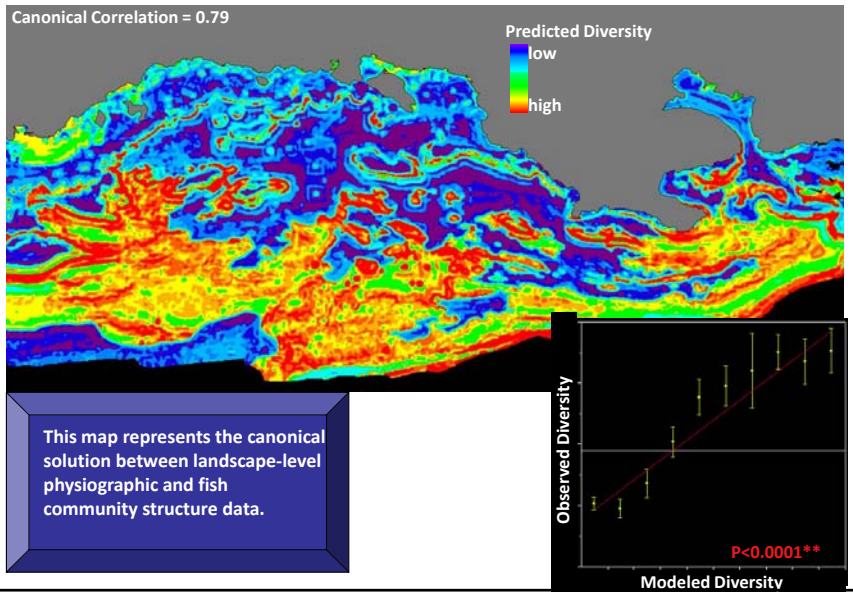
we deliver ecosystem science solutions to sustain thriving coastal communities and economies



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

Ecological Modeling



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

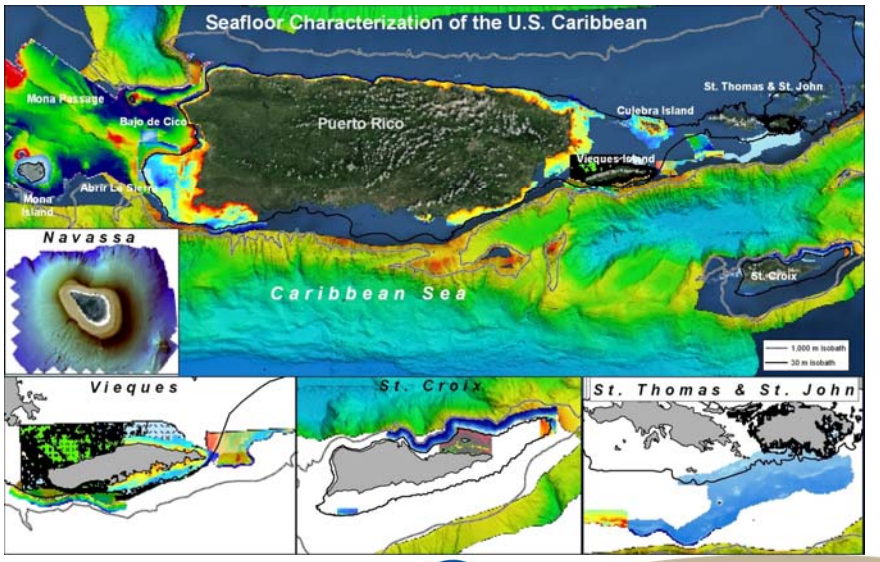
we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NOAA Ship Nancy Foster Missions

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

Marine Spatial Planning: MPAs



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

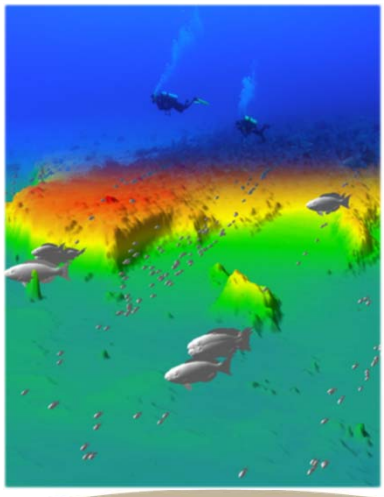
we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

Fisheries sonar in Coral Reef Ecosystems

- Fish acoustics processing: bottom detection, and noise removal.
- Fish counts, fish size, and fish density are summarized and mapped.
- Delivery as shapefiles with ISO metadata.



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

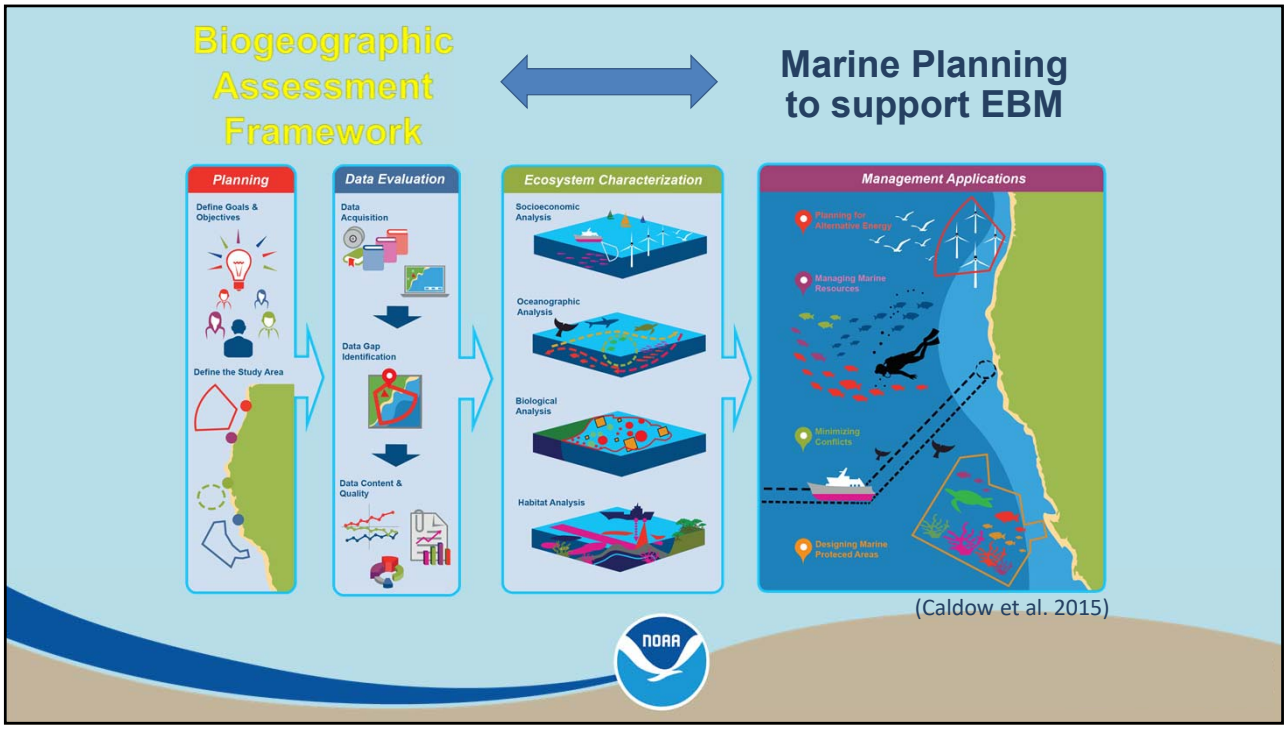
- Discovery & Identification of Deep Water Corals

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

BIOGEOGRAPHY PROGRAM REVIEW

BIOGEOGRAPHIC ASSESSMENT | HABITAT MAPPING | PRODUCTS

Program Evolution

Mark E. Monaco, Ph.D.
Chief, NCCOS Marine Spatial Ecology Division
240-533-0327 (mark.monaco@noaa.gov)

Ethos: The characteristic spirit of a culture, era, or community as manifested in its attitudes and aspirations

http://coastalscience.noaa.gov

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 2

MULTIBEAM SOUND NAVIGATION RANGING (SONAR)

Shallow Water Coral Reef Ecosystem Mapping

Tim Battista, Oceanographer

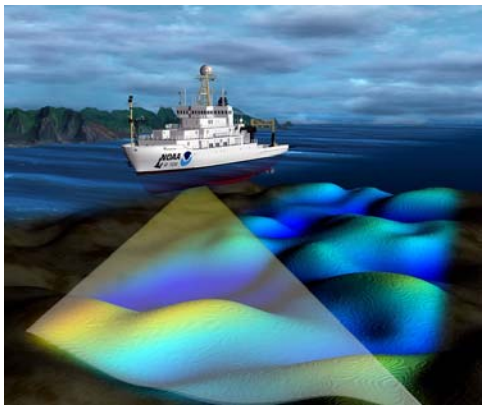
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Multibeam SONAR

DEFINITION

Sonar (sound navigation ranging) is a technique that uses sound propagation to navigate, communicate with or detect objects on or under the surface of the water. A ***multibeam echosounder*** is a type of sonar that is used to map the seabed. Like other sonar systems, multibeam systems emit sound waves in a fan shape beneath a ship's hull. The amount of time it takes for the sound waves to bounce off the seabed and return to a receiver is used to determine water depth and backscatter, a measure used to determine bottom type. Unlike other sonars, ***multibeam systems*** use spatial filtering to extract directional information from the returning soundwaves, producing a swath of depth readings from a single ping.



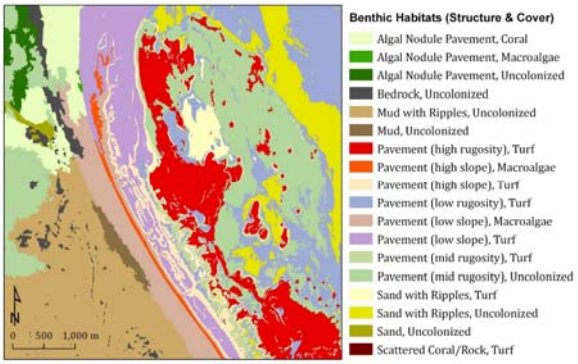
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Multibeam SONAR

WHAT WE DO

The Biogeography Program uses multibeam survey techniques to develop medium- to large-scale benthic habitat maps in waters ranging from 5 to 2,000 meters depth. Survey activities are often performed using NOAA fleet vessels in coordination with NOAA's Office of Coast Survey (OCS) to ensure charting grade bathymetric and navigational accuracy. Bathymetry and backscatter collected on these missions are processed by OCS and Biogeography Program staff to generate high resolution map products of depth, substrate hardness and roughness, and then further processed into maps depicting habitat type (*e.g.*, sand, mud, coral, seagrass, boulder, *etc.*). The Biogeography Program has developed data collection, accuracy assessment, and processing standards that are now commonly deployed by OCS during their navigational charting missions.



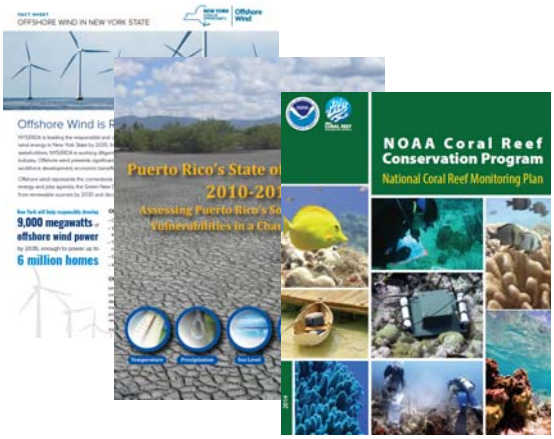
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Multibeam SONAR

PRODUCT APPLICATION(S)

Biogeography Program map products developed using multibeam SONAR have been used in a wide range of management, policy, and research settings by Federal, State, NGO and academic partners, including:

- Monitoring & Research Program Designs
- Marine Protected Area Designations/Expansions
- Submerged Lands Planning
- Local Area Use Regulations
- Climate Adaptation Plans
- Defense Facility Planning
- Integrated Ecosystem Models
- Biogeographic Assessments



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Multibeam SONAR

CASE STUDY

Shallow Water Coral Reef Ecosystem Mapping

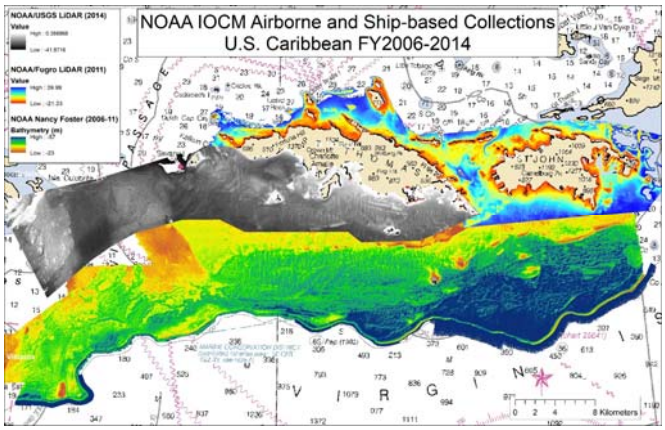
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Multibeam SONAR

WHY WE CARE

The condition and extent of coral reef ecosystems in U.S. States and Territories is still poorly understood in many areas. The collection of these data by NCCOS has provided critical informational to drive management decisions in areas ranging in depth from 5-2,000m by filling data gaps. The lack of continuous spatial information beyond divable depths (30m) NOAA's Coral Health and Monitoring Program (NCRMP) has limited the ability of resource managers to understand the condition and extent of coral reef resources; this project fills that gap.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Multibeam SONAR

WHAT WE ARE DOING

Our activities target high priority sites identified by local and regional managers where significant information gaps exist, and where the absence of sufficient biophysical modeling information has inhibited an evaluation management efficacy.

Our seafloor mapping has been supported by NOAA's Coral Reef Conservation Program since 2004 and we have successfully completed seafloor mapping of 3,000 km^2 in the U.S. Caribbean alone. Our efforts are focused on filling data gaps in the highest management priority areas. In addition, our data and related products are used by others, in following with the objective of the Integrated Ocean and Coastal Mapping (IOCM) effort, "Map once, use many times."

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Multibeam SONAR

BENEFITS OF OUR WORK

Our habitat maps provide a critical spatial framework for informing and understanding relationships in coastal coral reef ecosystems (5–2,000 m). Resource managers have expressly identified the need for data in the coastal environment, which is exceedingly difficult to collect over large areas other than with ships and aircraft. Stakeholders have identified the need for seafloor mapping to use in regulatory, management, infrastructure siting, damage assessment, and monitoring design applications.

An example of the impact of this work is Caribbean Council proposal to modify closure regulations for three seasonally closed areas off Puerto Rico. Our efforts were critical in collecting information for these closure areas.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Multibeam SONAR

NEXT STEPS

This project is ongoing and continues to focus and collect data in priority areas identified by jurisdictional partners through NOAAs Coral Reef Conservation Program (CRCP). In the near-term, we will specifically:

- Develop map products from the at-sea survey efforts;
- Assist NOAA's National Marine Fisheries Service (NMFS) in developing refined fishery independent sampling surveys stratified by our map products; *and*
- Identify critical fish aggregations sites in the US Caribbean region.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 3

SPLITBEAM SOUND NAVIGATION RANGING (SONAR)

Mapping animal and bubble abundance and distributions

J. Christopher Taylor, PhD
Research Ecologist

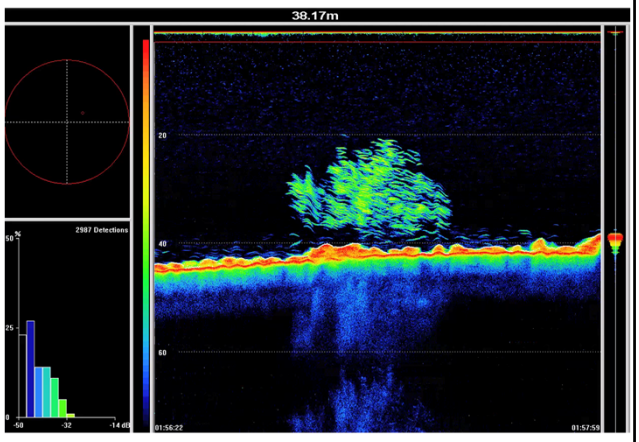
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Splitbeam SONAR

DEFINITION

Sonar (sound navigation ranging) is a technique that uses sound propagation to navigate, communicate with or detect objects on or under the surface of the water. A ***split-beam echosounder*** is a type of sonar that is used to detect, enumerate and map objects in the watercolumn. Splitbeam echosounder systems emit sound pulses that reflect off the seabed, fish, plankton and bubbles and return a range to target and backscatter or **target strength** used to infer object size, density and organism type. Calibration of splitbeam sonars allow for comparison of backscatter intensity from fishes across geography and ecosystems.



JULY 23-25, 2019
SILVER SPRING, MD

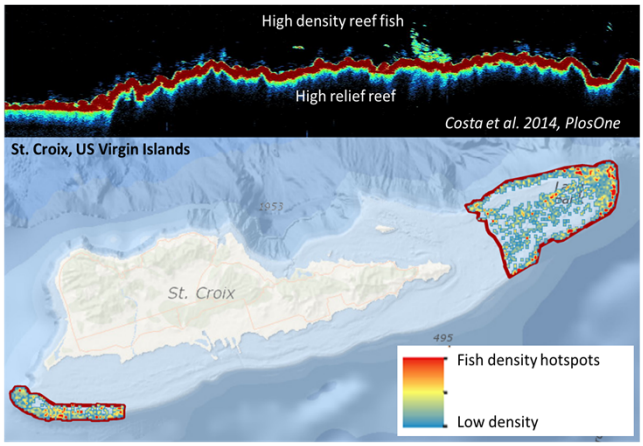
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Splitbeam SONAR

WHAT WE DO

The Biogeography Program uses splitbeam survey techniques to develop maps of relative fish biomass across seascapes. Surveys are often in conjunction with seafloor habitat mapping missions showing fish sizes and densities at high resolution over large extents. The techniques the Biogeography Program use are recognized in international standards such as International Council for the Exploration of the Sea (ICES) Workgroup on Fisheries Acoustics Science Technology (WGFAST). Products include:

- Defining relative habitat value in coral, rocky and artificial reefs
- Maps depicting fish aggregations or biological "hotspots" relative to management boundaries



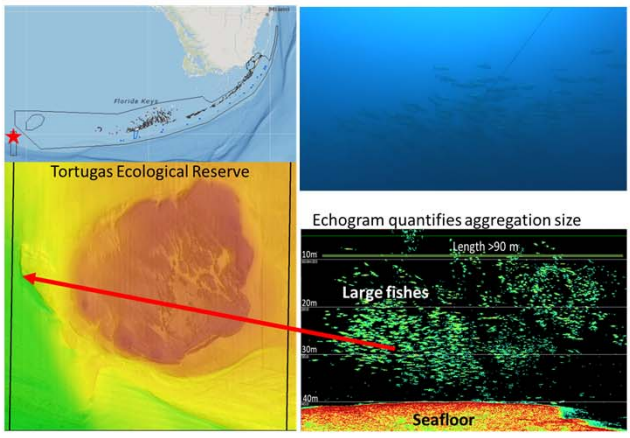
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Splitbeam SONAR

WHAT WE DO

The Biogeography Program uses splitbeam survey techniques to develop maps of relative fish biomass across seascapes. Surveys are often in conjunction with seafloor habitat mapping missions showing fish sizes and densities at high resolution over large extents. The techniques the Biogeography Program use are recognized in international standards such as International Council for the Exploration of the Sea (ICES) Workgroup on Fisheries Acoustics Science Technology (WGFAST). Products include:

- Defining relative habitat value in coral, rocky and artificial reefs
- Maps depicting fish aggregations or biological "hotspots" relative to management boundaries



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Splitbeam SONAR

PRODUCT APPLICATION(S)

Products developed using splitbeam SONAR have been used in research and place-based management by federal and state agencies and academic partners. These products include:

- Biogeographic assessments
- Marine Protected Area designation or expansion
- Offshore renewable energy planning and siting
- Environmental assessments of marine oil and gas leaks
- Visual and immersive tools for education and outreach

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Splitbeam SONAR

CASE STUDY

Mapping gas and oil seeps for environmental assessments: Actionable intelligence for containing a marine oil spill

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

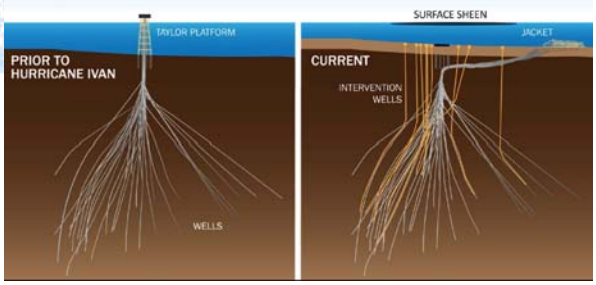
Habitat Mapping | Case Study | Splitbeam SONAR

WHY WE CARE

Natural and accidental oil seeps present potential risks to living marine resources. Remotely sensing and mapping plumes is a critical first step to defining source, extent and potential impact.

The Bureau of Safety and Environmental Enforcement (BSEE) requested support to characterize an oil and gas seep at the site of a hurricane-damaged platform toppled in 2004 in the northern Gulf of Mexico.

Oil and gas bubbles in water are excellent reflectors of sound pulses produced by high-frequency splitbeam and multibeam sonars.



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Splitbeam SONAR

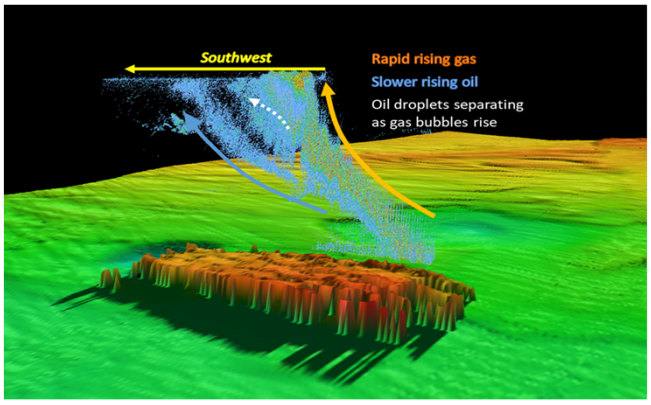
WHAT WE ARE DOING

Mobilized in <2 months:
Ship-integrated splitbeam and multibeam sonars were used to map the 3-dimensional extent and acoustic backscatter characteristics of the plume in the watercolumn.

ROV-integrated sonars were used to detect and locate the precise seabed origins and oil and gas components of the plumes.

Video observations validated plume components and used to estimate oil flow rates.

Chemistry confirmed age and degradation consistent with active well leaking oil and gas.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Splitbeam SONAR

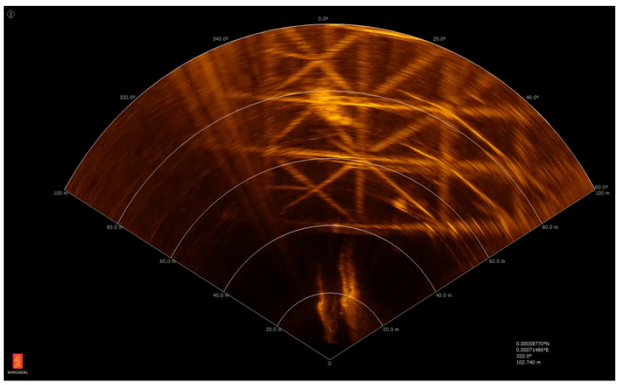
WHAT WE ARE DOING

Mobilized in <2 months:
Ship-integrated splitbeam and multibeam sonars were used to map the 3-dimensional extent and acoustic backscatter characteristics of the plume in the watercolumn.

ROV-integrated sonars were used to detect and locate the precise seabed origins and oil and gas components of the plumes.

Video observations validated plume components and used to estimate oil flow rates.

Chemistry confirmed age and degradation consistent with active well leaking oil and gas.



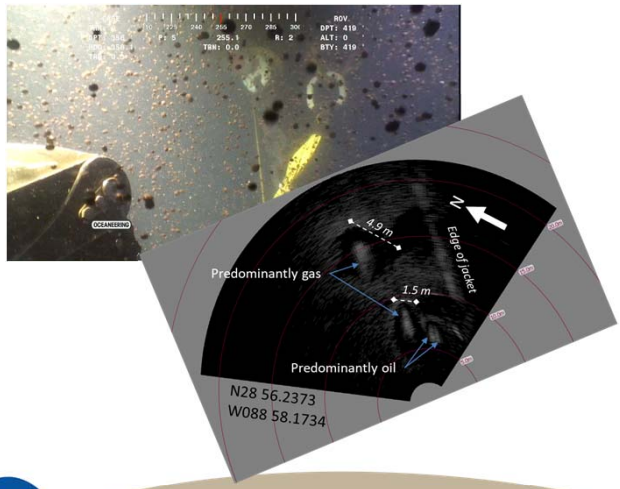
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Splitbeam SONAR

BENEFITS OF OUR WORK

Rapid mobilization of splitbeam and imaging sonars for watercolumn mapping determined the location and characterized the oil and gas components of the leak at the MC20 site.

US Coast Guard ordered containment of oil at the site relied on the location of the source at the seabed provided by NCCOS. Prior to containment, NCCOS produced acoustic-derived estimates of oil flow from the site. The values were validated by the containment system now capturing 1,000-1,300 gallons per day.



JULY 23-25, 2019
SILVER SPRING, MD

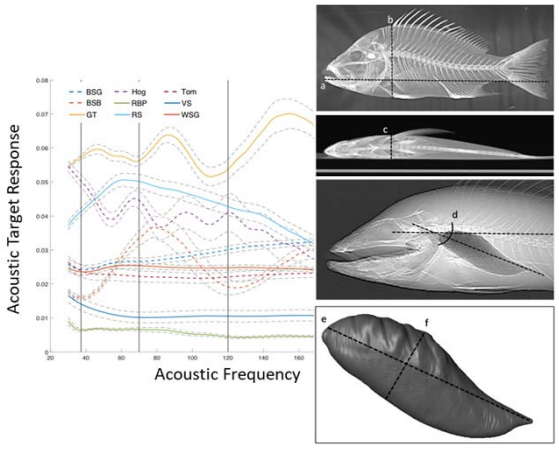
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Splitbeam SONAR

NEXT STEPS IN SPLITBEAM SONAR METHODS

The NCCOS and BSEE assessment of MC20 concluded in June 2019 with a final report available to the public in July 2019. A summary of best practices for conducting sonar assessments of oil and gas seeps is in development.

Theoretical models and 3D visualization tools are also in development to enhance interpretation of splitbeam and multibeam watercolumn backscatter and target strength leading to **interpretation of bubble types** in seeps or **differentiating fish species groups** in high diversity ecosystems.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 4

Unmanned Vehicles
Marine Mapping

Bryan Costa, Marine Ecologist

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

DEFINITION

Unmanned vehicles (also commonly known as **drones**) are planes, ships or submarines that can operate semi or fully-autonomously (Fig 1). Semi-autonomous vehicles are tethered and controlled remotely by humans. Remotely Operated Vehicles (**ROV**) are semi-autonomous. Fully-autonomous vehicles are untethered and can be programmed to operate independently of humans. These types of vehicles include autonomous underwater vehicles (**AUV**), autonomous surface vehicles (**ASV**), or small unmanned aerial systems (**sUAS**). Unmanned vehicles can be outfit with optical, sonar and/or chemical sensors and deployed in locations or in environmental conditions that are challenging or dangerous for humans. They can also be used as a force multiplier, increasing the amount and/or type of data being collected in the field.

Fig 1. Photographs of unmanned vehicles. (Clockwise from top left) ROV, AUV, sUAV and ASV.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Unmanned Vehicles

WHAT WE DO

The Biogeography Branch uses unmanned vehicles for a wide range of applications, from monitoring and characterizing seafloor habitats, to detecting and quantifying marine debris, to finding spawning sites for economically important fish, to mapping depths in shallow (<10 m) coastal areas. ROVs and AUVs are primarily deployed from NOAA fleet vessels (guided by multibeam SONAR, Fig 2). ASV and sUAS operations have been shore-based to date. Data collections are conducted in collaboration with internal and external partners, and tailored to meet specific data needs in the region. Products from these efforts include maps depicting shallow depths, fish distributions, habitat types and marine debris locations. The Branch and its partners are also currently developing best practices for mapping depths using sUAS.

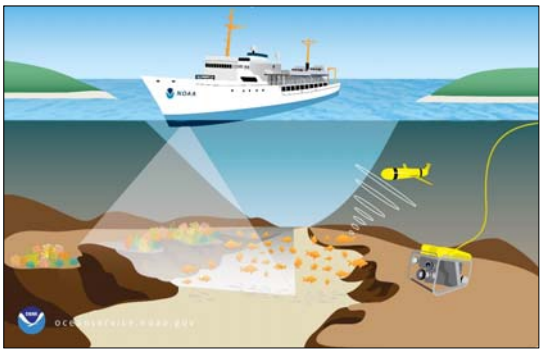


Fig 2. ROVs and AUVs were deployed after any area was mapped using multibeam SONAR.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Unmanned Technologies

PRODUCT APPLICATION(S)

Biogeography Branch's products (Fig 3) developed using unmanned vehicles have been used in a wide range of management, policy, and research settings by Federal, Territorial, NGO and academic partners, including:

- Stewardship, recreation, & tourism
  - Marine Protected Area Management
  - Monitoring, Research & Mitigation Program Designs
  - Supporting Habitat Mapping, Marine Animal Surveys
- Safe & efficient transportation & commerce
  - Potential for Nautical Charting, Shoreline Delineation
  - Fisheries Ecosystem Models
- Preparedness & risk reduction
  - Marine Spatial Planning
  - Local Area Use Regulations

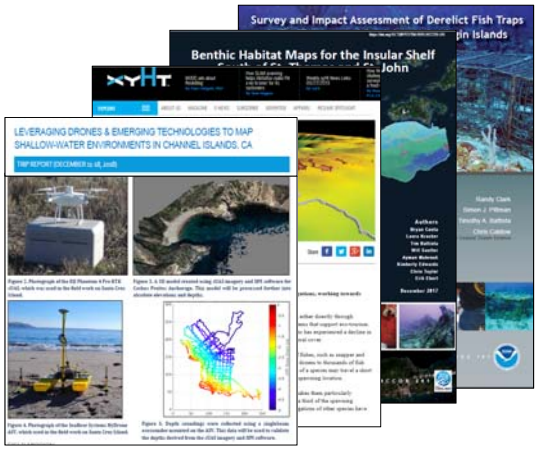


Fig 3. Biogeography Branch products developed using unmanned vehicles.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Unmanned Vehicles

CASE STUDY

Nearshore Mapping with sUAS and ASV

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Unmanned Vehicles

WHY WE CARE

Several organizations, including NOAA, need imagery, elevation and depth data to inform management decisions in the coastal zone. However, many near-shore areas are expensive, challenging and dangerous to map with existing technologies, resulting in data gaps in many coastal areas of the United States. sUAS are capable of producing centimeter-scale photographs (Fig 4), and when combined with Structure from Motion (SfM) software, elevation and depth surfaces for near-shore environments. sUAS could potentially fill these nearshore gaps accurately, safely and cost-effectively. However, additional research is needed to identify environmental and operational limitations of these systems before being implemented more widely across NOAA.

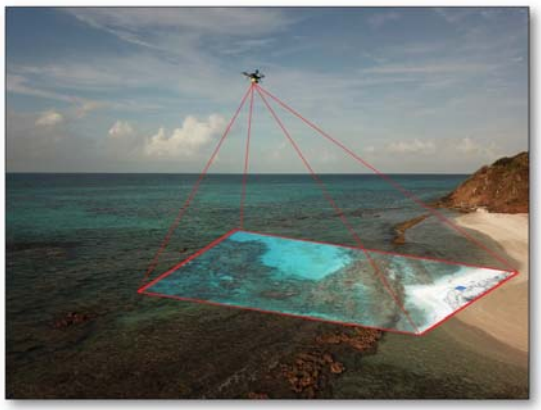


Fig 4. sUAS photographing shallow, coastal environments. These photographs are much higher resolution than from civilian satellites.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Unmanned Vehicles

WHAT WE ARE DOING

The Biogeography Branch is using sUAS, ASV and SfM to map nearshore depths and elevations. sUAS and SfM were first tested in tropical environments to identify optimal payloads and processing workflows. Initial results were promising, leading to follow on research on Santa Cruz Island, CA (Fig 5). The objective of this field work was to understand the limitations of sUAS and benefits of ASVs in more remote locations and challenging environments. In December 2018, scientists from the Biogeography Branch and Oregon State University collected thousands of aerial photographs using a sUAS, and thousands of depth soundings using an ASV. The photographs were processed in SfM to map depths, and the soundings are being used to independently validate these mapped depths.

Fig 5. sUAS and ASV deployed in Santa Cruz Island, CA. Data streams from these drones were used to map nearshore depths.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Unmanned Vehicles

BENEFITS OF OUR WORK

Our research was designed to support NOAA Office of Coast Surveys (OCS) nautical charting needs in shallow (<10 m) waters. OCS is developing procedures to operate sUAS from hydrographic vessels. Our methods will be integrated with these procedures to move this technology from research to operations at NOAA.

Federal marine managers have also shown tremendous interest in the Biogeography Branch's sUAS research (Fig 6). These same data products are being requested by managers to understand and monitor habitats, living resources and human activities in their coastal environments. Notably, our sUAS flights mapped depths in some locations that had not been surveyed since the early 1930s.

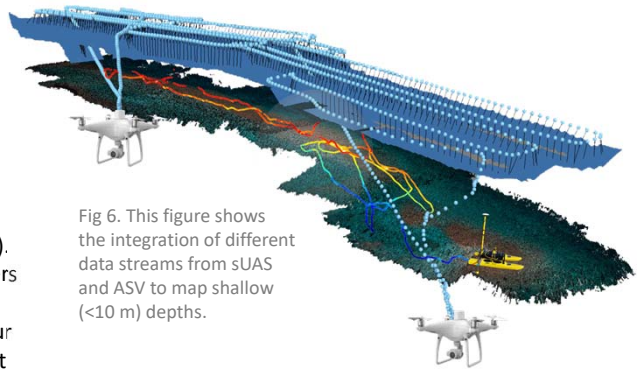


Fig 6. This figure shows the integration of different data streams from sUAS and ASV to map shallow (<10 m) depths.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Unmanned Vehicles

NEXT STEPS

The Biogeography Branch's research with unmanned vehicles is ongoing. In the near-term, we will focus our efforts on: (1) transitioning existing research to operations at NOAA and (2) developing new applications for commercially available technologies. The following projects are either currently proposed or were funded for FY20:

- Evaluate benefits of vertical take off and landing (VTOL) sUAS (Fig 7) for mapping nearshore depths
- Quantify benefits of flying multiple sUAS (swarms) when mapping nearshore depths
- Deploy a harmful algal bloom sensor on a sUAS
- Test utility of microAUVs (Fig 7) for efficiently collecting underwater photographs in the deep sea (>50 m)
- Co-host regional UAS workshop in the SE and Caribbean

Fig 7. (Left) VTOL sUAS can fly longer and take off and land vertically, making them potentially well suited for ship-based operations.

(Right) MicroAUVs are <3 ft long, rated up to 1500 m and can be fitted with lights and cameras, making them potentially useful and efficient choice for visual surveys in the deep sea.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Unmanned Vehicles

UNMANNED VEHICLES
Question & Answer Session

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 5

OCEAN REMOTE SENSING

Remote Sensing Toolbox

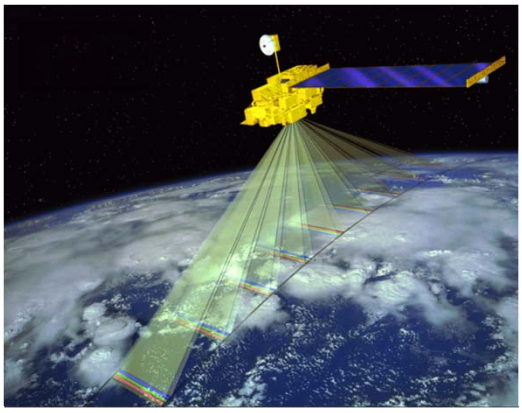
Michael Coyne, Data Scientist

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

DEFINITION

Remote sensing is a technique that uses sensors to collect information about an area from a distance, usually from a ship, aircraft or satellites. Remote sensors can be either passive or active. **Passive sensors** respond to external stimuli. They record natural energy, usually sunlight, that is reflected or emitted from the Earth's surface. Measuring specific wavelengths reflected from the ocean allows us, for example, to estimate temperature or chlorophyll at the surface. **Active sensors** use internal stimuli to collect data about Earth. For example, a laser-beam remote sensing system projects a laser onto the surface of Earth and measures the time that it takes for the laser to reflect back to its sensor, allowing us to measure the height of the Earth's surface (topography) or ocean (sea surface height).



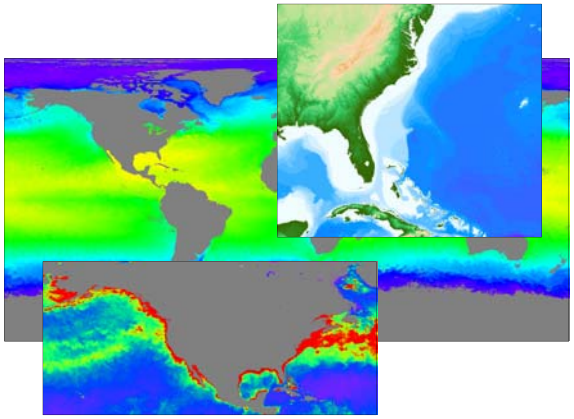
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Ocean Remote Sensing

WHAT WE DO

The Biogeography Program uses **ocean remote sensing** data to generate environmental "maps" that are used in a variety of ways. Remotely sensed data products are used as predictor variables in complex statistical models that look at the relationship between marine organism observations and the ocean environment to predict the distribution of biological resources where we might not have observation data. Oceanographic data products are used in mapping tools to provide context and as information layers. And they are used in biogeographic assessments to help describe the oceanographic environment of regions of interest.



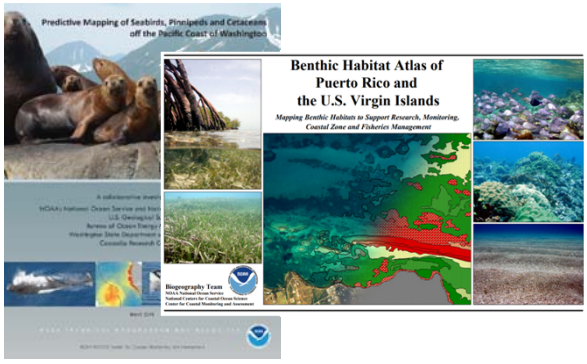
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Ocean Remote Sensing

PRODUCT APPLICATION(S)

Biogeography Program products developed using ocean remote sensing have been used in management, policy, and research settings by Federal, State, NGO and academic partners, including:

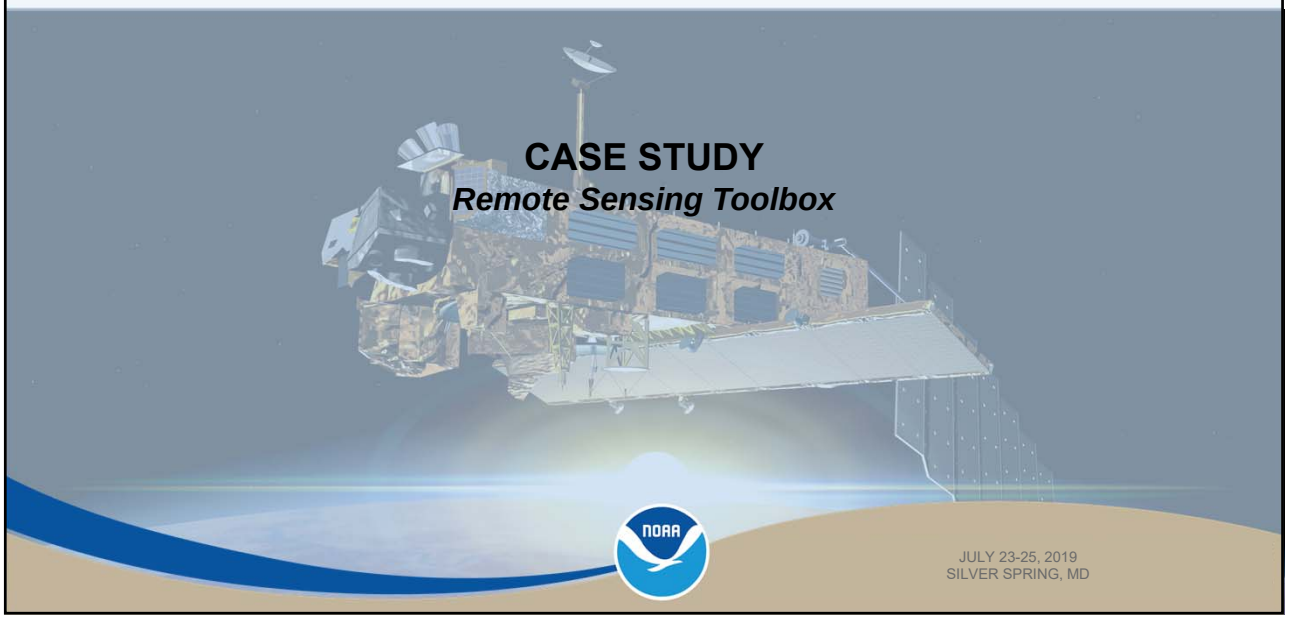
- Monitoring & Research Program Designs
- Marine Protected Area Designations/Expansions
- Offshore renewable & non-renewable energy planning
- Identification of ecologically important areas
- Definition of Essential Fish Habitat
- Regional Ocean Plans and Data Portals
- Integrated Ecosystem Models
- Biogeographic Assessments



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Ocean Remote Sensing



CASE STUDY

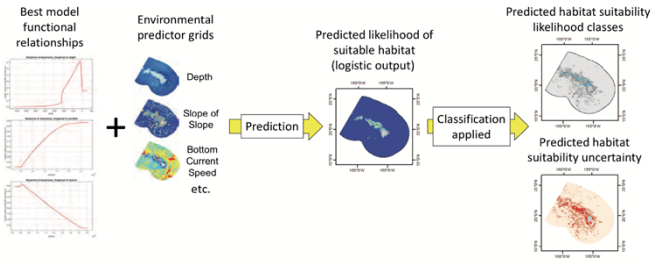
Remote Sensing Toolbox

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Ocean Remote Sensing

WHY WE CARE

Almost every project in the Biogeography Program uses remote sensing data in some way. While NCCOS collects a large amount of data on it's own and with partners, the vast majority of remote sensing data comes from third-party sources. In some cases the same external data sets are retrieved and processed multiple times over the years for different projects. This project aims to provide a significant increase in efficiency across Biogeography Program projects and those of our colleagues and partners.



From Marine Biogeographic Assessment of the Main Hawaiian Islands (2016)

JULY 23-25, 2019
SILVER SPRING, MD

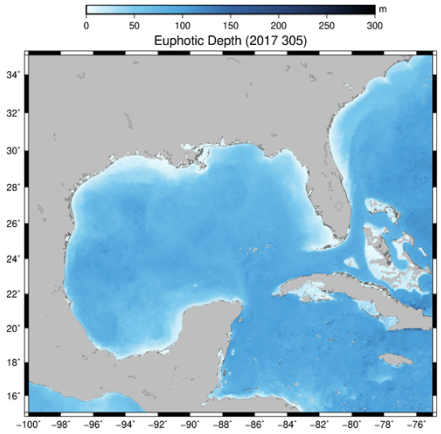
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Ocean Remote Sensing

WHAT WE ARE DOING

Our activities target frequently used data sets as identified by program scientists and partners, and data sets that would fill a need in one or more Biogeography Program projects.

Data are retrieved from a variety of third-party sources, including other NOAA programs, NASA, multinational consortia, academic groups and more. Data are then processed and stored in a standardized format for easy access and manipulation. The program currently holds more than 5 TB of ready-to-use data. In conjunction with the stored data, a base of reusable code is under constant development, designed to work with these data and quickly generate the most frequently needed data products. In addition, we use our remote sensing toolbox to generate products for others.

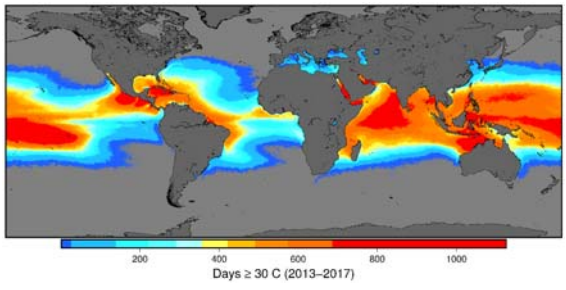


NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Ocean Remote Sensing

BENEFITS OF OUR WORK

Remote sensing provides spatial information to understanding relationships between marine resources and the ocean environment. Resource managers have expressly identified the need for data in the ocean environment, which is exceedingly difficult to collect over large areas other than with ships, aircraft and satellites. Comprehensive environmental data are critical to Biogeography Program predictive modeling efforts that are used in regulatory, management, infrastructure siting, damage assessment, and monitoring design applications. The availability of ready-to-use remote sensing data frees up program scientists to focus on important modeling and mapping efforts.



JULY 23-25, 2019
SILVER SPRING, MD

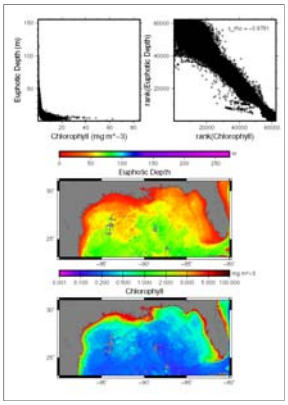
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Ocean Remote Sensing

NEXT STEPS

This project is ongoing and continues to identify, evaluate and process data to support current and future Biogeography Program projects. In the near-term, we will specifically:

- Evaluate and process several pending data sets;
- Continue to improve existing code base and develop new code to quickly and easily generate data products needed by Biogeography Program scientists; *and*
- Advertise the availability of Biogeography Program data and tools to colleagues and partners.



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 6

Mapping Prioritization

Washington State Priority Setting

Ken Buja, IT Specialist

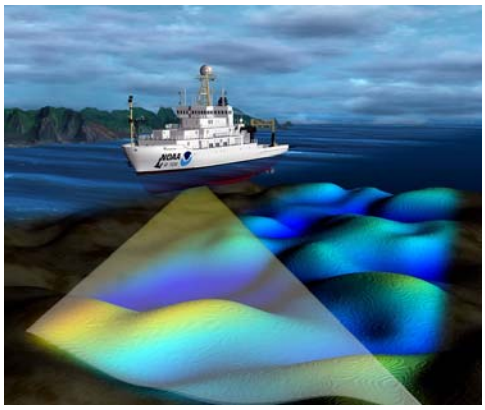
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Mapping Prioritization

DEFINITION

Spatial information about the seafloor is critical for decision-making by marine research and management organizations. However, collecting spatial information about the seafloor is expensive and time consuming, making its collection challenging for individual organizations. Coordination among these research and management organizations can help them more efficiently leverage resources to map and explore unknown seafloor areas in support of their individual objectives, mandates, and missions. Effective coordination requires that these organizations understand where and when their priorities overlap with others operating in the same regions.



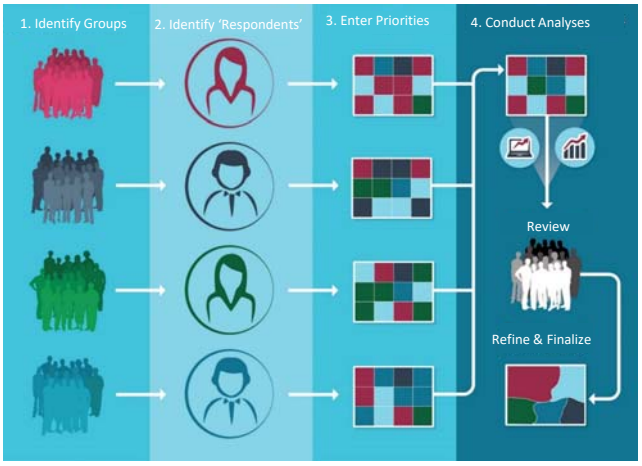
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Capability | Mapping Prioritization

WHAT WE DO

Participant priorities are entered into an online portal using an existing process and widget developed by NCCOS. Results are analyzed using clustering or other relevant techniques to identify significant relationships between priorities, issues, and ranking criteria. Spatial patterns are mapped using frequency and hotspot analysis. Preliminary results from the prioritization process are reviewed and finalized by partners online. Final prioritization results and maps are compiled in a technical report. This report will help guide future mapping and visual survey activities.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

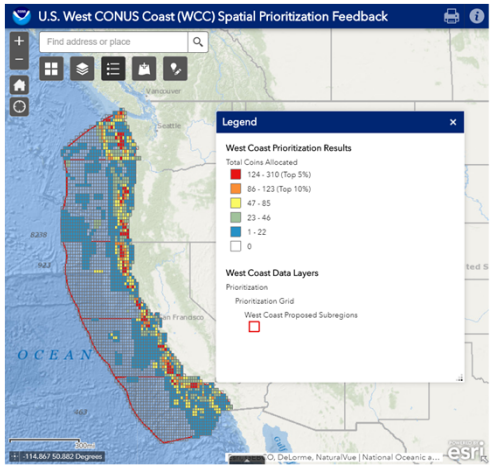
Habitat Mapping | Capability | Mapping Prioritization

PRODUCT APPLICATION(S)

This approach has been successfully applied by NCCOS in various regions around the U.S.

- New York
- Washington state
- Lake Michigan
- South Atlantic
- West Coast
- U.S. Caribbean

It has also been used by other NOAA program offices and by the Florida Coastal Mapping Program and the Great Lakes Observing System.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Mapping Prioritization

CASE STUDY

Washington State Priority Setting

JULY 23-25, 2019
SILVER SPRING, MD

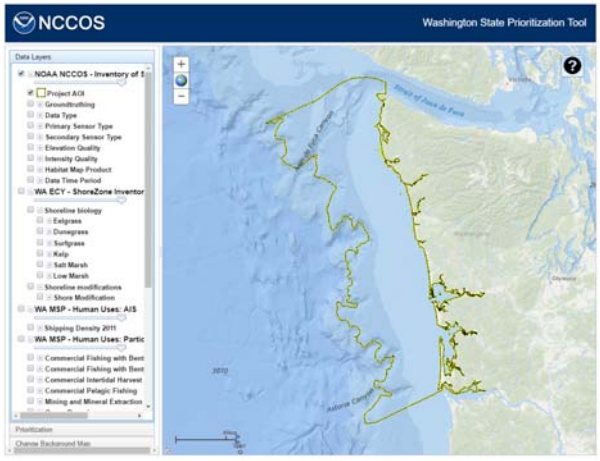
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Mapping Prioritization

WHY WE CARE

To plan for new ocean activities in this region and to reduce conflicts among existing uses, the state of Washington is undertaking marine spatial planning – a process that coordinates decisions about how marine resources and space are used.

By effectively planning ocean uses, coastal managers will reduce conflicts among users, encourage offshore investments, facilitate compatible uses, and preserve critical ecosystem services to meet economic, environmental, security, and social objectives.



JULY 23-25, 2019
SILVER SPRING, MD

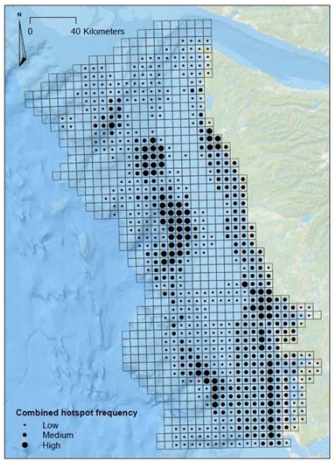
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

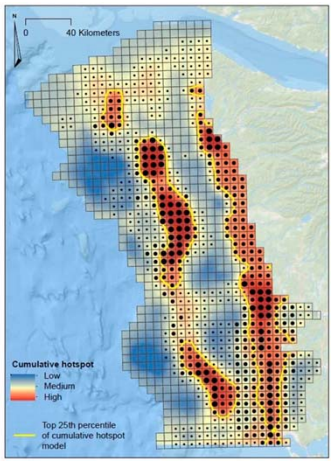
Habitat Mapping | Case Study | Mapping Prioritization

WHAT WE ARE DOING

This project began with a strategic assessment of data gaps for state-led marine spatial planning. NCCOS created an online geospatial data viewer of existing seafloor mapping information to visualize data by thematic categories and allow users to easily evaluate the extent, type, and quality of existing data sources. The site also allowed user to input the mapping priorities of their organization.

The analysis of the cumulative results identified several discrete, high priority mapping hotspots.





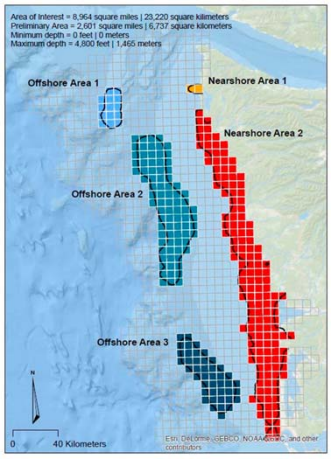
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Mapping Prioritization

BENEFITS OF OUR WORK

The results of the seafloor prioritization process were used in identifying the optimum remote sensing systems and project costs, estimating survey time and assessing ship time necessary to complete the priority areas. NOAA was able to allocate 21 days at sea in 2016 and 2017 on the NOAA ship Rainier to conduct seafloor mapping of the three identified offshore priority areas.

In 2018, Washington state utilized these prioritization analysis to help identify the next tier of offshore mapping priorities.



JULY 23-25, 2019
SILVER SPRING, MD

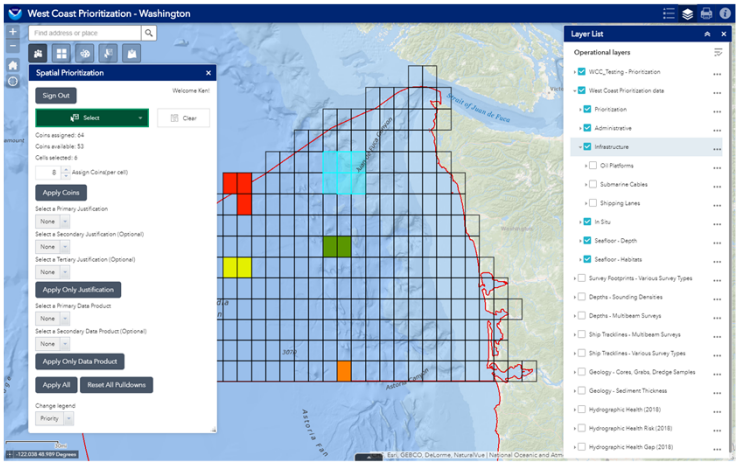
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Habitat Mapping | Case Study | Mapping Prioritization

NEXT STEPS

The code for Washington State Spatial Prioritization Tool was modified to conform to Esri's Web AppBuilder widget framework. This made the tool portable to outside organizations and NCCOS has provided technical assistance on how to set up and use the tool, as well as analyzing the results of user inputs.

We have been continually upgrading the tool to maintain its usability with each new version of the Web AppBuilder.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 7

BIOGEOGRAPHIC ASSESSMENT

Primary Observations

Peter Etnoyer, Marine Biologist

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Capability | Primary Observation

DEFINITION

The Primary Observations we collect at sea include photographic still images of marine organisms and their habitat, high-definition videos, biological samples, and water samples (Fig 1). Common species we observe include deep-sea corals, fishes, sponges, crustaceans, sea stars, and other invertebrates. These observations are linked to navigation and water chemistry information (salinity, temp, DO, TA, pH) using time as the common factor. The image data are analyzed in the lab to yield spatially explicit measures of presence/absence, abundance, and diversity. The images yield verifiable estimates of animal densities, size, and health, as well as proximity to the geological substrates. The tissue samples are used to confirm species ID through genetic studies.

Fig 1. Examples of primary observations of biology and oceanography that we collect using remotely operated vehicles (ROVs).

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Capability | Primary Observation

WHAT WE DO

The Biogeography Branch conducts field surveys each year to collect **primary observations** that support Federal and regional partners from the Pacific Ocean to the Caribbean Sea. These observations form the beginning of a cycle that will encompass our overall mission (Fig 2). Primary observations collected during **exploration** of habitat are **analyzed** to ask larger questions about population structure, affinity for substrate and ambient conditions. The result is a **characterization** of habitat. The data collected and created then feed habitat suitability models that predict the occurrence of species in unexplored areas. This, in turn, will catalyze new field surveys to verify those predictions, closing the loop on exploration and discovery.

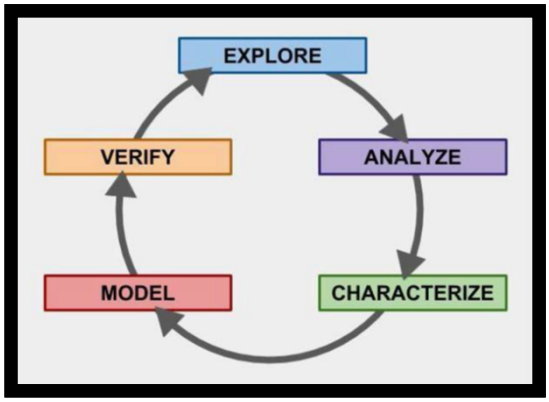


Fig 2. The cycle of exploration, analysis, and modeling that helps to drive demand for the primary observations collected by the NCCOS Biogeographic Assessments.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Capability | Primary Observation

PRODUCT APPLICATION(S)

Primary observations from the Biogeographic Branch have been applied in a wide range of management, policy, and research settings by Federal and regional partners in U.S. coastal and marine waters, including:

- Marine Spatial Planning
- Marine Protected Area Designations and Expansions
- Oil and gas leasing designations by BOEM
- Natural Resource Damage Assessments, e.g. DWH oil spill

Also
- Maps and models of species distributions
- Education, e.g. student curricula
- Social Media outreach

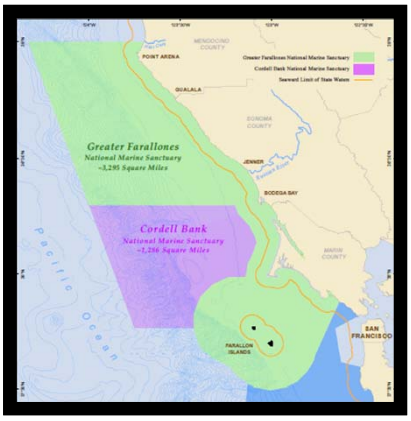


Fig 3. Greater Farallones NMS expanded in June 2016, based in part on NCCOS primary observations. Our models propelled other actions too.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Biogeographic Assessment | Case Study | Deepwater Horizon

CASE STUDY

Gulf of Mexico

10 Years of Field Research in the Gulf of Mexico: from Deepwater Horizon to new MPAs for deep-sea corals

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Biogeographic Assessment | Case Study | Deepwater Horizon

WHY WE CARE

The Gulf of Mexico is central to the **Blue Economy**. It is the most industrial basin in the USA (Fig. 4), but the least protected by area. Less than 1% of deep water is off limits to bottom contact fishing. The Gulf has the 2nd most offshore platforms in the world (175 rigs), with 84% of US offshore oil and gas platforms located there. The Gulf is home to the nation's largest shrimp fishery. Red snapper is also valued by commercial and recreational fisheries. All these resources were jeopardized by Deepwater Horizon spill in 2010. NOAA's Biogeography Branch has been working closely with federal partners in the region since 2007 and will remain engaged through the restoration phase, into 2027. Primary observations collected by our program provide critical information for management of these resources.

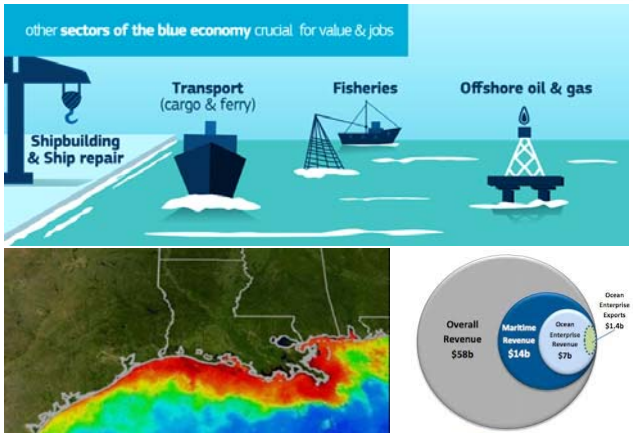


Fig 4. The Gulf region is a major contributor to US gross domestic product, accounting for 37% of the US ocean economy, est. $104 B annually.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Biogeographic Assessment | Case Study | Deepwater Horizon

WHAT WE ARE DOING

Since 2010, the Biogeography Program participated in a series of expeditions to document the extent of **deep-sea corals** and assess their **threats** throughout the Gulf. This work compiled existing data from museums, explored new areas using ROVs, assessed damage below the DWH oil slick, collected >1000 samples for genetic connectivity, and live samples for experiments. We generated new data describing benthic communities, their age, and distribution, and thresholds of tolerance. The products ranged from cruise reports to maps of fishing effort and mathematical models of probability for key species (Fig. 5). Our analyses and experiments were designed to address the needs of NOAA Office of Response and Restoration, support Gulf of Mexico Fishery Management Council, and inform BOEM's regulations for oil and gas leasing.

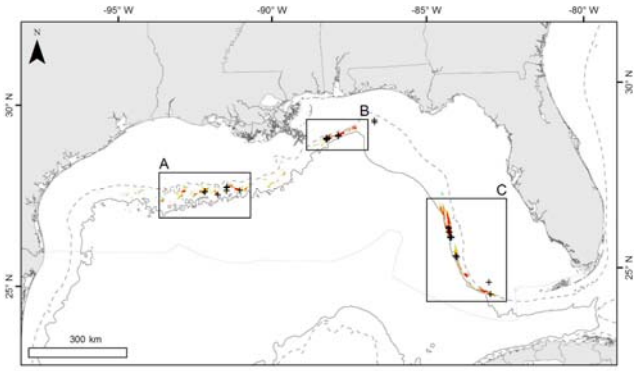


Fig 5. Maps showing 'hotspots' of probability for *Leiopathes glabberima* black corals, which grow to be 1000's of years old.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Biogeographic Assessment | Case Study | Deepwater Horizon

BENEFITS OF OUR WORK

Understanding the spatial distribution of vulnerable marine ecosystems and their threats is critical for marine spatial planning. Our benthic survey data. (Fig 6) was essential to the Natural Resource Damage Assessment for Deepwater Horizon (DWH NRDA), and to the establishment of 21 new MPAs for deep-sea corals. Our analytical work established a pre-spill baseline for health of mesophotic corals, and documented their post-spill decline. Our experimental work linked this decline to oil and dispersants. Our modeling and field surveys helped the Council protect these resources from fishing, in areas where the corals are most pristine. These products have catalyzed new collaborative studies funded by NMFS ($2.5 M), RESTORE ($1.2 M,) and CSCOR ($3.5M). Our strong history of research in the Gulf earned NCCOS a leadership role in the forthcoming 8 year restoration plan for Deepwater Horizon.

Fig 6. A still image showing three species of deep-sea corals in the Gulf of Mexico, with 'snake stars' wrapped around their branches.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Biogeographic Assessment | Case Study | Deepwater Horizon

NEXT STEPS

Many aspects of this work were completed in 2018, with the establishment of the 21 new MPAs, but several new products are forthcoming from BOEM and RESTORE funded projects.

A series of state-of-the-art habitat suitability models for deep-sea corals will be released in 2021 under contract with BOEM.

Maps of population connectivity for fishes and corals will be available in 2023 under the CYCLE project with RESTORE.

NCCOS will lead and participate in 7 yrs of restoration projects via NOAA's Open Ocean Restoration Plan for Mesophotic and Deep Benthic Communities. Projects total $175 M. Projects include mapping, monitoring & assessment, coral propagation, and adaptive management (Fig. 7).

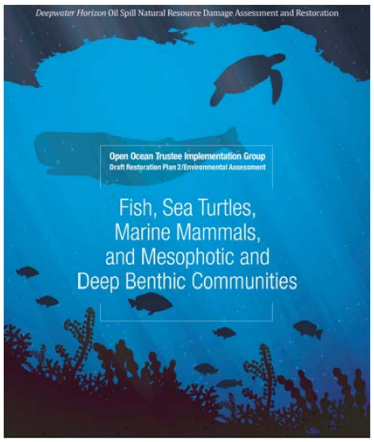


Fig 7. Cover of NOAA's Open Ocean Restoration Plan.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 8

National Coral Reef Monitoring Program

Fish, Benthic, and Human Use Monitoring

Chris Jeffrey, Marine Ecologist

JULY 23-25, 2019
SILVER SPRING, MD

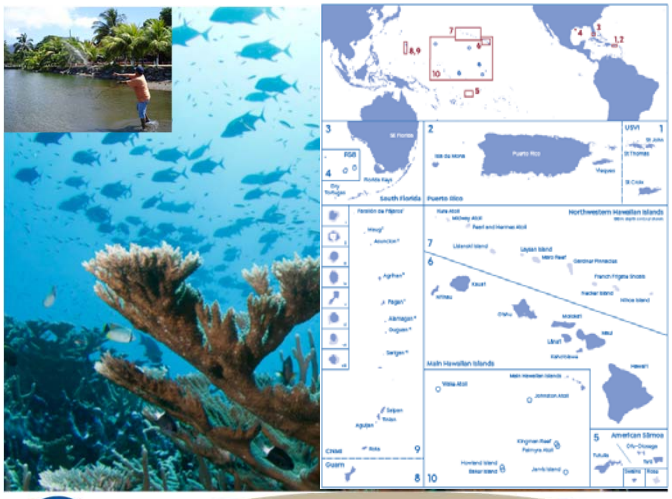
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Capability | National Coral Reef Monitoring Program

DEFINITION

NOAA's National Coral Reef Monitoring Program (NCRMP) is a strategic framework for conducting sustained observations of biological, climatic, and socioeconomic indicators to robustly assess the condition of U.S. coral reef ecosystems and the communities connected to them.

NCRMP consolidates monitoring of coral reef fish and benthic assemblages, ocean environment and climate, and human populations through a suite of uniformly designed methods for the US Atlantic (Florida), Caribbean (US Virgin Islands and Puerto Rico common wealth), Gulf of Mexico (Flower Garden Banks), and seven Pacific jurisdictions.



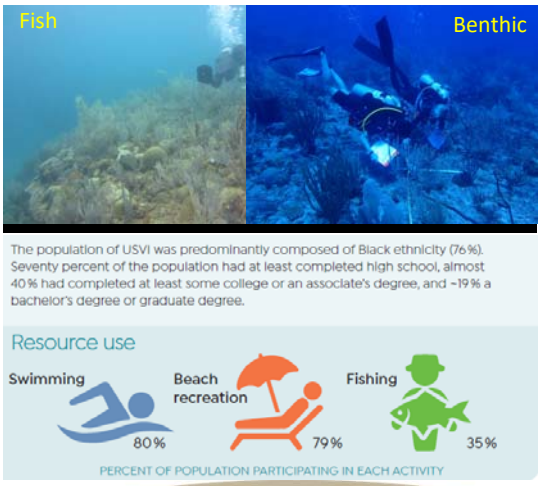
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Capability | National Coral Reef Monitoring Program

WHAT WE DO

- *Biological Monitoring:* We conduct visual *in-situ*, diver-based, and **habitat-stratified** surveys of fish and benthic assemblages from ~8,600 randomly selected sites on coral reefs (0-30 m deep) in the US Virgin Islands, Puerto Rico, and Flower Garden Banks, Gulf of Mexico. Data collected include density, and size for fish species and density, size, and health condition for corals taxa.
- *Human Socioeconomic Monitoring:* We have conducted over 9,000 surveys to estimate residents' uses of coral reef resources and people's knowledge, attitudes, and perceptions of coral reefs and coral reef management actions. We also develop indicators from secondary (e.g., US census data) to track human population structure and demonstrate how healthy coral reef systems contribute to human well-being.



JULY 23-25, 2019
SILVER SPRING, MD

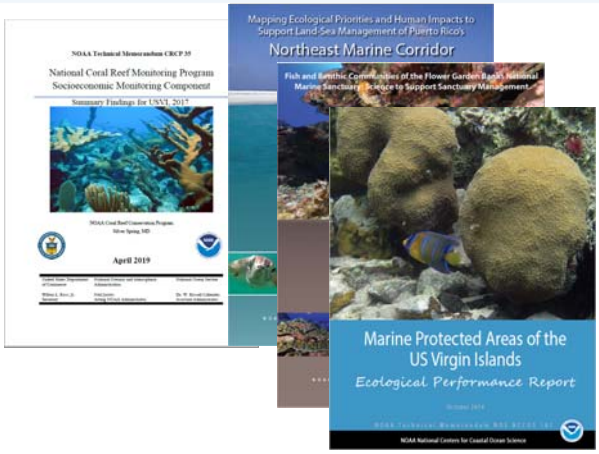
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Capability | National Coral Reef Monitoring Program

PRODUCT APPLICATION(S)

Biogeography Program ecosystem monitoring products for coral reefs have been used in a wide range of management, policy, and research settings by Federal, State, NGO and academic partners, including:

- Monitoring & Research Program Designs
- Marine Protected Area Designations/Expansions
- Submerged Lands Planning
- Local Area Use Regulations
- Integrated Ecosystem Models
- Biogeographic Assessments



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Case Study | National Coral Reef Monitoring Program

CASE STUDY

National Coral Reef Monitoring Program
Fish and Benthic Visual Surveys

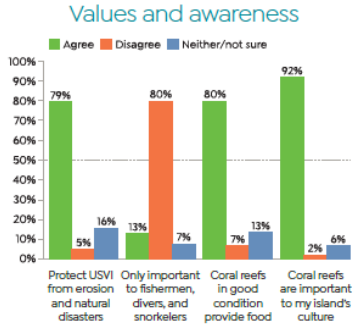
JULY 23-25, 2019
SILVER SPRING, MD

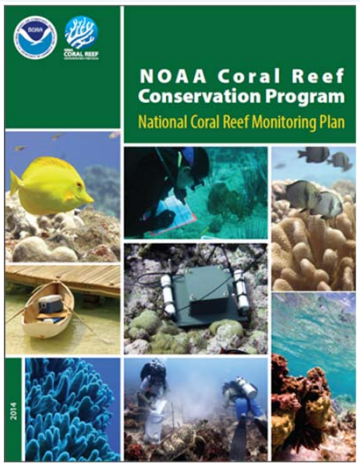
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Case Study | National Coral Reef Monitoring Program

WHY WE CARE

Coral reefs are valuable ecosystems that provide food, storm protection, recreational opportunities, and other goods and services worth billions of dollars to the US economy annually. The Coral Reef Conservation Act of 2000 authorizes NOAA to develop a national program that periodically monitors and reports on the sustainable use and long-term conservation of coral reefs to national, state, and territorial policy makers; resource managers; and the public.





JULY 23-25, 2019
SILVER SPRING, MD

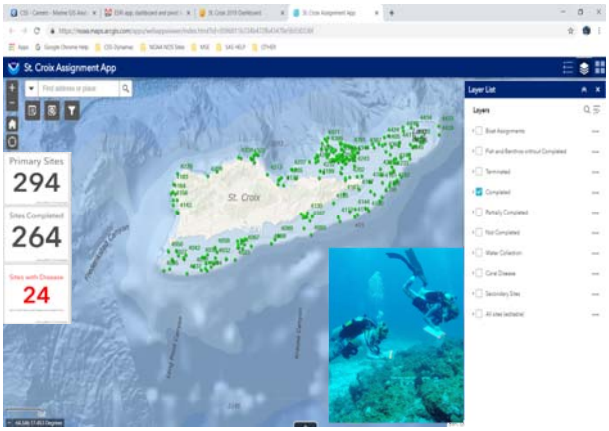
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Case Study | National Coral Reef Monitoring Program

WHAT WE ARE DOING

Our activities involve developing innovative and cost-effective approaches to implement diver-based visual surveys over large geographic areas. We optimize probabilistic sampling designs to maximize the number of surveys at minimum costs. We coordinate with local partners to implement sampling missions, manage field logistics, and deploy divers that conduct fish and benthic surveys at randomly pre-selected locations. Finally, we conduct analyses needed to develop indicators for documenting and tracking coral reef status and condition.

Since 2013, divers have conducted NCRMP fish and benthic surveys at 2,000 locations.

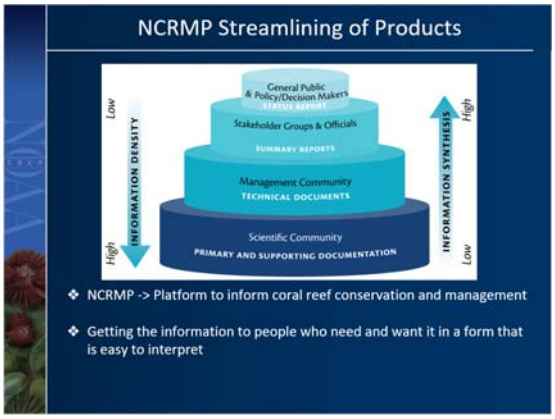


NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Case Study | National Coral Reef Monitoring Program

BENEFITS OF OUR WORK

NCRMP monitoring provide coral reef managers and decision makers with standardized information needed for tracking the status and trends of coral reefs nationally, regionally, and locally. NCRMP complements local and region specific coral monitoring help form a comprehensive view of the status and condition of coral reefs, related marine life, and adjacent human communities. NCRMP biological and social science data products are useful for evaluating the performance of marine protected areas, measuring broad-scale trends in coral reef fish assemblages, coral condition, and social and economic conditions, documenting how people use coral reef resources in coastal and marine areas.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Ecosystem Monitoring | Case Study | National Coral Reef Monitoring Program

NEXT STEPS

NCRMP monitoring is ongoing and continues to collect fish and benthic surveys in the US Caribbean and socio-economic data in areas identified NOAA's Coral Reef Conservation Program (CRCP). In the near-term, we will specifically:

- Complete fish and benthic surveys in the US Virgin Islands and Puerto during 2019.
- Assist CRCP with the development of Status Report Cards for The **US Virgin Islands and Puerto Rico based** on NCRMP data
- Conduct the second round of social science surveys, beginning with Florida in 2019-2020.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 9

ECOLOGICAL CONNECTIVITY

Animal telemetry - Transport simulations

Matt Kendall PhD, Marine Biologist

JULY 23-25, 2019
SILVER SPRING, MD

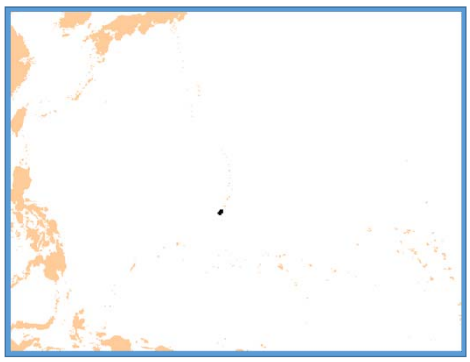
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Capability | Ecological Connectivity

DEFINITION

Telemetry is an automated communications process by which data are collected at one location and transmitted to receiving equipment for monitoring. ***Acoustic telemetry*** systems are used to transmit data in sea water including variables such as the identity of the transmitter and water temperature. Transmitters can be surgically implanted into fish and used to track their movements within an array of passive data loggers. This type of information is ideal for studying biogeographic aspects of habitat utilization, routes and timing of migration, MPA effectiveness, and site fidelity.

Transport simulations track advection of virtual particles in a multidimensional (x,y,z, and t) circulation model. They are used to identify important larval sources and destinations, plan optimal MPA locations, and promote sustainable fisheries.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

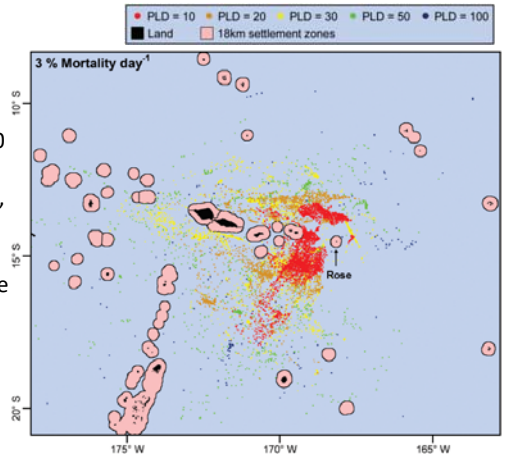
Monitoring, Assessment & Modeling | Capability | Ecological Connectivity

WHAT WE DO

The Biogeography Program uses acoustic telemetry and larval transport simulations to study different scales of ecological connectivity.

Telemetry studies reveal local or regional movement patterns of fish >20 cm TL. We maintain an inventory of ~60 acoustic data loggers that can be deployed for 1-3 simultaneous projects. Depending on project needs, 50-150 fish are tagged with one-time use transmitters. Project design and field activities are conducted collaboratively with local scientists. Biogeography Program staff have developed custom R scripts to facilitate data processing and analysis.

Larval transport simulations reveal regional connectivity patterns. We customize a geographic and temporal scope, set circulation parameters based on Global Drifter Program data, assign larval life-history parameters, and produce multivariate connectivity matrices.



JULY 23-25, 2019
SILVER SPRING, MD

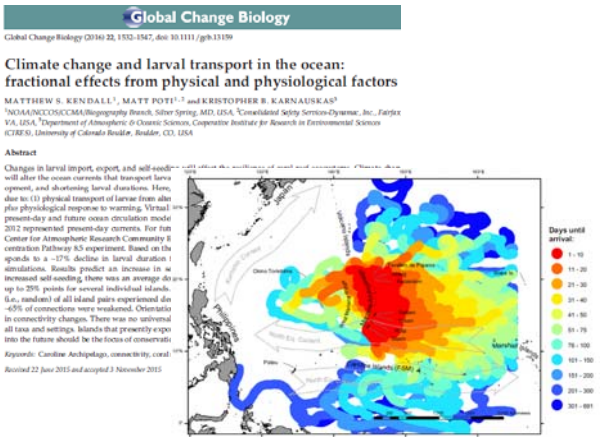
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Capability | Ecological Connectivity

PRODUCT APPLICATION(S)

Biogeography Program products developed using telemetry and transport simulations have been used in a range of management, policy, and research settings by Federal, State, Territorial, NGO, and academic partners, including:

- Marine Protected Area Designations/Expansions
- Resilience Initiatives
- Local Area Use Regulations
- Climate Adaptation Plans
- Biogeographic Assessments


Global Change Biology

Climate change and larval transport in the ocean: fractional effects from physical and physiological factors

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Case Study | Ecological Connectivity

CASE STUDY

Fish movements in Salt River Bay National Historical Park and Ecological Preserve

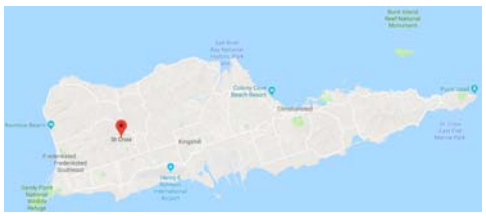
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Case Study | Ecological Connectivity

WHY WE CARE

MPA boundaries are often drawn based upon political feasibility rather than ecological requirements. Fish movement data collected by NCCOS provides managers with an understanding of the adequacy of boundary placement and to what extent they protect target resources. Boundaries may offer effective protection for some species or life stages, but not others. Documentation of actual levels of protection is needed for managers to set public expectations of MPA benefits and justify any restrictive regulations such as limits on fishing or access.



JULY 23-25, 2019
SILVER SPRING, MD

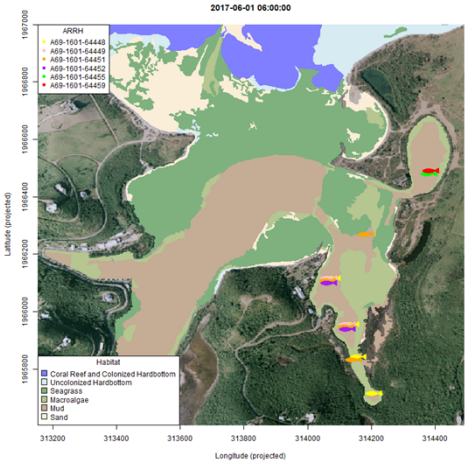
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Case Study | Ecological Connectivity

WHAT WE ARE DOING

Our activities target high priority sites and fish species identified by local managers where significant information gaps exist, and where the absence of sufficient fish movement information has inhibited an evaluation of management efficacy.

Our telemetry program has been supported by NOAA's Coral Reef Conservation Program since 2008 and NCCOS Science Board since 2016. We have tagged over 500 individuals from over 35 species in 5 MPAs including National Parks, National Monuments, National Marine Sanctuaries, and National Estuarine Research Reserves. Our telemetry assets are repositioned every 1-2 years to address movement questions of NCCOS clients and available funding. We actively participate and share data in collaborative telemetry networks including the Florida Atlantic Coast Telemetry Network and US Caribbean Acoustic Network.



JULY 23-25, 2019
SILVER SPRING, MD

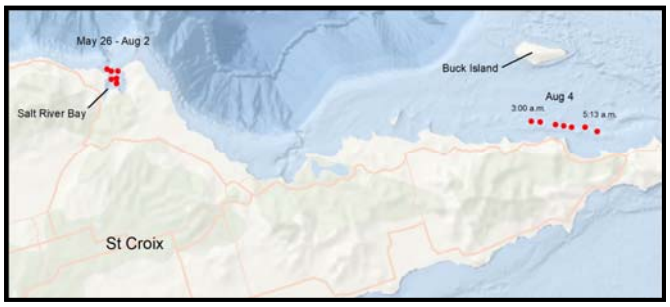
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Case Study | Ecological Connectivity

BENEFITS OF OUR WORK

Our telemetry studies provide a critical understanding of MPA effectiveness and biotic responses to the seascape. Resource managers have specifically identified the need for data regarding fish movements and habitat utilization, which is exceedingly difficult to collect with other techniques due to limitations in visibility and continuity of monitoring.

At Salt River we will document: 1) nearly continuous monitoring of fish movements in/out of Salt River Bay, 2) ecological connectivity among MPA units, and 3) emigration of fish commensurate with spawning behaviors.



JULY 23-25, 2019
SILVER SPRING, MD

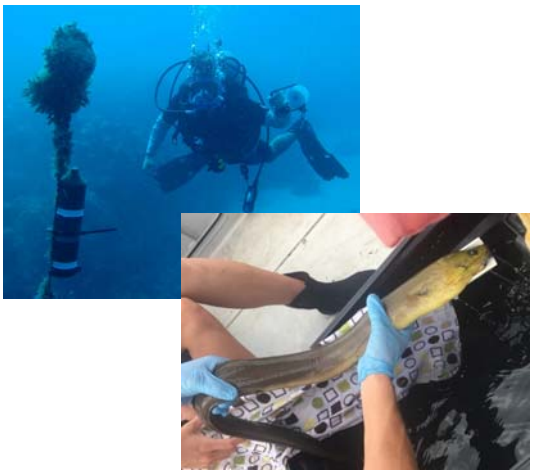
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Assessment & Modeling | Case Study | Ecological Connectivity

NEXT STEPS

This series of projects is ongoing and continues to study fish movements on priority species and locations as identified by jurisdictional partners through NOAA's Coral Reef Conservation Program (CRCP) and the NOS Science Board. In the near-term, we will specifically:

- Analyze and publish the telemetry data from SRBNHPEP;
- Maintain the array at Rookery Bay National Estuarine Research Reserve (through June 2020);
- Establish a new telemetry array at St.Croix's East End Marine Park (August-September 2019);
- Identify and secure funding for the next NCCOS client/site in need of telemetry assistance (e.g. ONMS, NERR).



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 10

PREDICTIVE MODELING

Modeling and Mapping Marine Bird Distributions

Arliss Winship, Marine Ecologist

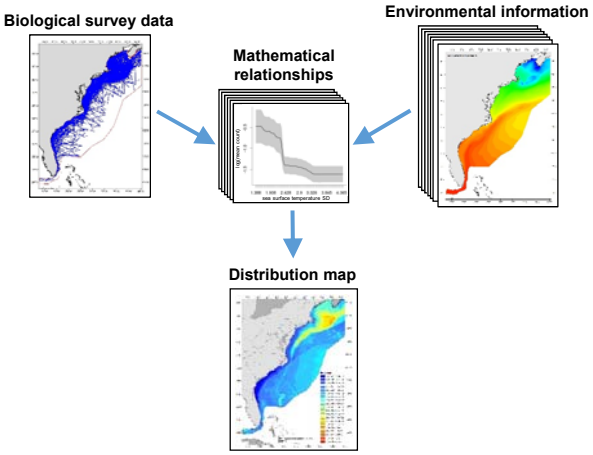
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Capability | Predictive Modeling

DEFINITION

Predictive modeling is a technique that combines biological survey data with environmental habitat information through statistical analyses to produce maps of the distributions of marine organisms. Comprehensive distribution maps over large areas are required for effective natural resource management. However, biological survey data typically have uneven spatial coverage with large gaps. In contrast, comprehensive environmental information is commonly available at regional and global scales. Predictive modeling establishes mathematical relationships between the occurrence of marine organisms and the environment in areas with biological survey data and then applies those relationships to ***predict*** the occurrence of marine organisms throughout a region.



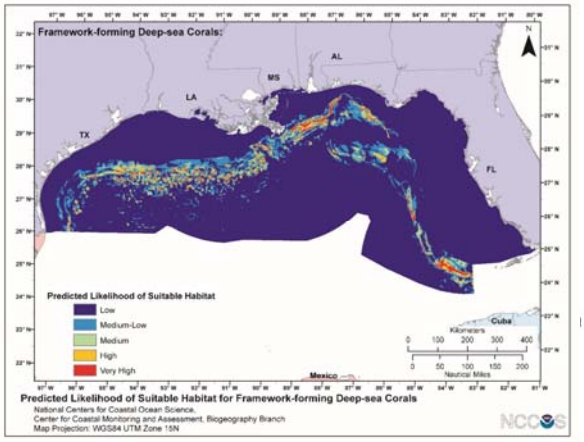
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Capability | Predictive Modeling

WHAT WE DO

The Biogeography Program uses predictive modeling to map the distributions of a variety of marine organisms including deep-sea corals, seabirds, and marine mammals throughout US waters. Biological survey data are obtained through partnerships with other government offices and agencies, NGOs, and academic institutions. Environmental information is obtained from a range of sources, often publicly available remote sensing datasets and ocean circulation models. A suite of statistical methods are employed depending on the nature of the biological survey data including more traditional regression techniques and more modern machine learning techniques. Metrics of model performance and maps of prediction uncertainty are provided to aid interpretation of distribution maps.



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Capability | Predictive Modeling

PRODUCT APPLICATION(S)

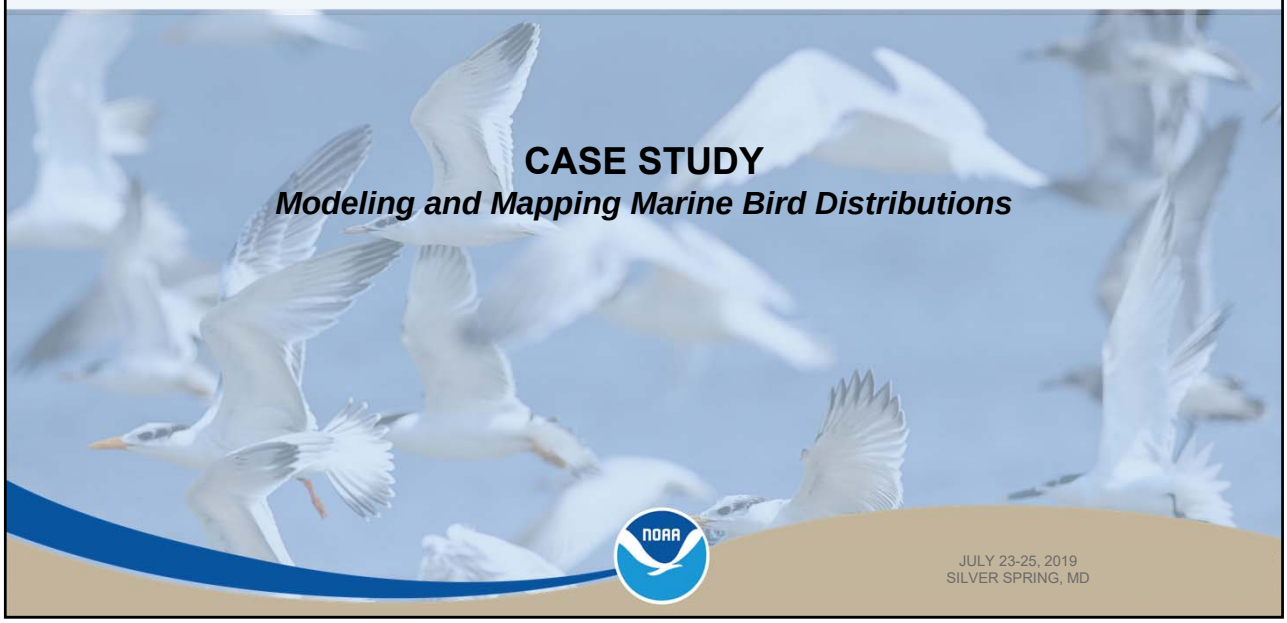
Biogeography Program map products developed using predictive modeling have been used in a range of management, policy, and research settings by Federal, State, NGO, and academic partners, including:

- Offshore renewable & non-renewable energy planning
- Identification of ecologically important areas
- Definition of Essential Fish Habitat
- Site selection for deep-sea exploration and sampling
- Environmental impact analysis
- Regional Ocean Plans and Data Portals
- Biogeographic Assessments
- MPA Designations and/or Expansions

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Case Study | Predictive Modeling



CASE STUDY

Modeling and Mapping Marine Bird Distributions

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Case Study | Predictive Modeling

WHY WE CARE

Marine birds range widely in coastal and offshore waters creating the potential for human activities to impact these often protected species. Offshore wind energy development in particular can affect birds through direct collision mortality and displacement from foraging areas. A prerequisite for assessing and mitigating potential impacts are comprehensive distribution maps for the numerous marine bird species in US waters. These maps need to capture seasonal distributional changes and must be of a spatial resolution that matches the resolution of management decisions.

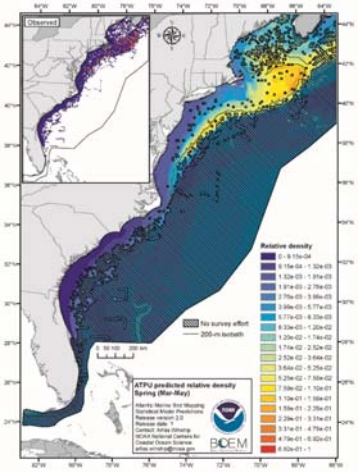
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Case Study | Predictive Modeling

WHAT WE ARE DOING

We have used predictive modeling to map the seasonal distributions of approximately 80 marine bird species across Atlantic and Pacific waters of the contiguous US as well as the Main Hawaiian Islands. Data partnerships with NOAA Fisheries, USGS, USFWS, and other organizations have provided access to large databases of at-sea bird survey data spanning decades. We have compiled a large library of bathymetric, oceanographic, and atmospheric datasets from which we derive seasonal characterizations of the environment. Final map products represent the long-term relative density of individual species, indicating where animals are more or less numerous. The maps have a spatial resolution of kilometers. Indications of model performance and uncertainty are also provided.

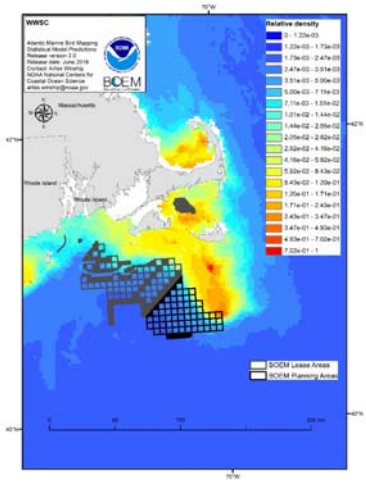


NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Case Study | Predictive Modeling

BENEFITS OF OUR WORK

Our distribution maps provide critical information for assessing and mitigating potential impacts of human activities on marine birds. For example, the Bureau of Ocean Energy Management who funded much of this work, has used our maps to develop call areas, NEPA analyses, EISs, and ESA consultations for offshore wind energy development. More generally, in the Atlantic, we contributed our maps to the Northeast and Mid-Atlantic regional ocean data portals for use in any ocean planning application.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Assessment, Monitoring & Modeling | Case Study | Predictive Modeling

NEXT STEPS

This work is ongoing and continues mainly to focus on the needs of the Bureau Ocean of Energy Management for offshore wind energy planning. In the near-term, we will specifically:

- Update maps for Pacific waters of the contiguous US;
- Take over management of the Northwest Atlantic Seabird Catalog at-sea survey database; *and*
- Reformulate our models to allow for distributional changes over time and to forecast distributions into the future under climate change.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 11

SOCIAL SCIENCE

Human Use - Ecosystem Services - Vulnerability and Resilience

Sarah Ball Gonyo PhD, Economist

JULY 23-25, 2019
SILVER SPRING, MD

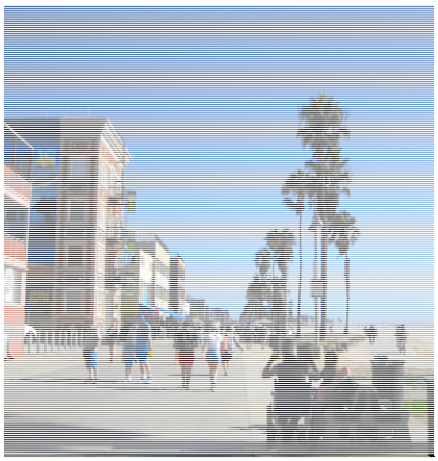
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Capability | Socioeconomic Research

DEFINITION

The ***social, economic, and behavioral sciences*** investigate human behavior and social organizations to understand how social, economic, political, cultural, and environmental forces influence the lives of people and how people, in turn, shape those forces.

Human use research characterizes how people understand, interact with, and use coastal and marine ecosystems. Patterns of social, cultural, and economic behaviors influence how spaces are impacted and valued. ***Ecosystem services valuation*** estimates the economic, social, and cultural value of ecological goods and services that benefit people. Community ***vulnerability assessments*** identify coastal or climate-driven risks to help communities plan for, recover from, and adapt to coastal hazards and events.



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Capability | Socioeconomic Research

WHAT WE DO

The Biogeography Program conducts social science research, providing information, data, tools, maps, and other products to inform policy and decision-making in coastal and marine contexts.

Biogeography Program staff conduct original research that 1) describes people, groups, issues, practices, and processes; 2) provides explanations for complex, relational, or causal questions about people and natural resources; and 3) assigns monetary values to things that are not traded in a market setting to understand preferences. Staff conduct primary data collections (such as social surveys) and use existing, secondary data to meet the informational needs of our customers. The Biogeography Program developed a novel approach for measuring community well-being, and is on the forefront of evaluating the nexus of social vulnerability and risk for communities in the coastal zone.

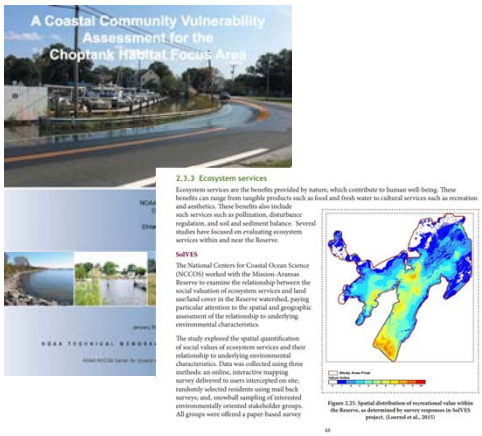
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Capability | Socioeconomic Research

PRODUCT APPLICATIONS

Biogeography Program products developed from social science research have been used by federal, state, territorial, and non-government organization partners in a range of management, policy, and research settings, including:

- Community visioning and planning
  - Resilience initiatives
  - Climate Adaptation Plans
  - Hazard Mitigation Plans
- Marine spatial planning
- Resource management and policy initiatives for NOAA management units (e.g., Sanctuaries, NERRs)
- Management, designation and expansion of marine protected areas
- Socioeconomic impact assessments
- Education and outreach programs and materials



JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Case Study | Human Use

CASE STUDY

Comprehensive Regional Decision Support Framework to Prioritize Site for Coral Reef Conservation in the U.S. Virgin Islands (USVI):

Survey of Occupational SCUBA Divers

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Case Study | Human Use

WHY WE CARE

Coral reef ecosystems in the Caribbean provide a range of valuable services to people, including reef-related tourism and recreation (e.g., SCUBA, snorkeling, recreational fishing), commercial fishing, coastal amenities related to real estate, and shoreline protection from coastal storms. However, long-term monitoring data indicate that Caribbean reefs are in decline. Coral reefs in the US Virgin Islands (USVI) have deteriorated also, but not all Territorial reefs have declined equally. Local resource managers, operating with limited funds, require reliable, spatially explicit, and easily interpretable data to prioritize coral reef sites for management action.

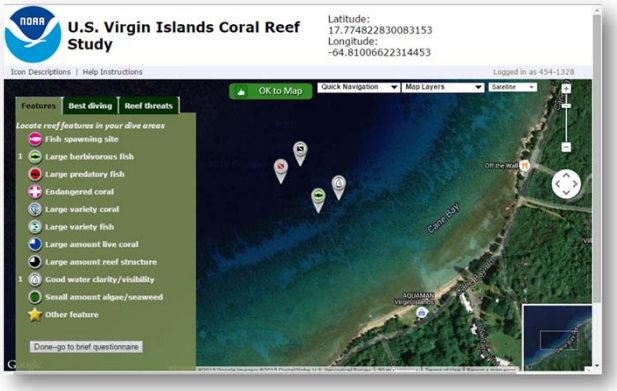
JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Case Study | Human Use

WHAT WE DID

NCCOS developed a decision support framework to help decision-makers manage coral reef ecosystems in the USVI. The framework integrated spatial information on coral reef distributions, associated biodiversity, and usage of important reefs by people. To integrate local knowledge about important coral reefs, Biogeography's social science team collaborated with the University of Queensland (AU) to develop a Google Map tool and survey to collect data from occupational SCUBA divers across the Territory. The mapping tool allowed participants to plot reef features, stressors, use importance, and recovery potential in an interactive format. Participants answered a short survey after the mapping exercise. Data were analyzed independently and also prepared for integration with the other framework components.

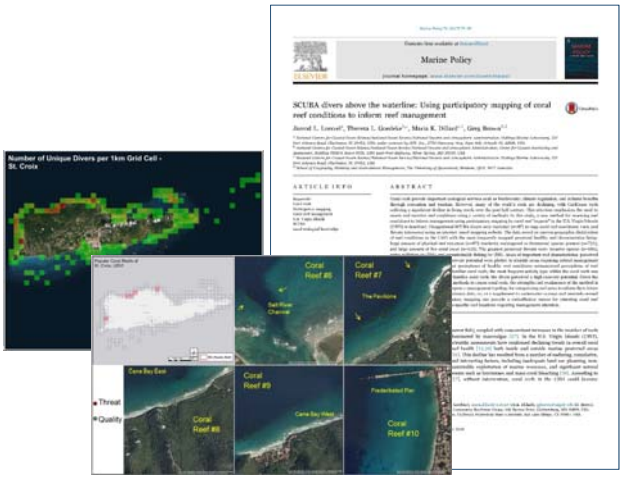


NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Case Study | Human Use

WHAT WE FOUND

- Within the larger reef system, occupational divers were able to identify distinctive areas or reef "hotspots" of ecological conditions and human activity types.
- Tourism diving was the most frequently mapped reef diving activity in the jurisdiction.
- Occupational divers in the USVI more often identified features associated with healthy reefs.
- SCUBA divers can provide spatially explicit, useable information about threats to coral reefs, reef qualities, dominant activities, and the perceived potential for reef recovery.



JULY 23-25, 2019
SILVER SPRING, MD

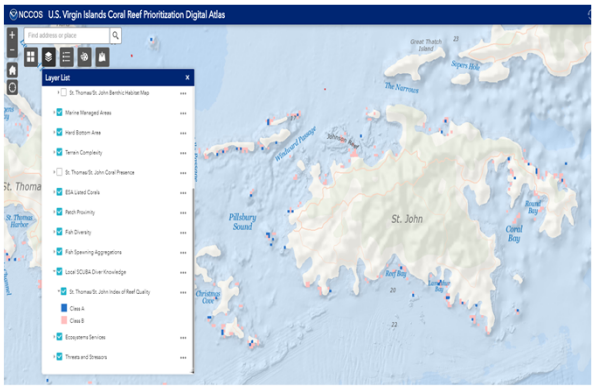
NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Social Science | Case Study | Human Use

BENEFITS OF OUR WORK

The occupational diver survey produced valuable data and findings for the USVI, independent of broader project goals. Study findings provided insight from local experts previously undocumented by traditional data collection methods. Further, the survey was instrumental for including the knowledge and voices of those who use the reefs and depend upon them for their livelihoods.

The resulting US Virgin Islands Coral Reef Prioritization Digital Atlas supports the USVI Department of Natural Resources in ocean planning, permitting of marine and coastal activities, and strategic investment of resources. It also facilitates informed input from constituents, such as planners and community members.



U.S. Virgin Islands Coral Reef Prioritization Digital Atlas
https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=3832758b3e4044c79079845e2c2487eb

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

we deliver ecosystem science solutions to sustain thriving coastal communities and economies

PRESENTATION 12

BIOGEOGRAPHIC ASSESSMENT

BOEM Biogeographic Assessment for Main Hawaiian Islands

Bryan Costa, Marine Ecologist

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

DEFINITION

Biogeography is the study of the spatial and temporal distributions of organisms, their associated habitats, and the historical and biological factors that influence species' distributions. The concept of a "biogeographic assessment (BA)" (Fig. 1) builds on these principles, and provides a process to compile and evaluate spatial and temporal data, characterize ecological patterns, fill data gaps, as well as measure and map spatial uncertainty in support of marine ecosystem-based management (Caldow et al., 2015). This framework and process was developed by the Biogeography Branch through two decades of close collaboration with scientists and resource managers.

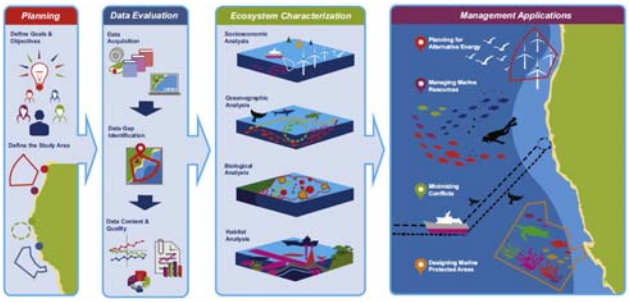


Fig 1. This diagram illustrates the three steps in the biogeographic assessment (BA) framework. Figure from Caldow et al. 2015.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

WHAT WE DO

The Biogeography Branch has conducted biogeographic assessments for Federal, State, and Territorial partners from the Atlantic Ocean to Samoan Archipelago. Typical products from an assessment range from distribution maps for species or habitats to more complex ecological analyses and mathematical predictions that integrate biological, physical and sociological variables (Fig 2). These assessments are usually conducted at broad (>10,000 sq km) spatial scales and often focused on long term (>10 years) spatial patterns. That said, a BA can be tailored to the specific needs of a marine resource agency, and applied to finer spatial and temporal scales as needed (Caldow et al. 2015). The final report and spatial products are made publicly available at the end of these projects.

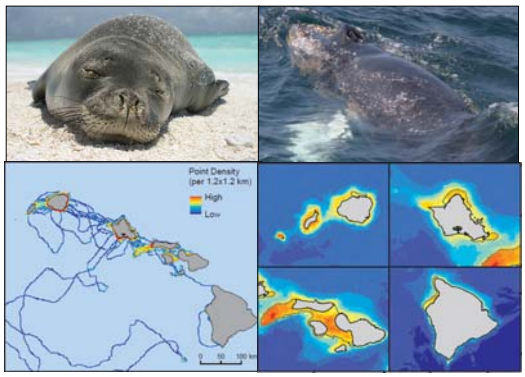


Fig 2. (Left) Maps showing areas frequently used by Hawaiian Monk Seals, and (right) the predicted distribution of Humpback whales around the Main Hawaiian islands.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

PRODUCT APPLICATION(S)

Biogeographic Assessments (Fig 3) have been used in a wide range of management, policy, and research settings by Federal, State, and Territorial partners in U.S. waters, including:

- Preparedness & risk reduction
  - Marine Spatial Planning
  - Local Area Use Regulations
- Stewardship, recreation, & tourism
  - Monitoring & Research Program Designs
  - Mitigating Impacts to Vulnerable Habitats & Species
  - Marine Protected Area Designations/Expansions
- Safe & efficient transportation & commerce
  - Fisheries Ecosystem Models
  - Undersea Cable Routing
  - Offshore Renewable Energy Leasing

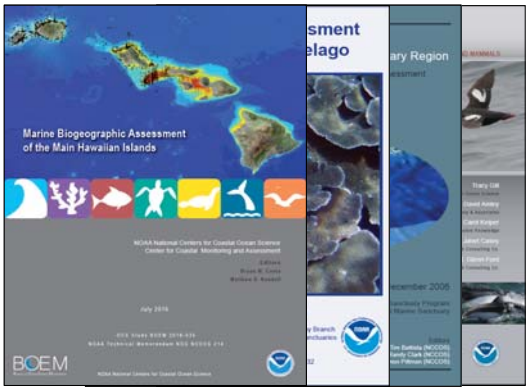


Fig 3. Examples of biogeographic assessment reports developed by the Biogeography Branch.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

CASE STUDY

BOEM Biogeographic Assessment of the Main Hawaiian Islands

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

WHY WE CARE

The state of Hawai'i is working to develop local renewable energy sources. Most of the State's potential renewable energy resources are located in federal waters. The Bureau of Ocean Energy Management (BOEM) regulates the leasing, construction and operation of most renewable energy projects in federal waters, and is required to evaluate the potential human, coastal and marine impacts from these projects. BOEM partnered with the Biogeography Branch to gather and synthesize spatial information around the Main Hawaiian Islands for this evaluation (Fig 4). Comprehensive and up-to-date spatial information is critical for assessing these proposals and minimizing their potential impacts on the surrounding ecosystems.

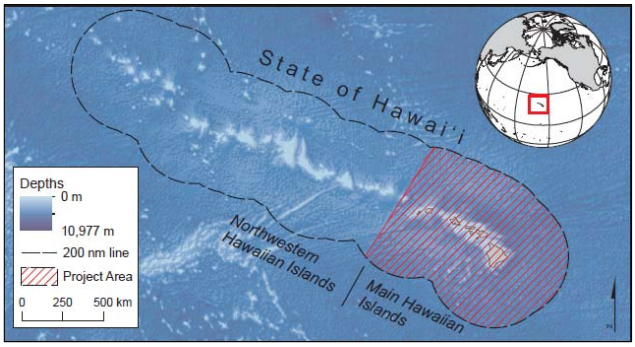


Fig 4. The Main Hawaiian Islands (MHI) includes Ka'ula (Rock), Ni'ihau, Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, Kaho'olawe and Hawai'i.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

WHAT WE ARE DOING

In 2013-2016, the Biogeography Branch conducted a biogeographic assessment for BOEM in the MHI. This work included compiling existing and synthesizing new spatial datasets describing the physical environment, benthic communities, fishes, turtles, whales, dolphins, seals, and seabirds around the MHI. No new information was collected *in situ*. Data and expertise came from a variety of federal, state, academic and non-governmental partners. The complexity of products ranged from simple animal distribution maps to mathematical models depicting the predicted distributions of animals. Analyses were specifically designed for compatibility with BOEM's regulatory framework (Fig 5), and tailored around BOEM's specific informational needs and regulatory mandates.

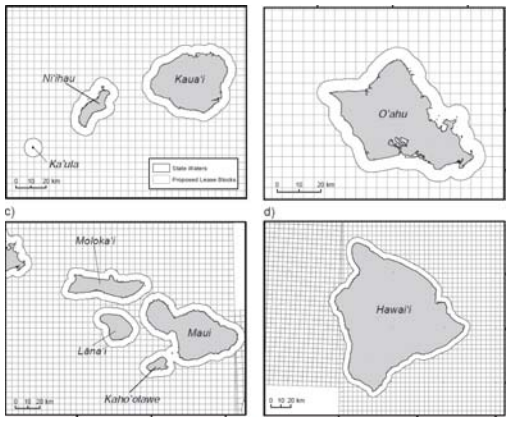


Fig 5. Maps showing the boundaries of BOEM's proposed lease blocks in the MHI.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

BENEFITS OF OUR WORK

Understanding spatial and temporal patterns is critical for marine spatial planning efforts. In the MHI, this biogeographic assessment was a critical component of larger BOEM and State processes to evaluate offshore renewable energy proposals and to effectively manage living marine resources around the MHI. This work was critical because it established a baseline for assessing potential impacts, a guide for monitoring change, a roadmap for prioritizing how to fill data gaps, and a framework for integrating ocean research and management efforts moving forward. These products are already being used by the state of Hawai'i is to support its '30 by 30' initiative (Fig 6). This initiative aims to effectively manage 30 percent of State waters by 2030. Our products are actively being used to optimize the selection of these new, state marine managed areas.

Fig 6. The state of Hawai'i's "30 by 30" initiative is using products from this assessment to choose key areas for protection.

JULY 23-25, 2019
SILVER SPRING, MD

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

NEXT STEPS

This project was completed in 2016.

On June 24, 2016, BOEM published a "Call for Information and Nominations" to seek additional nominations from companies interested in commercial wind energy leases offshore of the MHI. BOEM also sought public input on the potential for wind development in the Call Areas (Fig 7). The comment period is now closed. BOEM is now in the Area Identification stage of the leasing process, during which BOEM will identify areas for environmental analysis and consideration for leasing. For more information on the leasing process, please see: https://www.boem.gov/Hawaii/

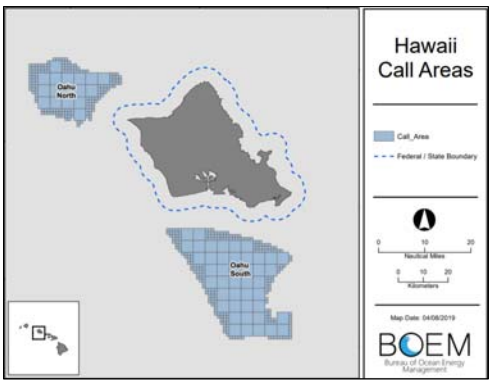


Fig 7. Areas in blue (above) are being considered by BOEM for renewable energy leasing and development offshore of O'ahu.

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**

Monitoring, Modeling & Assessment | Capability | Biogeographic Assessment

BIOGEOGRAPHIC ASSESSMENT

Question & Answer Session

JULY 23-25, 2019
SILVER SPRING, MD