

2021 NOS SCIENCE REPORT



NATIONAL OCEAN SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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About the NOS Science Report:

This report includes summaries of selected scientific projects undertaken by the program offices of NOAA's National Ocean Service (NOS) during Fiscal Year 2021 (FY21). All of these projects were submitted by each program office for consideration in the annual NOAA Science Report (2021), within which many are also featured. Each project summary includes a short description of the research conducted by NOS staff, major accomplishment(s), and points of contact, with links to published materials and online project information.

Project summaries are organized according to the three NOS and six National Centers for Coastal Ocean Science (NCCOS) primary priorities¹, and are cross-referenced with the six major [NOAA Science and Technology Focus Areas and Science Strategies](#) and additional NOAA cross Line Office efforts.

*Assembled by the National Ocean Service
Coastal Science Board*

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About the NOS Coastal Science Board:

The NOS Coastal Science Board serves as the forward-thinking science advisory group to the National Ocean Service. The Board provides a forum to strengthen internal connections between program offices, NOS Headquarters (HQ) & Leadership, and NOAA HQ, resulting in better service to NOS constituents and greater support of NOAA's mission. Additionally, the Board provides assistance to all NOS Program Offices in establishing and addressing priorities for coastal, ocean, and Great Lakes science, as well as in identifying current and future science and research requirements in support of NOS Program Offices, associated stakeholders, and statutory mandates. The Board reports to the director of the National Centers for Coastal Ocean Science (NCCOS), who serves as the NOS representative to the NOAA Science Council. The Board also provides annual updates of its progress to NOS program office leadership. For more information, please consult the NOS Science Board's [Terms of Reference](#).

¹ NCCOS (NOAA National Centers for Coastal Ocean Science). 2021. [Science Serving Coastal Communities: FY22-26](#). US Department of Commerce. National Oceanic and Atmospheric Administration. National Ocean Service. 20p.

² With contributions from Amy V. Uhrin, former OR&R representative to the NOS Coastal Science Board.

³ Currently assuming these duties. With contributions from Steve Hilla (retired), former NGS representative to the NOS Coastal Science Board.

About the Agency:

The National Ocean Service (NOS) is the nation's premier science agency for oceans and coasts. NOS delivers the applied science, modeling, tools, and services needed to understand, predict, and respond to the challenges we face along America's 95,000 miles of shoreline and 3.5 million square nautical miles of coastal, Great Lakes, and deep-ocean waters. Additionally, NOS oversees the definition, maintenance, and access to the National Spatial Reference System for all federal geospatial activities. This enables NOS to better manage the sea/shore boundary for coastal resilience and planning.

More information about the eight NOS program offices is available below:

Center for Operational Oceanographic Products and Services (CO-OPS)

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) is the authoritative source for accurate, reliable, and timely tides, water levels, currents and other oceanographic information. CO-OPS data, products and services support safe and efficient navigation, sound ecosystem stewardship, coastal hazards preparedness and response, and the understanding of climate change.

National Centers for Coastal Ocean Science (NCCOS)

The National Centers for Coastal Ocean Science (NCCOS) is the focal point for NOAA's coastal ocean science efforts. NCCOS helps NOAA to meet its coastal stewardship and management responsibilities, and provides coastal managers with the scientific information necessary to decide how best to protect environmental resources and public health, preserve valued habitats, and improve the way that communities interact with coastal ecosystems. NCCOS major focus areas include coastal change: vulnerability, mitigation, and restoration; marine spatial ecology; social science, and stressor impacts and mitigation.

NCCOS additionally funds external research through its Competitive Research Program.

National Geodetic Survey (NGS)

NOAA's National Geodetic Survey (NGS) provides the framework for all positioning activities in the Nation. The foundational elements of latitude, longitude, elevation, and shoreline information impact a wide range of important activities. NGS' mission is to define, maintain and provide access to the National Spatial Reference System to meet our nation's economic, social, and environmental needs.

Office of Coast Survey (OCS)

NOAA's Office of Coast Survey (OCS) maintains the nation's nautical charts and publications for U.S. coasts and the Great Lakes. OCS creates and maintains over a thousand charts covering 95,000 miles of shoreline and 3.4 million square nautical miles of water. OCS supports the 1.3 billion metric tons of cargo valued at \$1.8 trillion that comes in and out of U.S. ports every year. In addition, OCS conducts hydrographic surveys to collect depth measurements for nautical charts, and to aid in navigation, provides regional navigation support, develops models for storm surge and hurricane prediction, and develops and tests new technologies to improve mapping efficiencies.

Office of National Marine Sanctuaries (ONMS)

NOAA's Office of National Marine Sanctuaries serves as the trustee for a network of underwater parks encompassing more than 600,000 square miles of marine and Great Lakes waters. The network includes a system of 14 national marine sanctuaries and Papahānaumokuākea and Rose Atoll marine national monuments. The system works with diverse partners and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued ocean places. The Office of National Marine Sanctuaries also leads the National Marine Protected Areas Center, the nation's hub for building innovative partnerships and tools to protect our special ocean places. In addition, ONMS staff conduct and support research and monitoring programs tailored to the information needs of each sanctuary.

Office of Response and Restoration (OR&R)

NOAA's Office of Response and Restoration (OR&R) is a center of expertise in preparing for, evaluating, and responding to threats to coastal environments, including oil and chemical spills, releases from hazardous waste sites, and marine debris. OR&R's mission is to develop scientific solutions to keep the coasts clean from threats of oil, chemicals, and marine debris. To fulfill its mission of protecting and restoring NOAA trust resources, OR&R provides scientific and technical support to prepare for and respond to oil and chemical releases; determines damage to natural resources from these releases; protects and restores marine and coastal ecosystems, including coral reefs; and works with communities to address critical local and regional coastal challenges. OR&R comprises four technical divisions: Emergency Response, Assessment and Restoration, Marine Debris, and the Disaster Preparedness Program. Collectively, OR&R provides comprehensive solutions to marine pollution.

Office for Coastal Management (OCM)

NOAA's Office for Coastal Management (OCM) is the federal agency tasked with implementing the Coastal Zone Management Act, which is the guiding legislation for the decisions and actions taken to keep the natural environment, quality of life, and economic prosperity of coastal areas in balance. As a scientific organization, NOAA provides access to the science and environmental intelligence communities need for these tasks. Four major programs make up the Office for Coastal Management, and each counts on active partnerships with all sectors to be successful. They include the National Coastal Zone Management Program, the National Estuarine Research Reserves, the NOAA Coral Reef Conservation Program, and NOAA's Digital Coast.

The U.S. Integrated Ocean Observing System (IOOS)

The U.S. Integrated Ocean Observing System (IOOS) is a national-regional partnership working to provide new tools and forecasts to improve



safety, enhance the economy, and protect our environment. Integrated ocean information is available in near real time, as well as retrospectively. Easier and better access to this information is improving our ability to understand and predict coastal events - such as storms, wave heights, and sea level change. Such knowledge is needed for everything from retail to development planning. IOOS' mission is to produce, integrate, and communicate high quality ocean, coastal and Great Lakes information that meets the safety, economic, and stewardship needs of the Nation. IOOS' Operations Division coordinates the contributions of Federally-owned observing and modeling systems and develops and integrates non-federal observing and modeling capacity into the system in partnership with IOOS regions.

NOS PRIORITY:**PREPAREDNESS
& RISK
REDUCTION
(COASTAL
RESILIENCE)**

COASTAL COMMUNITIES represent a major economic engine for the United States. Immediate and potentially life-threatening events such as hurricanes, as well as long-term issues like high tide flooding, are real challenges to coastal communities. NOS brings a unique range of information and capabilities to help communities prepare for, respond to, and recover from these events. For example, NOS maintains the nation's network of coastal tide and water level sensors to provide real-time data that supports accurate weather forecasts, coastal storm and flood predictions, and tsunami warnings. NOS provides data and tools that enable businesses and coastal communities to better plan for and mitigate risk from changing conditions. The agency provides

information and data to protect human health and coastal economies with early warnings of harmful algal blooms and other threats. Every year, NOS responds to natural disasters and more than 150 oil and chemical spills in U.S. and state waters, which damage environments and disrupt economies. As the authoritative resource for science related to marine debris, oil, and chemical spills, NOS provides responders with the information they need to understand the severity of a spill and where it will travel.

Following are coastal resilience themed projects organized according to five primary scientific priorities of the National Centers for Coastal Ocean Science (NCCOS) strategic plan.

Advanced Observation Technologies and Ecological Forecasts

Included below are five highlighted scientific projects by CO-OPS, NCCOS, NGS, and IOOS researchers and their partners, which are focused on advanced observation technologies and ecological forecasting. Those listed here from CO-OPS and IOOS are in alignment with the implementation efforts of [NOAA's Earth Prediction Innovation Center \(EPIC\)](#).

The Operational Transition of the NOAA Rip Current Model

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS), together with partners from the National Weather Service (NWS), launched the first ever national rip current forecast

model developed by NOS and implemented into operations by NWS' Meteorological Development Laboratory (MDL), National Centers for Environmental Prediction (NCEP), and Analyze, Forecast, and Support Office (AFS). The model runs operationally at NCEP as a component of the Nearshore Wave Prediction System (NWPS) and predicts the likelihood of hazardous rip currents every kilometer along the coast, every hour up to six days out. The research creating the model was initially published by NOS scientists in 2013, and was successfully transitioned in FY21 following a multi-year assessment of model performance at numerous locations across the coastal U.S. Rip currents cause about 100 deaths in the U.S. each year, and the improved accuracy, resolution and lead-time this model provides has the potential to reduce the number of drownings and save lives.

FY21 ACCOMPLISHMENT:

The first ever national probabilistic rip current model was transitioned into NWS operations.

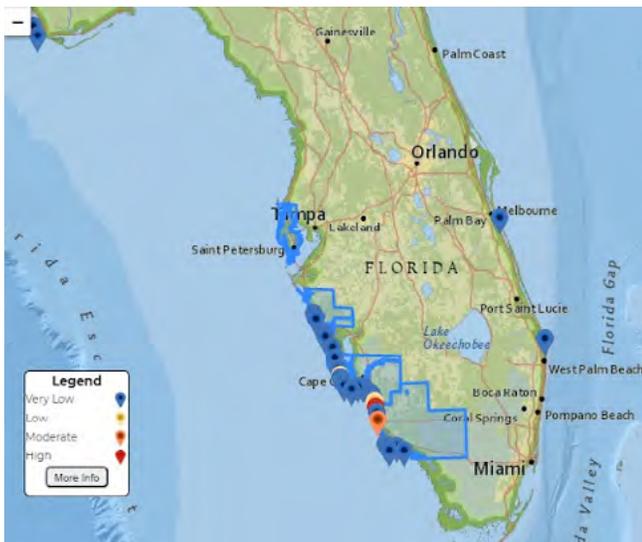
Project URL: <https://oceanservice.noaa.gov/news/apr21/rip-current-forecast.html>



The left panel image shows a rip current using a harmless green dye. Rip currents are powerful, narrow channels of fast-moving water (at speeds up to 8 feet per second) that are prevalent along the east, Gulf, and west coasts of the U.S., as well as along the shores of the Great Lakes. The Nearshore Wave Prediction System coverage for the continental U.S. (right panel), with an inset box showing hazardous rip current likelihood for the North Carolina coast. Alongshore color denotes rip current likelihood from low (gray) to high (red). Image credit: NOAA/NOS.

Improved Forecasts of Respiratory Illness Hazard from Gulf of Mexico Red Tide

Blooms of *Karenia brevis* (commonly known as “red tide”) produce a neurotoxin that often gets into particles in the air. When inhaled, the toxin causes respiratory irritation in healthy people, and may have severe impacts on people with asthma and other respiratory conditions. Many people tend to avoid all beaches during these red tides, which can result in negative economic impacts on local businesses. As these blooms are patchy, and winds that carry toxins onshore are variable, communities need high resolution information on where and when respiratory irritation may occur. The National Centers for Coastal Ocean Science (NCCOS) has substantially improved the spatial and temporal resolution of its predictions, from a daily forecast at the county level, to forecasts at every three hours for parks and other beaches.



A screen grab of the Red Tide Respiratory Forecast on December 15, 2020. Image credit: GCOOS.

FY21 ACCOMPLISHMENT:

With its partner, the Gulf of Mexico Coastal Ocean Observing System (GCOOS), NCCOS is producing and posting forecasts of respiratory irritation, updated every 3 hours, currently at 6-12 beaches in each county along the Gulf of Mexico and east coast of Florida.

Project URL: <https://coastalscience.noaa.gov/research/stressor-impacts-mitigation/hab-forecasts/gulf-of-mexico/>

AWARDS & RECOGNITION:

A component of this project, the NOAA HABSscope, a portable microscope system for citizen science-based volunteer monitoring of red tides, received a 2020 NOAA Technology Transfer Award

An Early Warning System for *Pseudo-nitzschia* HABs on Pacific Northwest Outer-Coast Beaches

A project funded by the NCCOS Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Research Program supports the development and demonstration of a monitoring and modeling-based seasonal (Spring and Autumn) HAB forecast system to generate Pacific Northwest (PNW) HAB Bulletins for state and tribal managers. The Bulletin provides advance warning of toxic *Pseudo-nitzschia* HAB events supporting targeted shellfish management decisions. Each Bulletin combines expert analysis of data on real-time ocean conditions, algae and algal toxin abundance in offshore hotspots and near the region’s clamming beaches, and forecast model output to predict toxic *Pseudo-nitzschia* events. The PNW HAB Bulletin pilot project has been supported largely by NOAA NCCOS grants to University of Washington and Oregon Department of Fish and Wildlife and in partnership with the Olympic Region Harmful Algal Bloom Partnership (ORHAB), the Washington Department of Health, the Washington Department of Fish and Wildlife, the Makah Tribe and NOAA Fisheries. The US Integrated Ocean Observing System has provided additional support to the University of Washington, the Northwest Association of Networked Ocean Observing Systems and NOAA Fisheries. NCCOS grant support runs through 2022 and efforts are

underway to transition the Bulletin to operations at NANOOS to ensure continued delivery of trusted PNW HAB Bulletin forecasts to managers.



Oregon Pacific razor clams (Siliqua patula).

Image credit: Oregon Department of Fish and Wildlife.

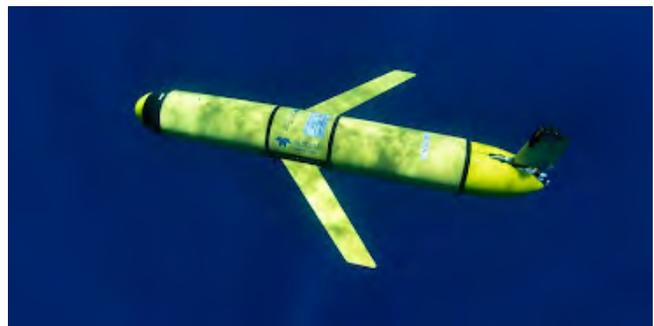
FY21 ACCOMPLISHMENT:

Timely PNW Harmful Algal Bloom (HAB) Bulletins, the result of a NOAA-funded pilot and good results from state shellfish toxin testing, helped the Quinault Indian Nation and Washington State Department of Fish and Wildlife (WDFW) decide to allow limited Spring razor clam digs in the spring of 2021. This decision resulted in the first instance of public access to this prized shellfish resource since the fall of 2020, when all clamming beaches in Washington and Oregon were closed due to a HAB event. WDFW estimated 27,850 participants enjoyed recreational razor clam digging at one beach in just six days.

Project URL: <https://coastalscience.noaa.gov/news/hab-bulletin-supports-quinault-tribal-access-to-razor-clams-after-algal-toxin-closure/>

Hurricane Glider project maximizes 2020 hurricane season subsurface ocean observing activities

A cooperative effort to gather ocean data in support of hurricane forecasting experienced its most successful year yet in 2020, gathering 163,000 glider profiles over 3,600 “glider days” (1 glider at sea for 1 day). Data from gliders improves the representation of specific ocean features, such as cold pools, which are known to affect hurricane intensity. When these features are correctly represented in coupled hurricane models, forecasts of tropical cyclone intensity are greatly improved. Since 2017, NOAA’s U.S. Integrated Ocean Observing System (IOOS) Office has collaborated with OAR’s Atlantic Oceanographic and Meteorological Laboratory (AOML) to lead a project among 15+ partner institutions — including NOAA, the U.S. Navy, and IOOS Regional Associations — that uses autonomous underwater gliders to gather temperature and salinity profiles that elucidate the ocean’s role in hurricane intensity. Glider data are delivered each time the glider surfaces, and transmitted in near-real time via the IOOS Glider Data Assembly Center to the GTS from where it is integrated into hurricane forecast models.



Deployed glider collecting profiles of water temperature and salinity during the 2020 hurricane season. Image credit: Dan Mele

FY 2021 ACCOMPLISHMENT:

IOOS Regional Associations, with OAR and Navy partners, collected the largest number of autonomous in-situ observations to date in support of hurricane forecasting improvements: 163,000 glider profiles and 3,600 glider days.

Project URL: <https://gliders.ioos.us/>

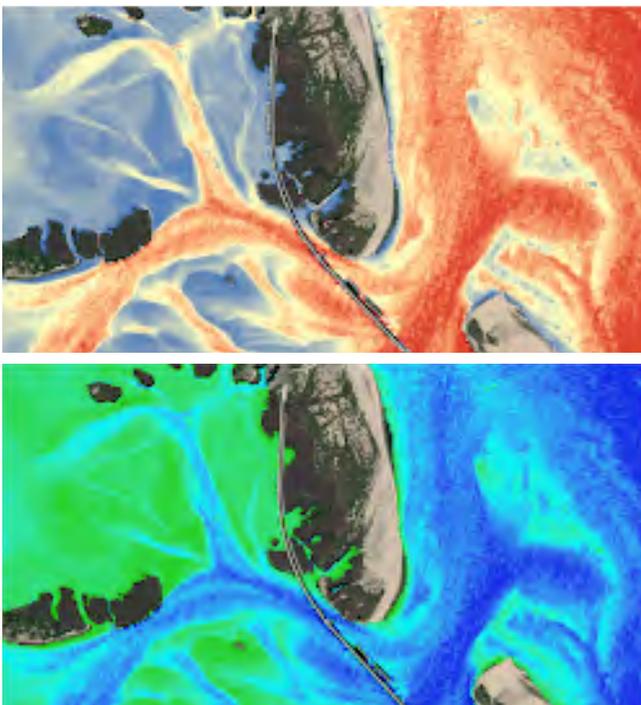
Applying new research and automating Satellite Derived Bathymetry

Beginning in 2016, NOAA's National Geodetic Survey (NGS) began collaboration efforts between the National Centers for Coastal Ocean Science (NCCOS) and the Office of Coast Survey (OCS) to create a user friendly Satellite Derived Bathymetry (SDB) tool that would provide consistent and quick results utilizing new research from NOS scientists and their partners. Since 2016, progress has been made to incorporate "a robust atmospheric correction, a multi-scene compositing method to reduce the impact of turbidity and a switching model to improve mapping in shallow water" to improve upon a past SDB algorithm (Stumpf et al. 2003). In tandem with this effort, NGS has been working with NCCOS to develop a framework and began developing the NOAA SatBathy tool.

FY21 ACCOMPLISHMENT:

NGS began creating the framework and creation of the SatBathy tool.

Peer reviewed journal article URL: Caballero & Stumpf 2020 *Remote Sensing* <https://www.mdpi.com/2072-4292/12/3/451>



Oregon SDB created Inlet (Oct 2020) using NGS' new pre-alpha SatBathy tool v1.0 based on research from NCCOS. Image credit: NOAA/NOS/NGS.

Detecting, Monitoring, and Mitigating Impacts of Chemical and Biological Stressors on Coastal Ecosystems

Below are four highlighted scientific projects by NCCOS and OR&R researchers and their partners, which are focused on detecting, monitoring, and mitigating the impacts of chemical and biological stressors in coastal systems.

Field-based mesocosms: in situ deployments for assessing impacts of chemical spills in coastal areas

The NCCOS Ecotoxicology Branch designed, engineered, and validated a system of field-deployed mesocosms for use by NOAA's Office of Response and Restoration (OR&R) in assessing oil or other chemical spill impacts. The system will serve as a rapid-response tool for determining chemical effects on fish and invertebrates, and addresses a critical need to collect data immediately after a spill. Researchers tested different enclosure designs to select a preferred model based on performance, durability, ease of use, and portability. The preferred design was tested using two common estuarine organisms (grass shrimp and mummichogs) in the laboratory (in Charleston) and in the field (Southeastern and Gulf Coasts). This technology was transferred to OR&R via a Standard Operating Procedure, a StoryMap describing purpose, design, construction, and usage of the systems, and three sets of field enclosures.



Field deployed mesocosms (outdoor experimental systems) at Rincon Bayou in the Nueces Delta near Corpus Christi, Texas.

Photo Credit: Elizabeth Harris, Texas A&M University Corpus Christi

FY21 ACCOMPLISHMENT:

Field-based Mesocosms: Construction and Deployment story map, which is intended as an instructional manual to guide you through the methods of construction and deployment of a field mesocosm.

Project Story Map: <https://storymaps.arcgis.com/stories/c1401f79e2364d3ab6dabfceefcc6a02>

Project URL: <https://coastalscience.noaa.gov/project/field-based-mesocosms-in-situ-deployments-for-assessing-impacts-of-chemical-spills-in-coastal-areas/>

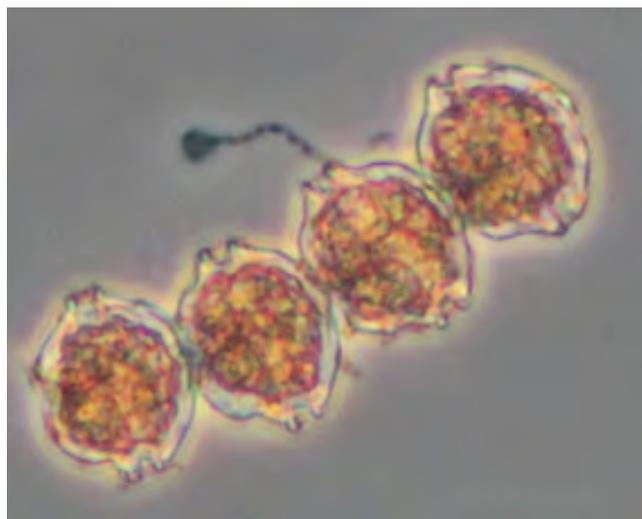
AWARDS:

A nomination was submitted for B. West for an NOS Team Member of the Year Award.

Research Paper on Influence of Copepod Grazers on HAB Toxicity Deemed One of Special Significance by Expert Faculty Opinion Group

A research paper, supported by **NCCOS**, measuring the metabolic cost to the red tide dinoflagellate *Alexandrium* to defend itself against predation (consumption) has been recommended by the prestigious *Faculty Opinions* as one of special significance in its field. The recommendation notifies others in the field of study, and beyond, that the paper is considered exciting and highly important emerging research. The research presents a novel framework to incorporate the cost of defense in toxin-producing prey/predator relationship models. Documenting such costs scientifically has proven very difficult, especially for chemical defenses such

as toxins used by phytoplankton vulnerable to grazing by zooplankton.



Chain of Alexandrium catenella cells.

Image credit: Brian Bill, NOAA Fisheries

FY21 ACCOMPLISHMENT:

The study, published in Proceedings of the Royal Society B, measured a potential direct fitness cost of copepod grazer-induced toxin production in a harmful algal bloom (HAB) dinoflagellate prey (*Alexandrium catenella*) using relative gene expression of a cell division gene that correlates to cell growth; previous experimental work has failed to clearly detect such induced defense cost in toxic phytoplankton.

Peer-Reviewed Publication: <https://royalsocietypublishing.org/doi/abs/10.1098/rspb.2020.2480>

Project URL: <https://coastalscience.noaa.gov/news/research-paper-deemed-one-of-special-significance-by-influential-faculty-opinions-group/>

AWARDS:

The research paper was highlighted in prestigious *Faculty Opinions* as one of special significance in its field.

Acute Polychlorinated Biphenyl Benthic Invertebrate Toxicity Testing to Support the 2017 Chronic Dose–Response Sediment Injury Model

OR&R and **NCCOS** researchers completed acute aquatic toxicity testing with polychlorinated biphenyls (PCBs) using three estuarine invertebrates and multiple lethal endpoints. The

new acute injury tests confirmed that an important injury assessment model in 2017 derived with chronic toxicity data was valid and a 1.0 µg/g chronic PCB sediment criterion is a reasonable estimation of potential benthic invertebrate injury. The new data and improved sediment injury model is expected to be applied at hazardous waste site damage assessments across the country.



PCB contamination is high in water bodies such as the Housatonic River and New Bedford Harbor in Massachusetts.

Image credit: U.S. Fish and Wildlife Service.

FY21 ACCOMPLISHMENT:

A key sediment injury model was improved and is more defensible for use in Natural Resource Damage Assessments (NRDAs) across the country.

Peer Reviewed Publication: <https://setac.onlinelibrary.wiley.com/doi/10.1002/etc.4977>

Project URL: <https://response.restoration.noaa.gov/noaa-study-featured-journal-environmental-toxicology-and-chemistry>

New Interface in the GNOME Oil Spill Model for Modeling Suspected Oil Spills Detected in Satellite Imagery

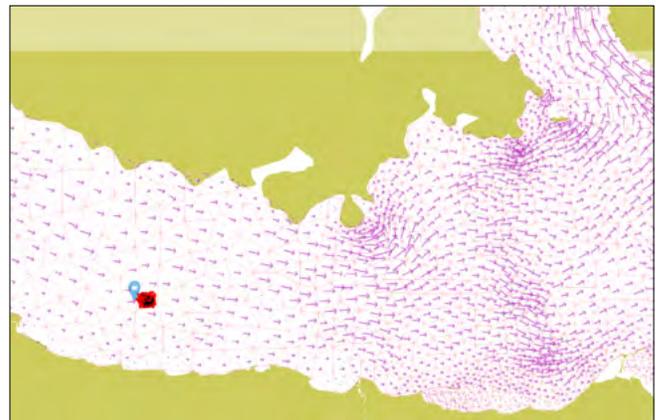
The General NOAA Operational Modeling Environment (GNOME) model is used by OR&R researchers for predicting the movement of pollutants, like oil, spilled in coastal waterways. This information is used to support emergency response actions undertaken to mitigate the impacts of spills on marine resources. Through a partnership with the Bureau of Safety and Environmental Enforcement (BSEE), development work in FY21 integrated the use of operational

Marine Pollution Surveillance Reports produced by NOAA’s National Environmental Satellite Data and Information Service (NESDIS) in the GNOME model. These satellite-based analyses are derived from monitoring of U.S. coastal waters for anomalous features in satellite imagery that are believed to have resulted from an accidental or intentional crude oil discharge. These reports can now be loaded directly via the WebGNOME interface to initialize a spill and model its transport.

FY21 ACCOMPLISHMENT:

Integrated the use of operational Marine Pollution Surveillance Reports produced by NOAA NESDIS into the GNOME model for oil spills.

Project URL: <https://gnome.orr.noaa.gov/>



Top panel: A map view from WebGNOME, showing currents moving the oil in a simulated spill. Bottom panel: Oil fate (weathering) view from WebGNOME, showing an oil budget for a simulated spill.

Image credit: NOAA/NOS/ORR.

Ecosystem Science for Conservation and Sustainable Use

Below are six highlighted scientific projects by NCCOS, ONMS, and OCS researchers and their partners, which are focused on ecosystem science for conservation and sustainable use of coastal systems.

RESTORE Council Monitoring and Assessment Program (CMAP): A Comprehensive Monitoring Network

The Gulf Coast Ecosystem Restoration Council⁴ Monitoring and Assessment Program (CMAP), administered by NOAA (with support from NCCOS) and the US Geological Survey (USGS), developed foundational components for a Gulf of Mexico-wide monitoring network to support the Council in making science-based decisions and evaluating restoration effectiveness. Programmatic



RESTORE Council Monitoring and Assessment Program Area of Interest (within aqua line). Image credit: NOAA.

metadata for 544 Gulf of Mexico water quality and habitat monitoring and mapping programs were assembled into a database that was the foundation for a web-accessible data discovery and visualization tool. The information provides the best available science for RESTORE Council restoration activities and supports broader Gulf of Mexico restoration, monitoring and research communities by providing a single access point for monitoring metadata.

FY21 ACCOMPLISHMENT:

Updates to and maintenance of the monitoring metadata database.

Project URL: <https://restorethegulf.gov/cmap>

AWARDS:

Contract staff have won the NCCOS Peer Recognition Special Achievement Award. The project Team has been nominated for a NOAA Bronze Medal.

Improved geospatial tools for vibrio and harmful algal bloom risk assessment for the Alaska shellfish mariculture industry and coastal communities

Alaska communities face ongoing and increasing climate change-driven threats for public health and shellfish mariculture operations from vibrio and paralytic shellfish poisoning caused by *Vibrio* bacteria and harmful algal blooms (HABs) of *Alexandrium* phytoplankton species. To help communities and managers assess risks for shellfish consumption and more efficiently target *Vibrio* monitoring and HAB toxin efforts, NCCOS developed pilot Alaska vibrio and HAB risk assessment products from high resolution, satellite sea surface temperature imagery. The web-based, geospatial tools build on previous NCCOS Alaska research and monitoring efforts to identify *Vibrio* species and quantify relationships between water temperature and *Alexandrium* blooms. The pilot risk assessment products are being tested by state, federal, Alaska Native tribal and academic stakeholders, including through the multi-agency Alaska HAB Network, and NCCOS will refine the product in response to user feedback.

⁴ This council, also referred to as the RESTORE Council, was established by the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE Act).



*NCCOS researchers testing for *Vibrio parahaemolyticus* in the laboratory to examine its effects on Pacific northwest and Alaskan shellfish. Image credit: NOAA.*

FY21 ACCOMPLISHMENT:

Pilot satellite-based *Vibrio* and HAB risk assessment products provided for Alaska shellfish mariculture operators, resource managers and community harvesters.

Marine Sanctuaries Respond to and Prepare for Stony Coral Tissue Loss Disease

Stony Coral Tissue Loss Disease (SCTLD), a new outbreak which causes rapid death in roughly half of all Caribbean coral species, including endangered and rare species, has spread throughout the Florida Reef tract and to 20 Caribbean countries and territories. Since 2014,

this disease has expanded throughout the western Atlantic, including the Florida Keys National Marine Sanctuary (FKNMS), U.S. Virgin Islands, and Puerto Rico, and recently emerged in the Dry Tortugas as of May 2021. It has yet to be detected in the the remote reefs of the Flower Garden Banks National Marine Sanctuary (FGBNMS) or in the Indo-Pacific region. However, the number of susceptible coral species present and high coral cover at the Flower Gardens (over 50%) suggest this location may be hit hard, should the disease ever reach the Sanctuary. Given the proliferation of this disease, **NOAA's Office of National Marine Sanctuaries (ONMS), NOAA's Coral Reef Conservation Program (CRCP)**, and partners are working to find solutions and minimize damage to coral reefs. NOS staff have partnered with regional organizations to develop a cooperative network among 20 Caribbean countries and territories that works to build disease response capacity and to share information on the status of the disease and lessons learned on efforts to address it. In Florida, the U.S. Virgin Islands, and Puerto Rico, partners from federal, state, and local agencies, nongovernmental organizations, universities, and members of the community are collaborating in response. Scientific activities have included compiling a case definition, over 100 environmental and epidemiological studies, development of gear disinfection protocols to prevent further spread, the development and application of specially designed treatments to save diseased corals, rescue efforts to preserve genetic diversity, and



*Rapid mortality progression in a brain coral colony (*Pseudodiploria strigosa*) on the Florida reef tract.*

Image credit: Brian Reckenbiel/Florida Fish and Wildlife Conservation Commission.

coral propagation and outplanting trials to guide future restoration efforts. Building on knowledge gained within the FKNMS, FGBNMS established a comprehensive SCTLD prevention and response plan. The plan includes prevention, education, preparedness, early warning, response, and intervention strategies, which could help prevent disease spread within the sanctuary and allow for a rapid and effective response should the need arise. NOAA has released a strategy for the response to SCTLD. The high-level strategy provides a framework and focus for ongoing efforts to slow the spread of the disease across the Atlantic and Caribbean regions and to prevent and prepare for the possible spread of the disease into the FGBNMS and the Indo-Pacific region in support of resilient coastal ecosystems, communities, and economies nationwide. The strategy will inform a national implementation plan to understand, respond to, and mitigate the disease.

FY21 ACCOMPLISHMENT:

Florida Keys National Marine Sanctuary and its partners have implemented a comprehensive, science-based response to Stony Coral Tissue Loss Disease in the Florida Keys, and FGBNMS is using that experience to prevent, but prepare for the possibility of infection.

Project URL (Florida Keys): <https://floridakeys.noaa.gov/coral-disease/disease.html>

Project URL (Flower Gardens NMS): <https://sanctuaries.noaa.gov/science/conservation/east-west-flower-garden-banks-long-term-monitoring-2019.html>

Development of an Arc online mapping tool to track coral health and conservation for Caribbean NPS parks.

Monitoring conducted by the National Park Service (NPS) Inventory and Monitoring Program, South Florida Caribbean Network and NCCOS staff observations at individual park units, have identified coral disease as the primary cause of coral loss at NPS coral reef park units over the last 10 years, and the spread of disease is on the rise. In the last several years, there has been an unprecedented outbreak of several diseases distributed across multiple coral species over a wide geographic area. Response to this disease outbreak has included monitoring, coral rescue, research, and intervention. This project developed an Arc online mapping tool, the Coral Conservation and Management Dashboard, for Southeast coral reef parks to be used by park staff to track these efforts in a manner that allows visualization or searching for particular activities within or across parks. The tool includes coral species and associated health and disease measures needed to understand what actions are occurring where and to track the status of multiple coral diseases.

Selected view (coral disease) of the NPS Coral Conservation and Management Dashboard.

Image credit NOAA/NOS/NCCOS.



FY21 ACCOMPLISHMENT:

The online mapping tool was demonstrated virtually to over 100 participants from the National Park Service and others, including international participants in March 2021.

Presentation on the Coral Conservation and Management Dashboard: <https://noaacsc.adobeconnect.com/p641siag2sa5/>

Project URL: <https://coastalscience.noaa.gov/news/nccos-spatial-analysis-products-get-shoutouts-at-federal-gis-conference/>

Assessment and decision support for North Carolina artificial reefs

The North Carolina Artificial Reef Program manages 43 ocean artificial reefs, intended to supplement existing natural reefs, enhance fisheries, and improve the recreational fishing experience. These artificial reefs include intentionally sunk structures, such as ships, concrete pipes, and reef balls, and are defined as Essential Fish Habitat (EFH) because they likely function as nursery, foraging, and spawning grounds, as well as refuge and nearshore connectivity corridors. Collectively, these reefs provide habitat for a diversity of commercially and recreationally important fish species that fishers of NC depend upon and that divers come to see. A three-year **NCCOS** study addresses six research needs related to artificial reefs, nearby natural reefs, and their associated fish communities: 1) Evaluate temporal changes in fish assemblages on artificial reefs and natural reefs; 2) Determine connectivity between artificial reefs

and nearby natural reefs; 3) Create a reference tool to guide new enhancement decision-making toward positive biological impacts; 4) Develop indicators for assessing fish utilization of strategic coastal habitats, including artificial and natural reefs; 5) Develop fisheries-independent indices of abundance for the snapper-grouper complex, and 6) Evaluate movement of snapper-grouper at state and regional level with tagging studies.

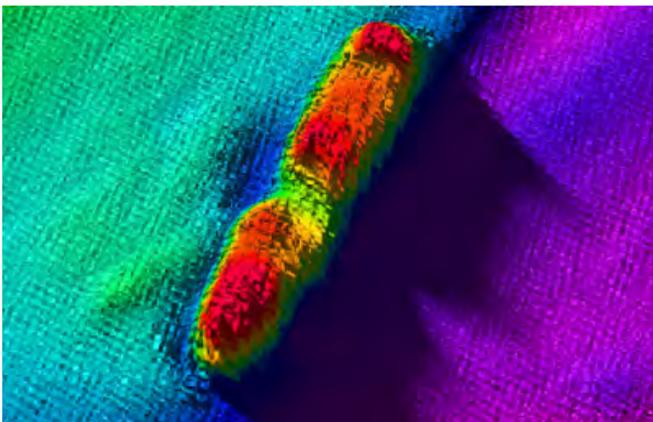
FY21 ACCOMPLISHMENT:

Collected and analyzed data on seafloor habitat structure, fish communities, and the reefs that they occupy using visual and acoustic methods.

Project URL: <https://coastalscience.noaa.gov/news/living-shipwrecks-3d-virtually-explore-north-carolinas-shipwrecks-and-marine-life/>

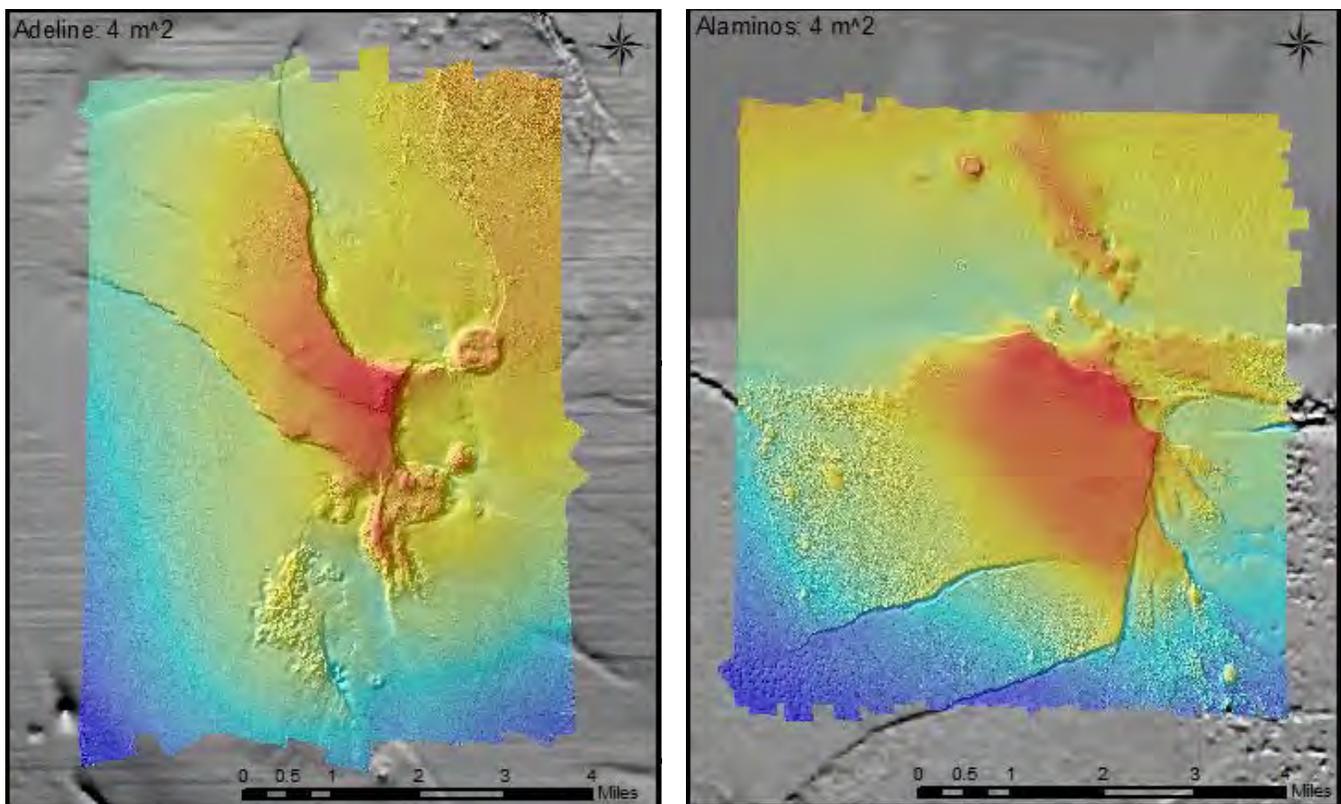
Multibeam Survey of Small Topographic Features to Determine Efficacy of Current “No Activity Zones”

ONMS staff from the Flower Garden Banks National Marine Sanctuary (FGBNMS) successfully coordinated with **NOAA’s Office of Coast Survey (OCS)** and Office of Marine and Aviation Operations to collect high resolution multibeam bathymetry of 14 reefs and banks in the Northwestern Gulf of Mexico (313.3 mi²). This data collection effort completed a five-year endeavor by Flower Garden Banks NMS to map 19 reefs and banks (341.6 mi²). The work was carried out under an Interagency Agreement (IA) between FGBNMS



Left panel: An image of the Bluefields shipwreck (offshore, North Carolina seafloor) from the NCCOS Living Shipwrecks 3D Viewer. Right panel: A diver examines marine life along a North Carolina shipwreck. Image credits: NOAA/NOS/NCCOS; Tane Casserly, NOAA.

and Bureau of Ocean Energy Management (BOEM) to collect multibeam data in the region, and supported BOEM's objective to reassess the efficacy of "No Activity Zones" (NAZs) currently in place to protect biological resources from harmful impacts from oil and gas industry activities. The current NAZ boundaries were mapped using now out-of-date bathymetric data available in the 1970s. Modern bathymetric mapping methods result in far superior levels of resolution, and have revealed areas of high biological potential outside of the current NAZs, portions of which are now within the newly expanded FGBNMS.



Multibeam survey images of Gulf of Mexico small topographic features (Adeline and Alaminos Banks) taken by the hydrographic survey vessel, NOAA Ship Thomas Jefferson. Image credit: NOAA.

FY21 ACCOMPLISHMENT:

Successful collection of valuable high resolution multibeam data for 19 reefs and banks in the Northwestern Gulf of Mexico, through a coordinated effort between multiple NOAA offices and BOEM.

Flower Garden Banks National Marine Sanctuary Mapping Projects
2017-2020 Report: <https://nmsflowergarden.blob.core.windows.net/flowergarden-prod/media/archive/doc/reports/mappingprojectreport.pdf>

Resilience and Adaptation to Inundation and Climate Impacts

Below are five highlighted scientific projects by **NCCOS** and **OCM** researchers and their partners, which are focused on resilience and adaptation to inundation and climate impacts in coastal systems.

Coastal managers use model results and a story map from a NOAA funded project to evaluate the vulnerability of San Francisco Bay tidal marshes to inform restoration.

This **NCCOS**-supported project, funded by the NOAA Effects of Sea Level Rise (ESLR) research program and led by scientists at Oregon State University and USGS, enhanced an ecosystem model that projects how sea-level rise may affect tidal marshes in the San Francisco Bay-Delta including their long-term elevation and capacity for

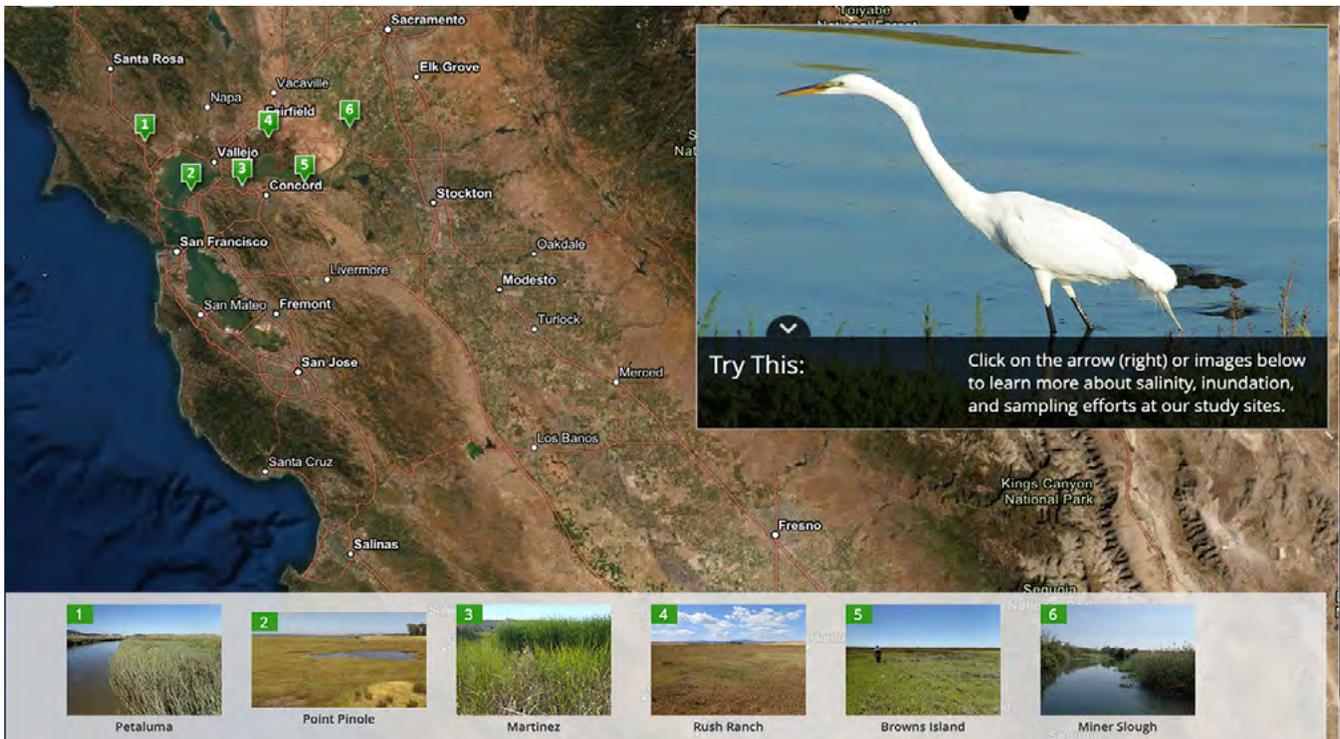
carbon sequestration. This project produced results at a regional scale that are assisting local partners in making natural resource management decisions. For example, the San Francisco Bay National Research Reserve is using these results to better understand impacts of SLR and other changing environmental conditions (e.g., salinity, sediment, and vegetation) on their managed wetlands. The Delta Stewardship Council has integrated these results into their Delta climate change planning work. Finally, the Sonoma Land Trust is using this information for their long-term planning of the Petaluma River watershed, including informing land acquisition and restoration plans.

FY21 ACCOMPLISHMENT:

In FY21, an NCCOS-led Story Map was published that will allow coastal managers to understand the science and visually evaluate wetland vulnerability to SLR, continuing to influence how marshes are managed in the region, as described above.

Story Map: <https://storymaps.arcgis.com/stories/768622e923024ef19a211b5073af0e2b>

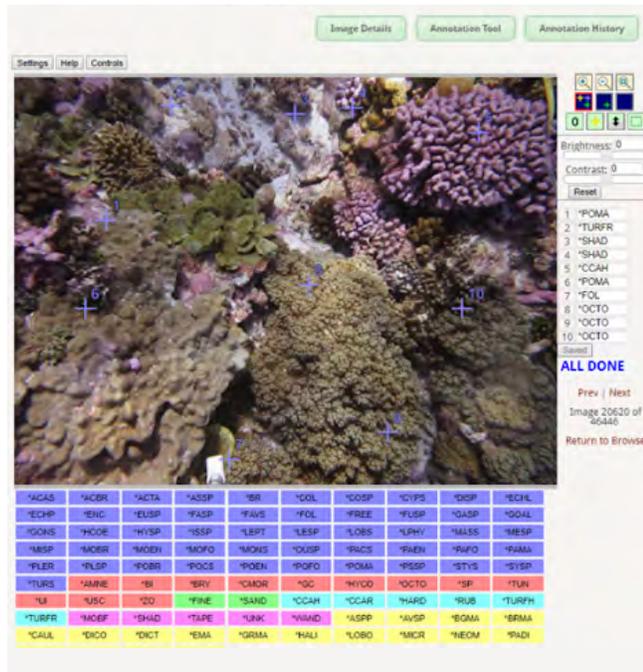
Project URL: <https://coastalscience.noaa.gov/news/story-map-highlights-marsh-vulnerability-in-san-francisco-bay-delta-estuary/>



Screen grab from the Story Map, “Marsh Vulnerability in the San Francisco Bay-Delta Estuary” that includes SLR predictions throughout specific tidal marsh systems. Image credit: NOAA/NOS/NCCOS.

Testing Intervention Strategies to Enhance Coral Resilience to Climate Change

As a result of a National Academies of Sciences, Engineering, and Medicine recommendation to review and evaluate potential novel ecological and genetic coral interventions, the Coral Reef Conservation Program (CRCP), overseen by NOAA’s Office for Coastal Management (OCM), is supporting work identified in NOAA’s Action Plan to increase coral resilience to climate change. The plan encompasses four actions for the agency: (1) research and test priority interventions, (2) develop local or regional structured decision support, (3) review policy implications of coral interventions, and (4) invest in infrastructure, research, and coordination. This action plan delineates the steps NOAA aspires to undertake in the near term toward continued persistence and conservation of coral reef systems. Examples include research on thermotolerant symbiotic algae, novel imaging from Structure-from-Motion photogrammetry to model coral population growth, and innovative rescue efforts in response to stony coral tissue loss disease.



CoralNet is a software package that uses artificial intelligence to analyze benthic photos to classify corals. Image credit: NOAA Fisheries.

FY21 ACCOMPLISHMENT:

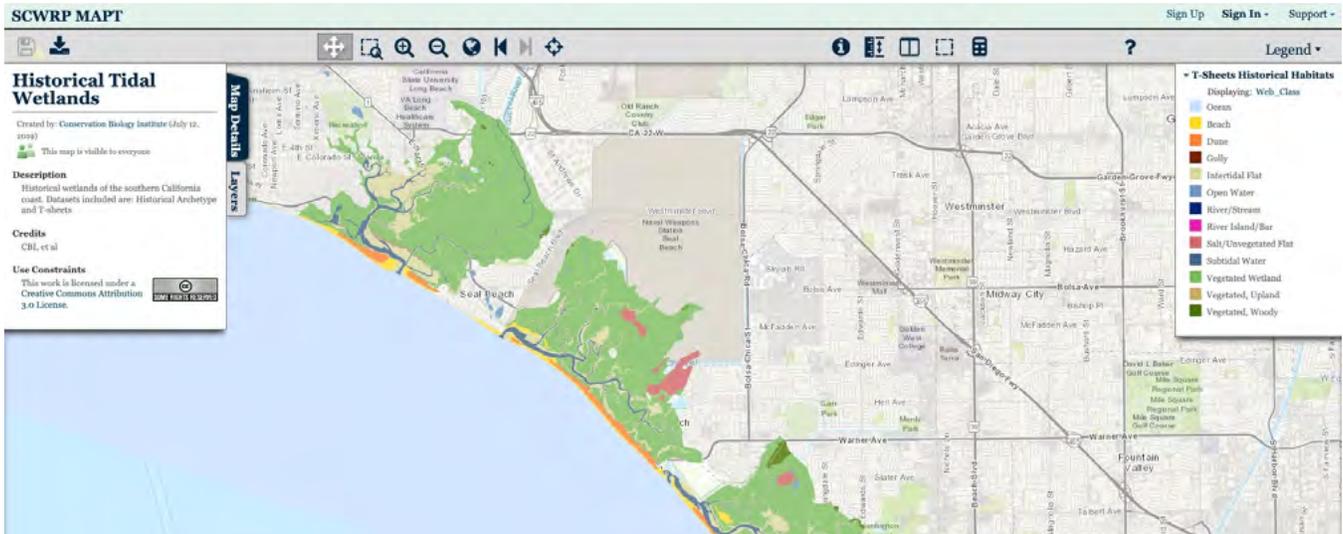
Several study results guide progress to enhance coral resilience to climate change.

Program Office: NOS/OCM/CRCP and CRCP matrix partners (NMFS/PIFSC, NMFS/SEFSC, NMFS/SERO)

NOAA Technical Memo: <https://spo.nmfs.noaa.gov/sites/default/files/TMSPO208.pdf>

Developing Tidal Wetland Adaptation strategies in Southern California, including the Tijuana National Estuarine Research Reserve

A team of scientists supported by NCCOS and USGS, including the California State Coastal Conservancy, University of California Davis, Environmental Science Associates, Blue Point Conservation Science, Southern California Coastal Water Research Project, San Francisco Estuary Institute, Tijuana River National Estuarine Research Reserve, and University of Southern California Sea Grant, advanced coastal marsh modeling in Southern California, in partnership with local natural resources managers. The team then held workshops with members of the Southern California Wetlands Recovery Project (WRP) to develop definitions, maps, and restoration guidance on wetland transition zones to ensure restoration planning activities are resilient to sea level rise. WRP includes 18 state and federal agencies focused on restoration and protection of wetland habitats between Santa Barbara County and Mexico. The team delivered restoration guidance products to WRP’s Marsh Adaptation Planning Tool (MAPT) and hosted meetings to present model results to WRP members and receive feedback to improve the utility of the outputs; leading to Los Cerritos wetlands including transition zone restoration guidance in their restoration plans, Goleta Slough wetlands identifying the need for a restoration project, Los Penasquitos Lagoon including modeling results into the north parking lot climate adaptation project, and the Tijuana Estuary Tidal Restoration Program including modeling results into their restoration project.



The Southern California Wetlands Recovery Project (SCWRP) Marsh Adaptation Planning Tool provides a platform for high-quality geospatial datasets, maps, and information to facilitate acquisition and restoration of rivers, streams, and wetlands in coastal Southern California. Image credit: SCWRP.

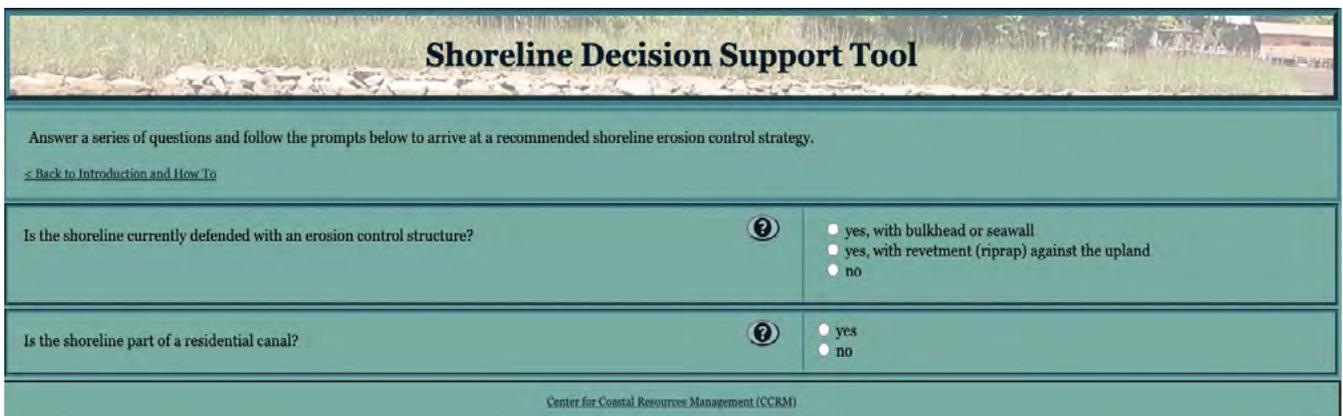
FY21 ACCOMPLISHMENT:

Updated an existing marsh restoration guidance tool and train natural resource managers on the updated information and improved definitions for wetland transition zones, leading to an online application

Project URL: www.ourcoastourfuture.org; <https://coastalscience.noaa.gov/project/tidal-wetlands-adaptation-strategies-southern-california/>

A Tool for Finding the Right Living Shoreline for You

When coastal landowners along the Gulf of Mexico see signs of shoreline erosion, they can now turn to a new online tool for recommendations on how to protect their property and coastal resources at the same time with a living shoreline. A project team from Troy University, Geological Survey of Alabama, Galveston Bay Foundation, and Virginia Institute of Marine Science, funded by NOAA’s RESTORE Science Program (overseen through NCCOS), has customized a computer model for



The Living Shoreline Decision Support Tool is a query-based tool designed to recommend shoreline best management practices. Image credit: Virginia Institute of Marine Science.

interactive, online decision support tool is linked to the customized models so that accessing the models' results is easy. This model and tool combination will help promote the wise use of living shoreline protection options by federal and state agencies, homeowners, marine contractors, natural resource managers, and city planners. A living shoreline uses native vegetation alone, or in combination with stone, sand, or other structural and organic materials, to stabilize a shoreline while also letting natural functions take place.

FY21 ACCOMPLISHMENT:

Following extensive engagement with end users, the project team completed a computer model for assessing the suitability of a site for construction of a living shoreline customized to sites in Alabama (Perdido Bay/Wolf Bay/Ono Island Complex), Louisiana (Lake Pontchartrain), and Texas (Galveston Bay) and packaged it in an interactive decision support tool that allows for a rapid assessment by government agencies, homeowners, marine contractors, and others.

Project URL: <https://cmap2.vims.edu/LivingShoreline/DecisionSupportTool/index.html>

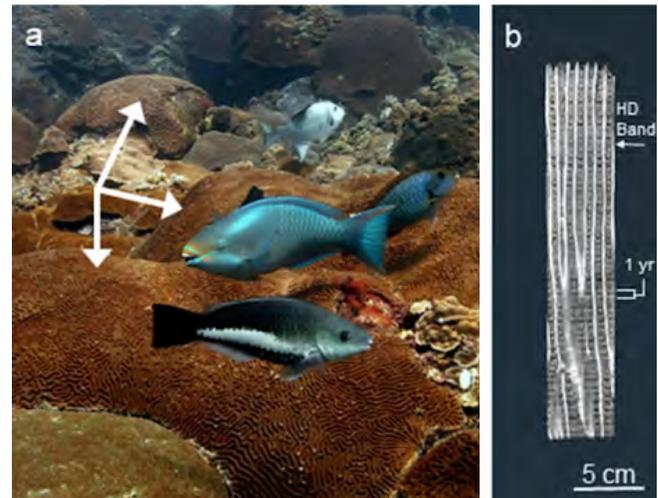
Web Story URLs: <https://restoreactscienceprogram.noaa.gov/miscellaneous/a-tool-for-finding-the-right-living-shoreline-for-you>, <https://restoreactscienceprogram.noaa.gov/projects/living-shoreline-tool>

Uncovering Corals Resilient to Climate Change

Climate data collection via the National Coral Reef Monitoring Program and **ONMS** has shown that two key coral species in the Flower Garden Banks (FGB) National Marine Sanctuary, *Pseudodiploria strigosa* and *Orbicella faveolata*, have increased calcification, an outlier to a trend of live coral cover loss throughout western Atlantic reefs. The FGB in the Gulf of Mexico are high-latitude, remote coral reefs that have maintained $\geq 50\%$ coral cover since at least 1989. Observations from coral cores for these two species of interest have shown increased linear extensions and calcification rates (with no change in skeletal density) over a 57 year period. These findings for both species were negatively correlated with discharge from the Atchafalaya River, but positively correlated with maximum sea surface temperatures (SSTs).

This study provides evidence that runoff from the Atchafalaya River impacts corals at the FGB and is a major control on their growth at the sanctuary, while their increased growth can be attributed to the significant warming trend in maximum monthly SSTs. This study provides further evidence that some high-latitude, cooler reef sites have experienced a stimulation in coral growth with ocean warming.

However, given the warming trend and recent increase in coral bleaching severity at FGB, the prognosis is that bleaching events will become more deleterious with time, which will lead to a breakdown in the positive relationship between coral growth and maximum SST.



Photographs of (a) parrotfish and *Pseudodiploria strigosa* coral colonies at east Flower Garden Bank and (b) computerized tomography (CT) images of cores for *P. strigosa*. CT images illustrate clear annual banding.

Images from: Manzello et al. 2021, Coral Reefs, Springer.

FY21 ACCOMPLISHMENT:

Several study results guide progress to enhance coral resilience to climate change.

Program Office: NOS/OCM/CRCP and CRCP matrix partner OAR/AOML

Peer-reviewed journal article URL: <https://link.springer.com/article/10.1007/s00338-021-02108-8>

NOS PRIORITY:**SAFE AND
EFFICIENT
TRANSPORTATION
AND COMMERCE**

SHIPS MOVE **\$1.5 TRILLION** worth of products in and out of U.S. ports every year. Every ship moving in and out of U.S. ports relies on navigation charts and water level information that NOS alone provides. All mapping, charting, and transportation activities and infrastructure are founded on a reliable, accurate national coordinate system. NOS is solely responsible for maintaining that system, which provides more than \$2.4 billion in potential annual benefits to the U.S. economy. Businesses in the maritime community rely on NOS for a range of decisions, from how much cargo to load to choosing the safest and most efficient route between two points. They use NOS data, tools, and services to plan seasonally

for ship schedules to service global trade more safely and efficiently as significantly larger vessels transit through U.S. ports.

Following are transportation and commerce themed projects organized according to two primary scientific priorities of the National Centers for Coastal Ocean Science (NCCOS) strategic plan.

Advanced Observation Technologies

Included below are nine highlighted scientific projects by NGS, OCS, and IOOS researchers and their partners, which are focused on advanced observation technologies.

Determining the Rotation of the Mariana tectonic plate

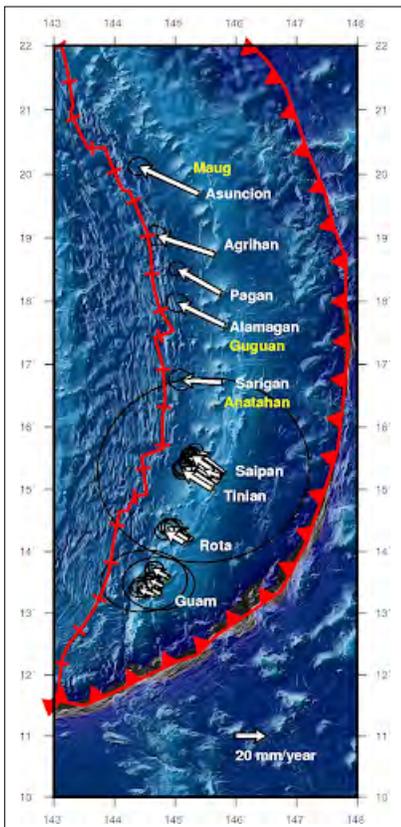
In a few years, NGS will modernize the National Spatial Reference System (NSRS). This system will include the definition of a plate-fixed reference frame for Guam and the Commonwealth of the Northern Mariana Islands (CNMI) called the Mariana Terrestrial Reference Frame of 2022 or MATRF2022. To define such a frame, the absolute rotation of the underlying tectonic plate (Mariana) must be known relative to a global

plate-independent frame, such as the International Terrestrial Reference Frame. Very few studies of the Mariana plate have ever been performed, and most are only relative to other plates. To address this situation, NGS in 2017 performed a complicated GPS survey of geodetic control points on numerous islands on the plate. This survey collected data on points that had been previously surveyed by GPS between 2003 and 2014. By differencing these various surveys, linear velocities were implied and subsequently used to define the rotation of the plate. This estimate of the plate's rotation was the most accurate and data-rich estimate ever performed for this small tectonic plate and will serve as the underlying model for MATRF2022. The results were published in the NOAA Technical Report series in August 2020.

FY21 ACCOMPLISHMENT:

Peer reviewed publication in the NOAA Technical Report series quantifying the absolute rotation of the Mariana plate.

NOAA Technical Memorandum: https://geodesy.noaa.gov/library/pdfs/NOAA_TR_NOS_NGS_0074.pdf



GPS-implied velocities on the Mariana plate (left), and some of the ground truth surveys which generated them in Maug (top right) and Alamagan (bottom right), CNMI.

Image credit: NOAA/NOS/NGS.

Machine Learning Applications for the Effective Operation of Autonomous Surface Vessels in Ocean Mapping Missions

In FY 2021, the NOAA/University of New Hampshire Joint Hydrographic Center and Center for Coastal and Ocean Mapping Autonomous Surface Vessel (ASV) Team, together with OCS, achieved significant improvements in the use of Machine Learning for ASV operations. The team has developed a software framework based on the Robotics Operating System, integrating cameras, swath mapping echo-sounders, marine radar, lidar, marine automatic identification service (AIS), National Marine Electronics Association (NMEA) based sensors for engine monitoring and vehicle health. The software framework builds on the open source nature of ROS with algorithms for object detection and classification and system control and includes a custom operator's interface and map-based mission planning software. Its modular architecture allows for rapid integration of new algorithms and technologies into robotic vessels and for collaboration and sharing of those algorithms with others.



The Joint Hydrographic Center uncrewed surface vessel underway off Portsmouth, New Hampshire. Image credit: NOAA/NOS/OCS.

FY21 ACCOMPLISHMENT:

The program achieved significant improvements in autonomous surface vessel operation for hydrographic survey and ocean mapping.

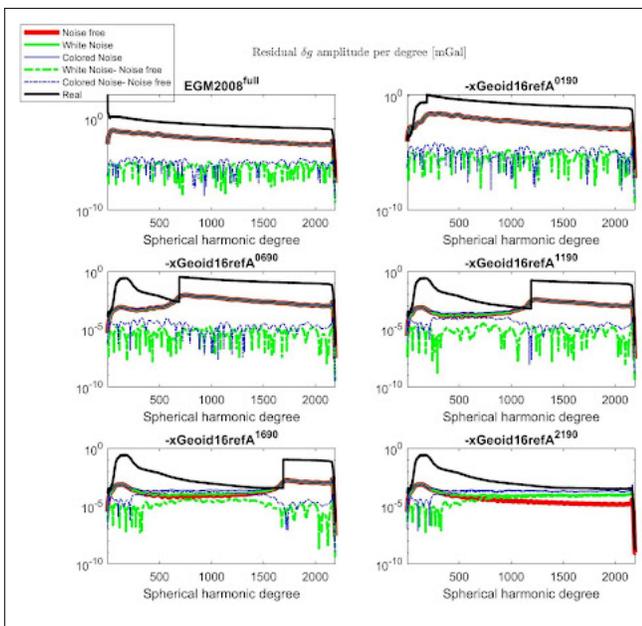
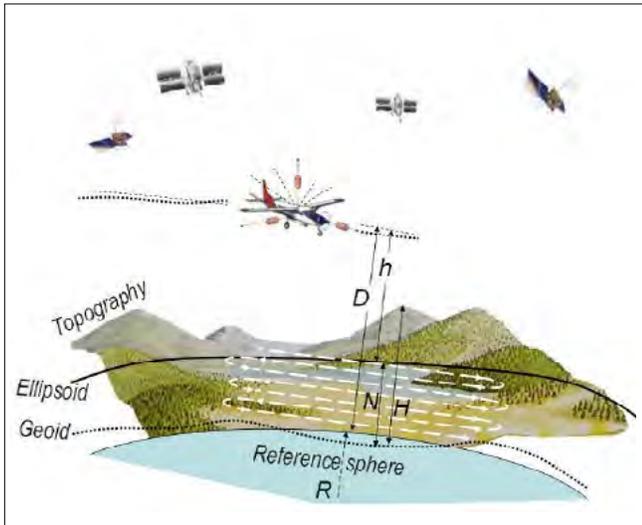
Project URL: <https://www.unh.edu/unhtoday/2021/01/seas-day>

AWARDS:

The project team won first place in the Virtual Ocean Robotics Challenge (<https://www.oceanroboticschallenge.com>) sponsored by Open Robotics, the Naval Post Graduate School and the Office of Naval Research.

Downward continuation of airborne gravity data for vertical datum determination

NGS is conducting a large-scale campaign, called Gravity for the Redefinition of the American Vertical Datum (GRAV-D), to collect airborne gravity data over wide areas at a nominal flight height of 6 km. This project started in 2007 and has currently flown 86% of the U.S. and its territories. The flights also extend 100 km over the border into Mexico and Canada as well as into the open ocean areas. These newly acquired gravity data will serve as the backbone for computing the forthcoming vertical datum in North America (the North American-Pacific Geopotential Datum of 2022). How to downward continue the gravity data from flight trajectories to a reference ellipsoid surface, and how to render the 3D scattered data into a 2D grid with regular grid intervals, have been difficult problems in the field of physical geodesy for many decades. It is important to find the optimal solution to derive the best information from these aerial gravity data for the vertical datum computation. An NGS research geodesist has led an international working group within the International Association of Geodesy to tackle this problem. The group includes professors and scientists from numerous universities and agencies in the United States, Europe, Taiwan, and Canada. The working group has used both simulated data, and real GRAV-D data in the Colorado area, as a test bed to analyze various downward continuation methods. The resulting geoid models agreed at the mm-level, once data editing problems were addressed. The analysis also showed that there are spectrum leakage problems for some of the methods. The group developed high-performance-computation (HPC) software packages for comparing the six different methods, and these will be shared with the global geodetic community.



Schematic of airborne data collection and software outputs for vertical datum determination. Image credit: NOAA/NOS/NGS.

FY21 ACCOMPLISHMENT:

Established solid theoretical background to downward continue aerial gravity data for geoid modelling; developed HPC software to share; obtained 1mm model agreements from the different formulizations; found and fixed the spectral leakage problem in the current NGS operational tools.

Published Abstract: Li, X., Huang, J., Willberg, M., Pail, R., Slobbe, C., Klees, R., Forsberg, R., Hwang, C., and Hilla, S.: On Downward Continuing Airborne Gravity Data for Local Geoid Modeling, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-2706, <https://meetingorganizer.copernicus.org/EGU21/session/39915>

Multi-Constellation GNSS Calibration of User/Receiving Antennas at the National Geodetic Survey

Sub-centimeter positions with the Global Navigation Satellite System (GNSS) require modeling and correction for the electrical properties of the receiving antenna. Creating a correction table for the antenna’s electrical properties is called antenna calibration. Although NGS has calibrated GPS user antennas since 1994, recent acquisition and programming of a 6-axis industrial robotic arm (a device capable of achieving positions with sub-mm accuracy) and tunable multi-GNSS receivers has allowed NGS to increase the capabilities of the antenna calibration program. The NGS calibration system has successfully demonstrated that it will be able to calibrate user antennas for all GNSS frequencies, with results that agree well with community standards.



Top: KUKA 6-axis robotic arm, as installed at NGS’s Testing and Training Facility, with a choking GNSS antenna mounted on the robot’s tool end. Bottom: The robotic arm is housed inside a retractable dome, and is pictured here with several antennas used to validate the system’s results. Image credit: NOAA/NOS/NGS.

FY21 ACCOMPLISHMENT:

Achieved multi-GNSS, full-spectrum calibrations with new high-accuracy 6-axis robotic arm.

Project URL: <https://www.ngs.noaa.gov/ANTCAL/>

AWARDS:

A previous, less accurate system using a 2-axis robot won a 2014 Bronze Medal “for the design and implementation of a NOAA absolute GPS/GNSS antenna calibration program to improve GPS positioning accuracy for all users.”

Modeling Geoid Change in Alaska at Higher Resolution

NGS’ upcoming geopotential datum requires a dynamic component to ensure it matches the changing shape of the geoid—the level surface formed by Earth’s gravity that best describes mean sea level—with centimeter accuracy. NASA’s GRACE and GRACE-FO satellites have provided a record of changes to Earth’s gravity field due to ice mass loss, hydrology, and solid-Earth processes. While they adequately capture these changes over most of North America, ice mass loss in Alaska changes the gravity field at much smaller scales than these satellites can resolve, resulting in errors of omission of more

than 1 centimeter per decade. NGS scientists augmented the spatial resolution of the satellite models with predictions of geoid change derived from glacier elevation change measured with airborne altimetry and photogrammetry. These models were used to generate predictions of geoid change in southern Alaska since the mid-20th century that will be compared with historical gravity, elevation, and astronomical measurements.

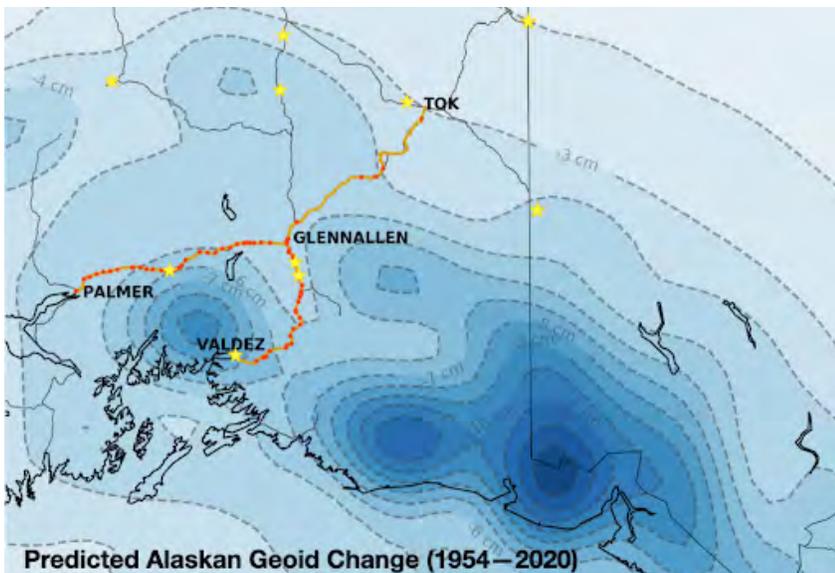
FY21 ACCOMPLISHMENT:

Created models of geoid change in Alaska with enhanced spatial resolution and developed and carried out a survey campaign to validate the models against historical measurements.

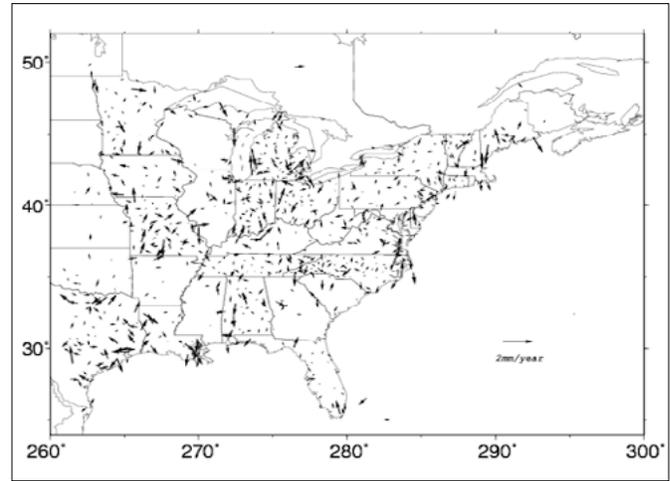
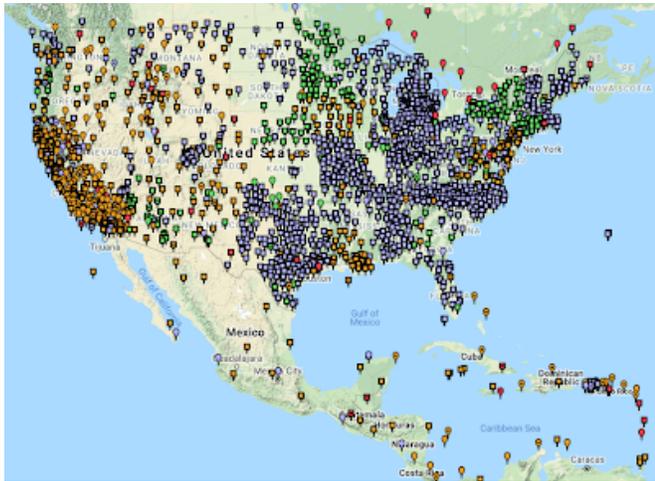
Presentation URL: https://www.ngs.noaa.gov/web/science_edu/presentations_library/files/agu2019_hardy.pdf

New position time series, velocities and quality measures for the CORS Network

The NOAA Continuously Operating Reference Station (CORS) network is a volunteer-based network of Global Positioning System (GPS) reference stations located mainly in the US and its territories. NGS scientists have reprocessed all GPS data collected via this network since 1996. Daily data



Left panel: A map of predicted geoid change in southern Alaska from ice mass loss with sites of historical gravity, elevation, and astronomical measurements. Right panel: NGS scientist collecting gravity measurements using a relative gravimeter during an Alaska survey. Image credit: NOAA/NOS/NGS.



Left panel: Major part of the NOAA CORS Network. Right panel: Velocity noise east of the Rockies (RMS ~ 0.2 mm/yr). Image credit: NOAA/NOS/NGS.

for GPS weeks 834 through 1933 were reprocessed leading to reference coordinates and velocities for 3049 stations aligned to the global reference frame IGS14. The derived velocity field was compared to several other solutions and to three regional geophysical and geodetic velocity models. These comparisons uncovered unstable stations which move differently than the regional kinematics around them. Once these were identified and excluded, we estimated the horizontal and vertical stability of this updated realization to be better than ~ 0.3 and ~ 0.6 mm/year, respectively. We used the position residuals and estimated uncertainties from this reprocessing to derive long-term stability measures for all active stations. These measures exposed ~ 60 CORS with the poorest long-term stability, which have been consequently excluded from serving as mapping control.

FY21 ACCOMPLISHMENTS:

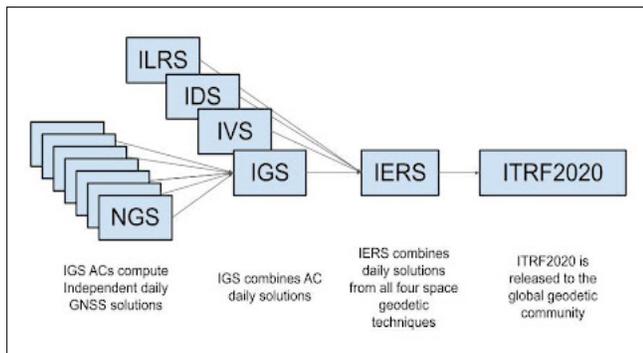
(1) The updated realization of the US National Spatial Reference System derived in this work is now officially in use; (2) This work was published in the *Journal of Applied Geodesy* in January 2021; (3) The work is based on intensive use of estimation theory and statistical analysis and successfully incorporated concepts and in-house developed Artificial Intelligence tools: edge detection, cluster analysis and information theory.

Peer reviewed journal article: <https://www.degruyter.com/document/doi/10.1515/jag-2020-0041/html>

NGS participation in the 3rd IGS reprocessing of GNSS data (REPRO3)

In early 2022, the International Earth Rotation and References Systems Service (IERS) will release the 2020 iteration of the International Terrestrial Reference Frame (ITRF2020). The forthcoming realization of ITRF2020 will combine observations from all of the major space geodetic techniques, including data from global navigation satellite systems (GNSS). The international body responsible for coordinating the GNSS contribution to ITRF2020 is the International GNSS Service (IGS). This effort by the IGS, completed in April 2021, was called the 3rd IGS reprocessing campaign. **NGS** is one of several IGS Analysis Centers (ACs) that participated in this campaign. To do so, we reprocessed all available GNSS data from 533 global continuously operating reference stations for the period between January 1, 1994, through December 31, 2020. These data were reprocessed using the most up-to-date techniques and models to produce three primary products: daily ground station positions, daily Earth-orientation parameters, and daily precise orbit solutions. These products, representing 27 years of daily solutions, were then sent to the IGS and were combined with independently computed solutions from the other IGS ACs. The combined IGS daily solutions were then sent to the IERS to be incorporated into ITRF2020. ITRF2020, much like previous iterations

of the ITRF, will form the backbone for all scientific positioning applications around the globe. It will also be the basis for the modernized U.S. National Spatial Reference System (NSRS), the official U.S. reference frame for all federal civilian applications. By participating in this campaign, NGS has ensured that there is superb representation of GNSS data from ground stations within the U.S. and our areas of interest (e.g. Caribbean, Pacific islands, etc.). This will allow NGS to very strongly tie the upcoming modernized NSRS to ITRF2020.



IGS ACs, including NGS, submitted 27 years of daily GNSS solutions to the IGS. The combined daily IGS solutions were then sent to the IERS for combination with solutions from the International Laser Ranging Service (ILRS), the International DORIS Service (IDS), and the International VLBI Service (IVS).

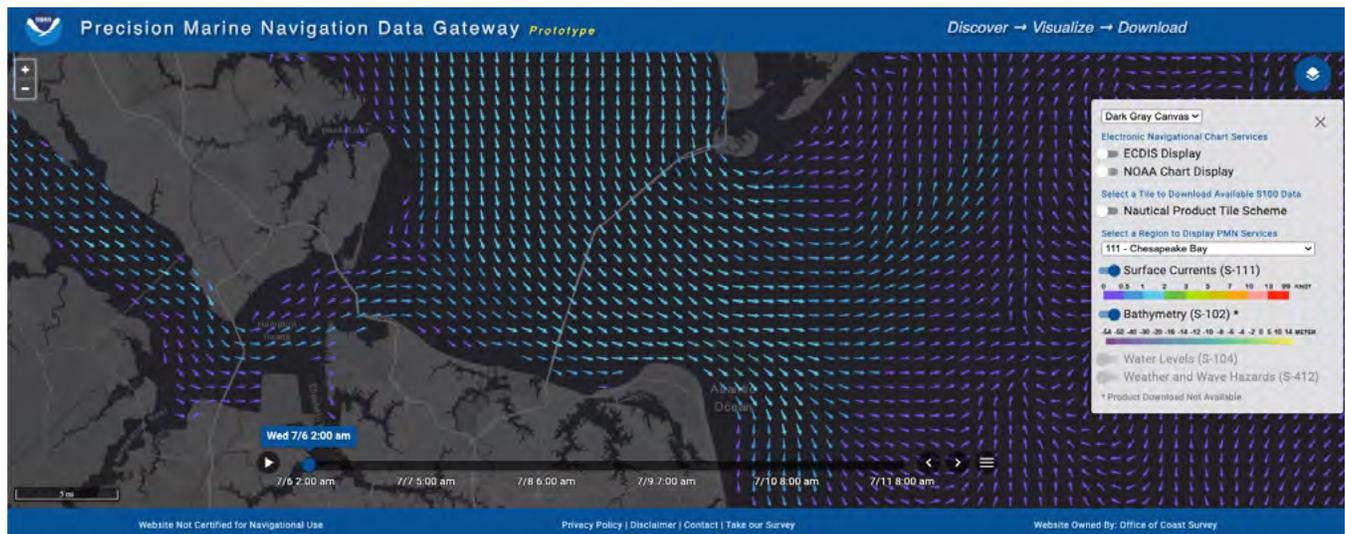
Image credit: NOAA/NOS/NGS.

FY21 ACCOMPLISHMENT:

NGS reprocessed 27 years of daily GNSS solutions dating back to January 1, 1994. These solutions will contribute directly to the forthcoming ITRF2020 reference frame.

Precision Marine Navigation Data Gateway Viewer

NOAA and OCS have developed a web-mapping application that enables users to explore NOAA’s navigation datasets that are formatted based on international standards. The Data Gateway Viewer provides an easy-to-use, interactive resource for discovering NOAA’s navigation data products. Users can navigate to a region of interest, find the data that are available for that area, and access downloadable versions of the data in the cloud through the NOAA Big Data Program. It also uses new visualization techniques to make the data easy to comprehend. The beta version of the Data Gateway is one piece of NOAA’s larger effort to integrate marine navigation data services. The Data Gateway provides a visualization of the data NOAA is also serving via the cloud in a machine-to-machine readable format for software companies to utilize in various navigation software applications from portable pilot units to electronic charting systems and even mobile applications. The Data Gateway Viewer is an important tool



Screen grab from the Precision Marine Navigation Data Gateway Viewer. Image credit: NOAA/NOS/OCS.

for making the maritime community aware of NOAA’s navigation data, and it represents the continued commitment to ensure precision marine navigation in U.S. waters.

FY21 ACCOMPLISHMENT:

A beta version of the Precision Marine Navigation Data Gateway Viewer was launched in January 2021 that provides surface current forecast guidance (S-111 data).

Data Gateway Viewer Application URL: <https://beta.marinenavigation.noaa.gov/gateway/>

Data Gateway Viewer Press Release URL: <https://nauticalcharts.noaa.gov/updates/noaa-releases-new-visualization-resources-precision-navigation-data-gateway-and-data-dashboard/>

Short Term Predictive System (STPS) Enhancing Search-and-Rescue Nationwide with IOOS Oceanographic High Frequency Radar

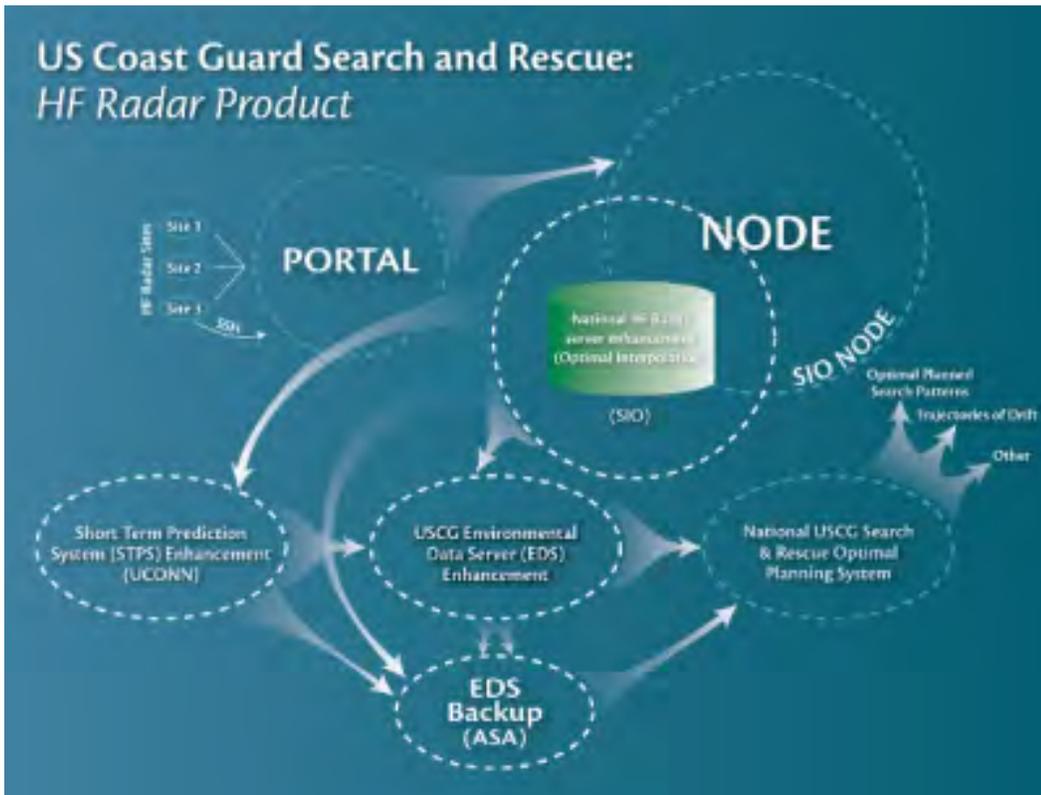
In FY 2021 the Short Term Predictive System model (STPS) footprint expanded to cover the entire continental United States, Hawaii, and Puerto Rico. The model now assimilates data from newly added IOOS High-Frequency (HF) radar sites around the country into surface current

forecasts for the U.S. Coast Guard’s (USCG) Search and Rescue Optimal Planning System (SAROPS) and also provides the framework to deliver data from future IOOS HF radar installations to the system. In 2000, the USCG Research & Development Center began a multi-year investigation into the utility of NOAA IOOS real-time HF radar surface current measurements for search and rescue. This assessment showed HF radar derived currents performed better when compared against available NOAA tidal current predictions. A team at the University of Connecticut, with IOOS funding, developed the STPS empirical statistical model to deliver these HF radar current forecasts; in May 2009 the STPS forecasts went live in the SAROPS for the mid-Atlantic, and later expanded to the U.S. West Coast in 2012.

FY 2021 ACCOMPLISHMENT:

The STPS ocean surface current forecast model expands to provide IOOS HF radar data nationwide for improving U.S. Coast Guard search-and-rescue.

Technical Paper: <https://rucool.marine.rutgers.edu/media/downloads/papers/National%20IOOS%20High%20Frequency%20Radar%20SAR%20Project.pdf>



Schematic of the data pathways and components of the IOOS enhancements to the HF radar component of USCG SAROPS. The blue dotted lines enclose components that existed prior to the project. The enhancements are shown within the white dotted lines.

Image credit: NOAA/NOS/IOOS.

Ecosystem Science for Conservation and Sustainable Use

Below is a highlighted scientific project by OCS researchers and their partners, which is focused on ecosystem science for conservation and sustainable use of coastal systems.

Building the National Bathymetry

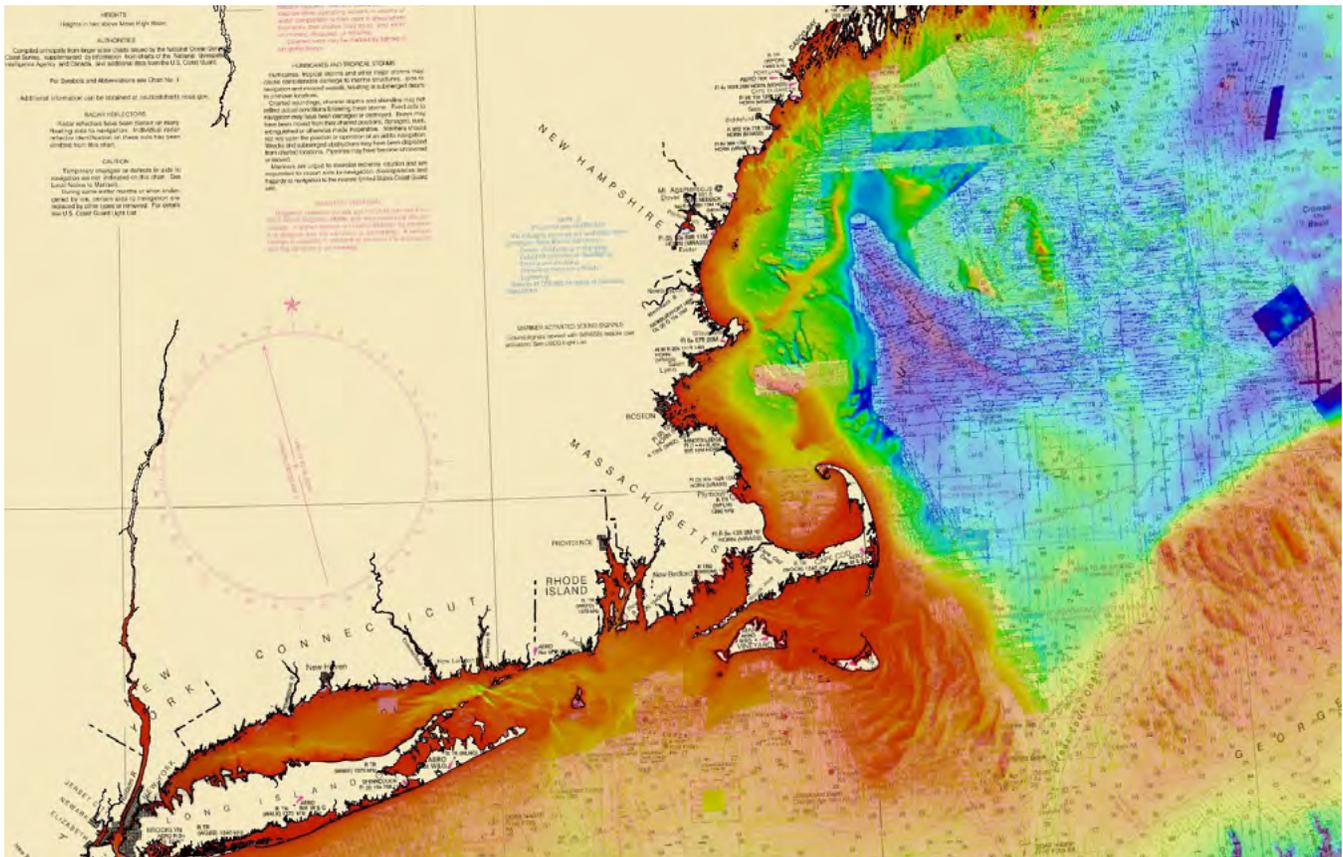
The National Bathymetry is a foundational dataset that supports the next-generation of navigation services as well as commerce, science, industry, and public curiosity. OCS compiles disparate hydrographic and LIDAR source surveys based

on standard metrics like resolution, accuracy, survey date, and data license. In fiscal year 2020, the team built the New England dataset and that region is now being updated monthly as new sources are available. This year, the team is building out the National Bathymetry for the Gulf of Mexico region and work is underway to distribute products of this critical bathymetric compilation in various datum, formats, and resolutions. The establishment of a data-driven workflow through automation and expertise allows for increased quality, accessibility, and timeliness of bathymetric source data.

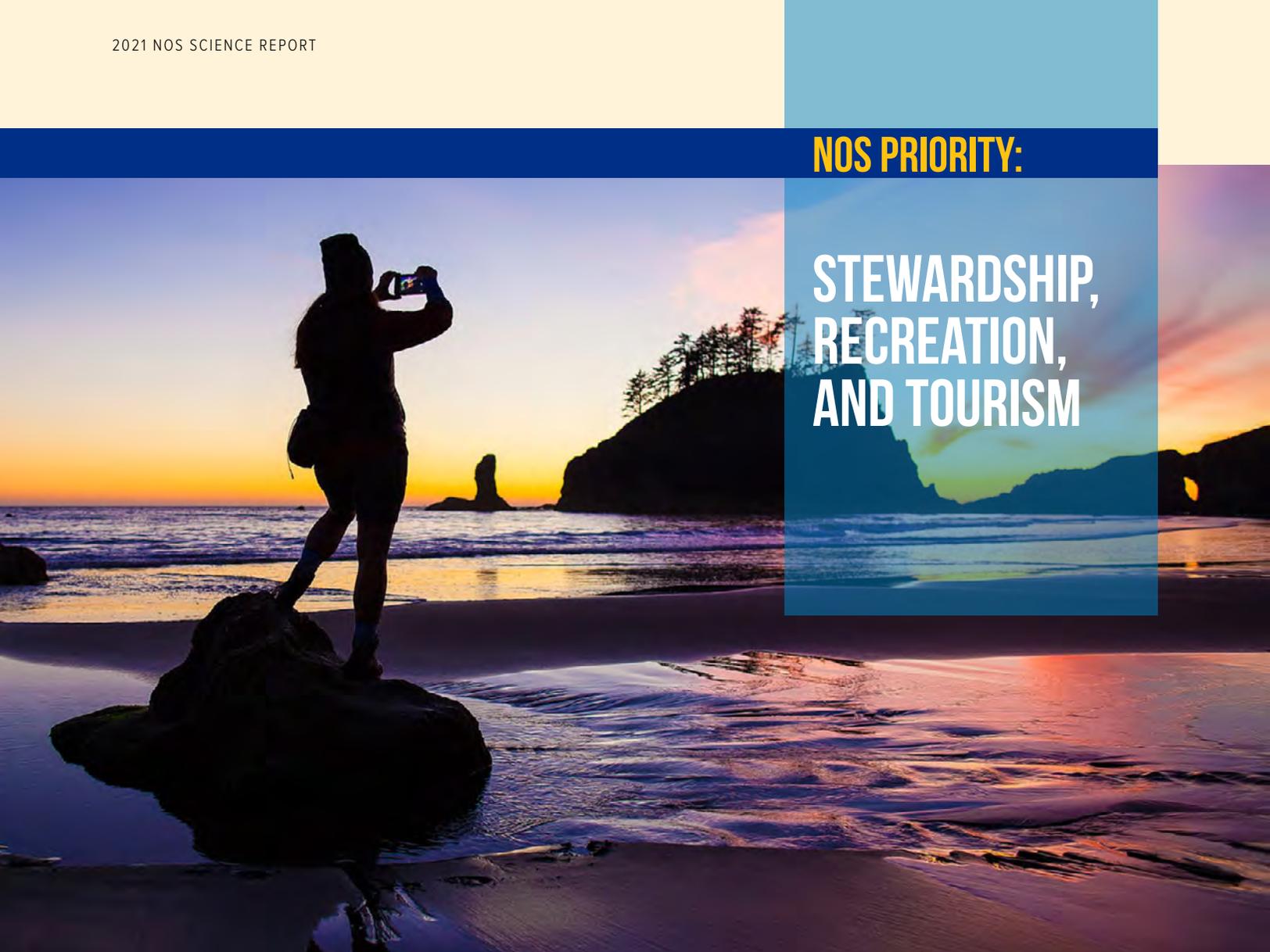
FY21 ACCOMPLISHMENT:

The National Bathymetry is being built out for the Gulf of Mexico region while the already built New England region is regularly updated with newly available source surveys.

Project URL: <https://nauticalcharts.noaa.gov/updates/building-the-national-bathymetry/>



A preliminary build of the bathymetry for New England. Image Credit: NOAA/NOS/OCS.


 NOS PRIORITY:

 STEWARDSHIP,
 RECREATION,
 AND TOURISM

THE UNITED STATES boasts some of the most important natural, cultural, and historical resources in the world—not just on land but under the water as well. The value of the U.S. coastal tourism and recreation industry in 2009 was \$62 billion. NOS plays a critical role in protecting and promoting access to these special coastal and marine places. NOS is entrusted with the responsibility to manage a network of underwater parks encompassing more than 600,000 square miles of coastal, marine, and Great Lakes waters. Across all national marine sanctuaries, about \$8 billion annually is generated in local economies from activities like commercial fishing, tourism, and recreation. NOS also partners with states to manage national estuarine research reserves, a

network of 29 coastal sites designated to protect and study estuarine systems. The reserves reflect the rich diversity of environments along our coasts and Great Lakes, and provide places for education, recreation, and boosting local economies.

Following are stewardship, recreation, and tourism themed projects organized according to three primary scientific priorities of the National Centers for Coastal Ocean Science (NCCOS) strategic plan.

Advanced Observation Technologies

Included below are two highlighted scientific projects by OR&R and OCM researchers and their partners, which are focused on advanced observation technologies.

Advancing the Use of Unmanned Platforms to Respond to and Assess Spills in Ice Environments

Scientists from **OR&R**, funded by the United States Coast Guard Research Development Center, and in collaboration with scientists from US EPA, Applied Research Associates, and Water Mapping LLC, are developing and testing new remote sensing tools and technologies (UAS and ROV) to more efficiently and effectively detect and characterize surface oil in icy waters. The researchers are looking at the oil both from above the slick looking down, and from beneath the slick looking up. Scientists remotely characterize oil slicks flying a quadcopter carrying multispectral sensors over various configurations of surface oil and ice, at the same time as underwater ROV mounted acoustic sensors characterize the oil from beneath. These tools are advancing our ability to ‘see’ oil in more complex ice-water environments. Additionally the team, in partnership with the USEPA’s Office of Research and Development to monitor smoke plumes from in situ burns using UAS mounted sensor packages. These projects demonstrate the rapidly advancing utility of using UxS for spill responses and assessments.



Dr. Oscar Garcia (Water Mapping, LLC) prepares to launch the hexacopter platform with multispectral sensors for floating oil detection. Image credit: NOAA/NOS/ORR.

FY21 ACCOMPLISHMENT(S):

Successful completion of experiments at the Cold Regions Research and Engineering Laboratory (CRREL), an oil-ice testing facility in Hanover, New Hampshire. Eight oil thickness categories were measured in combination of various ice cover regimes. Nine successful in situ burns were conducted and monitored using fresh and weathered Alaska North Slope Crude oil.

Project URL: <https://response.restoration.noaa.gov/fire-and-ice-noaa-and-us-coast-guard-partner-study-oil-ice-environments>

Advancing Coastal Mapping/Management through Artificial Intelligence

OCM, through its Coastal Change Analysis Program (C-CAP), has been working to develop the next generation of land cover data for the coastal U.S. This work has focused on the research and implementation of methodologies that increase the program’s efficiency and impact. By applying artificial intelligence/machine learning algorithms in a cloud-based environment, these efforts have resulted in several high spatial detail land cover and habitat datasets which serve not only as proof of concept demonstrations but are also informing coastal management decisions at regional and local levels. The

state of New Hampshire, for instance, has been utilizing saltmarsh habitat data produced through these efforts to better inform marsh resilience assessments and to inform the state’s comprehensive marsh management planning.



Saltmarsh habitat data (2013) for New Hampshire. Image credit: NOAA/NOS/OCM.

FY21 ACCOMPLISHMENT:

Statewide saltmarsh habitat mapping informs New Hampshire’s comprehensive marsh management planning.

C-CAP database URL: <https://coast.noaa.gov/digitalcoast/data/ccaphighres.html>

Ecosystem Science for Conservation and Sustainable Use

Below are five highlighted scientific projects by NCCOS and ONMS researchers and their partners, which are focused on ecosystem science for conservation and sustainable use of coastal systems.

New Research Informs Management of Rare Gulf of Mexico Whale

With a very small population size, the Gulf of Mexico Rice’s whale (*Balaenoptera ricei*), designated as an endangered species in April 2019, is one of the rarest whales on the planet. Previously thought to be a subpopulation of the Bryde’s whale species, recent genetic and morphological data now identify the filter-feeding Rice’s whales as a separate species. It is more important than ever to learn about the whale’s critical habitat as a first step in planning for its recovery. Since 2017, a NOAA-led project supported by the NOAA RESTORE



Rice’s Whale. Image credit: Wayne Hoggard, NOAA Fisheries

on understanding Rice’s whale movement habits and feeding patterns for recovery planning efforts. Investigators have conducted three research cruises dedicated to learning about the whale. Recent research has revealed that the whales spend most of their daylight hours in a constant diving and feeding pattern; and then rest just below the surface most of the night. The Rice’s whale feeds on dense aggregations of fish that form just above the bottom during daylight hours, and may be selectively feeding on one or two fish species. The presence of upwelled water near the bottom, along with seasonal inputs of high productivity shelf water into the habitat, are likely important factors in maintaining enough prey to support the energetic requirements of the whales. By working closely with the people responsible for marine mammal management in the Gulf of Mexico, NOS-supported researchers are ensuring that their discoveries about the whale’s feeding and movement are integrated into recovery plans.

FY21 ACCOMPLISHMENT:

The project team has greatly increased our knowledge about the whale’s habitat and feeding processes and provided this information to resource managers who are designating critical habitat ahead of developing and implementing a recovery plan across the Gulf of Mexico.

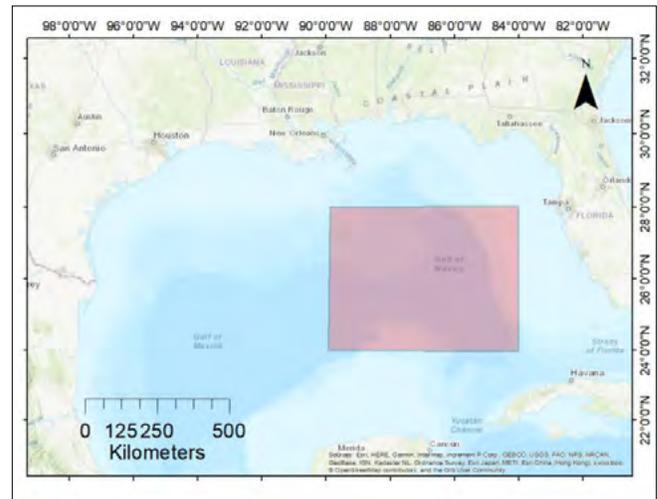
Project URLs: <https://restoreactscienceprogram.noaa.gov/living-coastal-and-marine-resources/new-research-informs-management-of-rare-gulf-of-mexico-whale>

<https://restoreactscienceprogram.noaa.gov/projects/brydes-whales>

Unlocking the food web-dynamics sustaining Atlantic bluefin tuna larvae

Atlantic bluefin tuna (*Thunnus thynnus*) are highly migratory and spawn in the Gulf of Mexico, but are distributed as adults throughout the Atlantic Ocean. This migratory behavior, as well as year to year changes in environmental conditions at sites where Atlantic bluefin tuna spawn, makes management of the species complex. Being able to track how changes in nutrient availability impact tuna food webs and larval survival is essential to managing open ocean ecosystems. A project supported by the NOAA RESTORE Program through NCCOS investigated the impact of

variability in a key nutrient, nitrogen, on lower food webs and the resulting availability of zooplanktonic food resources for Atlantic bluefin tuna larvae in the Gulf of Mexico ecosystem. This information will inform Atlantic bluefin tuna stock assessments by making it possible to more accurately estimate feeding, growth, and survival of Atlantic bluefin tuna larvae based on ocean conditions.



Area of the Gulf of Mexico where researchers collect Bluefin Tuna larvae (red square). Image credit: NOAA RESTORE Program.

FY21 ACCOMPLISHMENT:

The project team revealed the link between nutrients, food availability, and the survival of Atlantic bluefin tuna larvae which can be used to improve stock assessments for this commercially and recreationally important species.

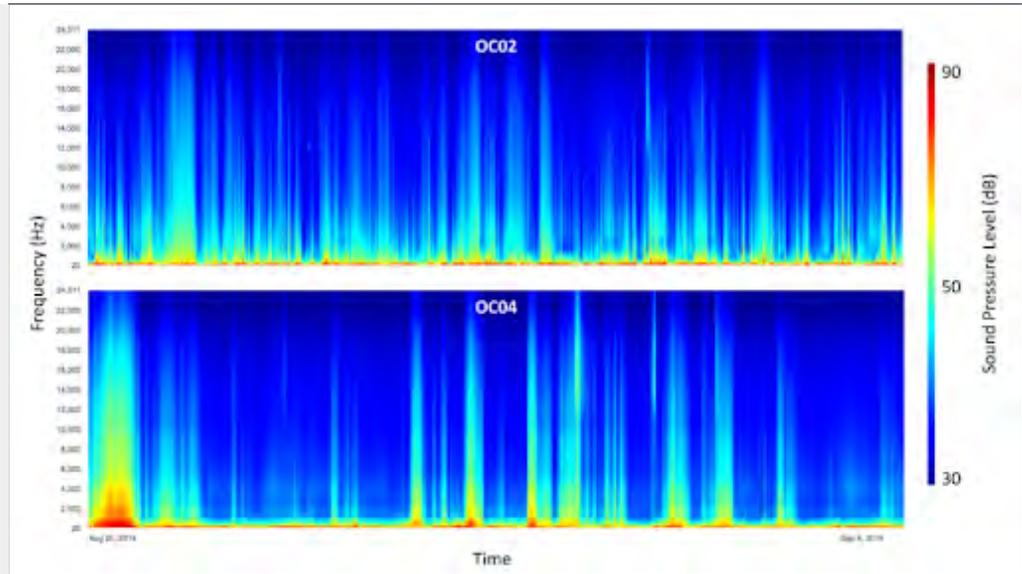
Project URL: <https://restoreactscienceprogram.noaa.gov/projects/bluefin-tuna-larvae>

Data and Applications from Sanctuary Soundscape Monitoring Project Now Available to the Public.

Since 2018, ONMS and the US Navy have co-led the Sanctuary Soundscape Monitoring Project (SanctSound) to monitor underwater sound at 30 locations in seven national marine sanctuaries and one Marine National Monument. Over 20 institutions participate in this nationwide effort to understand sound conditions and ocean noise impacts across the National Marine Sanctuary

Spectrograms from two SanctSound listening stations (OC02, top; OC04, bottom) in Olympic Coast National Marine Sanctuary between August 20 and September 4, 2019.

Image Credit: NOAA/NOS/ONMS SanctSound.



System. SanctSound results and management applications were disseminated in FY 2021 through a multi-faceted outreach campaign to reach audiences ranging from students to decision-makers, including: a web story series highlighting place-based results, an interactive StoryMap, a Congressional briefing, two published and four accepted peer-reviewed publications and over 20 virtual presentations and webinars. SanctSound data are archived and publically accessible through NOAA’s National Centers for Environmental Information and the public can explore results via a web portal under construction in partnership with NOAA’s IOOS program. It will go live at the project’s completion in spring 2022. The objectives of SanctSound are to 1) build collaborative research capacity to monitor and assess sanctuary resources, and 2) support natural resource management by providing baseline standardized time-series data that can be used to detect changes in sanctuary ecosystems and support noise impact management.

FY21 ACCOMPLISHMENT:

In FY 2021, SanctSound released an interactive StoryMap, published 10 web stories, was featured in two magazines, presented at nine conferences/ international workshops, provided reports to eight Sanctuary Advisory Councils, hosted four educational webinars, and headlined a Congressional briefing.

Project URL: <https://sanctuaries.noaa.gov/science/monitoring/sound/sanctsound-storymap.html>

Revisiting an Octopus Nursery and a Whale Fall

In 2018 and 2019, E/V Nautilus expeditions discovered extensive octopus nurseries in at least two areas in the southeastern flanks of Davidson Seamount at 3,200 m depth. These nurseries each featured thousands of mother octopus brooding their eggs within seeps of elevated water temperature (up to 10.4°C).



Octopus brooding their eggs within a warm water seep near Davidson Seamount in Monterey Bay National Marine Sanctuary. This genus has an unusual upside-down brooding posture. Credit: Ocean Exploration Trust/NOAA.

Also in 2019, an extremely rare find was made: a relatively fresh whale fall, and samples revealed a new species of bone-eating worm, *Osedax*, living on the whale's bones. In October 2020, **ONMS**, Monterey Bay, and Greater Farallones national marine sanctuaries teamed up on E/V Nautilus to explore Pioneer Canyon, then revisited the two previously discovered octopus nurseries and whale fall. Collecting 10 hours of video footage, they surveyed 15 acres of seafloor and counted 3,647 octopus, of which 2,938 (81%) were brooding mothers. The whale fall was more decomposed than we expected, but flourishing populations of *Osedax* and ampheretid worms were still present. Samples were collected along with whale bones, baleen, worms, sediment and water for eDNA analyses (results are pending).

FY21 ACCOMPLISHMENT:

Confirmation of second distinct massive octopus brooding colony, documentation of the changes in a whale fall after 12 months, and characterization of deep-sea corals in Pioneer Canyon and at Davidson Seamount.

Special Issue of Oceanography (see pp. 34-35): https://tos.org/oceanography/assets/docs/34-1_ocean_exploration.pdf

Video - Discover Wonder: The Octopus Garden: <https://sanctuariesimon.org/2021/04/discover-wonder-the-octopus-garden-wins-best-short-film-at-the-international-ocean-film-festival/>

AWARDS:

The video, *Discover Wonder: the Octopus Garden*, summarizing previous work at the “octopus garden” in 2018 and 2019 won the “short film” category at the International Ocean Film Festival in April 2021.

Findings from West Coast Deep-Sea Coral Initiative Will Inform Management for Years to Come

In 2018, a NOAA-led steering committee was formed with members from National Marine Fisheries Service, **ONMS**, the NOAA Office of Exploration and Research, **NCCOS**, and the NOAA Deep Sea Coral Research and Technology Program to guide the West Coast Deep-Sea Coral Initiative, a four year research program dedicated to increasing scientific understanding of deep-sea coral and sponge ecosystems. The Initiative's highest priority science and management needs were determined at a kick-off workshop in 2018, which was attended by over 40 key partners representing state and federal management agencies, academics, NGOs, the fishery management council, and first nation communities, with the following objectives: (1) collecting baseline information on deep-sea coral and sponge communities in areas prior to essential fish habitat and rockfish conservation protection changes; (2) identifying areas with the highest deep-sea coral and sponge bycatch; and (3) exploring and assessing deep-sea coral and sponge habitats within national marine sanctuaries.



A sponge garden on Daisy Bank off the coast of Oregon.

Image Credit NOAA Deep Sea Coral Research & Technology Program.

Since 2018, the Initiative has supported extensive field surveys, mapping, modeling, and data analysis projects by relying on strong, multi-agency partnerships, and has resulted in substantial areas of new protection for seafloor habitats in the five west coast marine sanctuaries. In its final year (2021), Initiative collaborators across the U.S. are concluding the remaining data analysis to generate new, publicly available information that will contribute to outreach products, describe newly discovered species and habitats, advance new modeling techniques and technologies, and inform fishery management decisions, sanctuary condition reports, and management plan updates.

FY21 ACCOMPLISHMENT:

The West Coast Deep-Sea Coral Initiative fully funded four field expeditions and provided partial support to 14 others for field surveys, mapping, and sample collections, producing over 450 hours of video, tens of thousands of still images, samples, and over 28,000 km².of newly acquired seafloor data.

West Coast Deep Sea Coral Initiative Science Plan (2018-2021): https://deepseacoraldata.noaa.gov/library/WCDSCI%20Science%20Plan_Final.pdf

Detecting, Monitoring, and Mitigating Impacts of Chemical and Biological Stressors on Coastal Ecosystems

Below are two highlighted scientific projects by NCCOS, OR&R, and ONMS researchers and their partners, which are focused on detecting, monitoring, and mitigating the impacts of chemical and biological stressors in coastal systems.

Great Lakes microplastic pollution pilot field study

Plastic pollution has been identified as one of the most critical environmental problems of our time. A pilot field study was executed by **OR&R** researchers in Milwaukee Estuary on Lake Michigan.



NOAA researchers process mussels from Lake Michigan at the University of Wisconsin-Milwaukee School of Freshwater Sciences. Mussel samples were analyzed for body burdens of chemical contaminants, metabolomics, and biomarkers.

Image credit: NOAA/NOS/ORR.

Invasive mussels (*Dreissena sp.*) were used to monitor microplastics. This project increases the capability of NOAA's Mussel Watch Program to characterize the magnitude and extent of microplastic pollution and its potential to adversely impact fish and wildlife and possible humans. Funding for this project was provided by NOAA's Marine Debris Program to support the field pilot study and laboratory analysis of samples.

FY21 ACCOMPLISHMENT:

Results revealed the potential utility of dreissenid mussels as biomonitors of microplastic pollution, the impact of microplastic on mussels, and the relationship between emerging and legacy chemical pollutants, and inform models of chemical contaminants in the Great Lakes and other freshwater ecosystems around the world. **NOAA Ocean Podcast Coverage:** NOAA Ocean Podcast: episode 39 <https://oceanservice.noaa.gov/podcast/sep20/nop40-microplastic-mussels-part-two.html>

Using Citizen Science Data to Assess Shoreline Marine Debris Within Two US National Marine Sanctuaries

Researchers from NOAA's Marine Debris Program (**OR&R**), together with staff from the NOAA Southeast Fisheries Science Center, **ONMS**, Olympic Coast National Marine Sanctuary (OCNMS), and Greater Farallones National Marine

Sanctuary (GFNMS), analyzed multi-year shoreline monitoring data collected by citizen scientists from OCNMS and GFNMS to estimate marine debris abundance and temporal trends, and identify drivers of debris loads. Data were gathered by 57 individuals as well as by students from five area schools using the established protocols of MDP's Marine Debris Monitoring and Assessment Project, a citizen science initiative that facilitates a national network of shoreline monitoring to guide marine debris research, prevention, and policy-making. Changes in debris counts and composition within each Sanctuary reflect seasonal patterns of coastal upwelling and downwelling, but longer temporal trends in overall debris loads depend on the sampling window. A linear increase in total expected debris counts was observed when up to five participants are conducting a survey, suggesting a need to standardize the number of participants and their search pattern. Results from this study have contributed to the refinement of MDMAP on-site monitoring protocols.

FY21 ACCOMPLISHMENT:

Results from this NOS-NMFS collaboration were published in the journal, *Frontiers in Environmental Science*.

Project URL: <https://blog.marinedebris.noaa.gov/using-citizen-science-understand-marine-debris>

Peer-reviewed journal article URL: <https://doi.org/10.3389/fenvs.2020.604927>



Citizen scientists collect water samples for microplastic debris analyses.

Image credit: Florida Sea Grant.

NOS FUNDING OPPORTUNITIES:

RESEARCH GRANTS AND FELLOWSHIP SUPPORT

NOS SUPPORTS SCIENTIFIC RESEARCH

that addresses its aforementioned priorities through multiple internal and extramural funding opportunities. Several program offices oversee annual competitive research programs to foster enhanced knowledge and scientifically informed management of coastal ecosystems, including efforts to advance coastal resilience, sustainable transportation and commerce, and marine stewardship. These also include multi-year fellowship awards to graduate students and support to NOAA Cooperative Science Center institutions working to increase the number of graduates, particularly from underrepresented communities, with degrees aligned with the NOAA mission. Below is information about NOS funding programs that provide applied research support to grantees:

In addition to supporting efforts by its Regional Associations, **IOOS** also funds the US Marine Life Observations: Coordinated Marine Biodiversity Observation Network (MBON) and Animal Telemetry Network (ATN) Activities to Ensure Resilient, Productive Ecosystems and Human Communities in the Face of Change funding opportunity. This effort, together with National Oceanographic Partnership Program (NOPP) partner agencies, funds research that builds upon the foundation established by MBON, ATN, and the US IOOS Regional Associations to work across sectors and disciplines towards an integrated, sustained marine life observing capability for the U.S. ocean, coasts and Great Lakes, from estuaries to the deep ocean; advance technologies for efficient and/or automated collection of species and associated habitat observations; enable open access to biodiversity data and information; and utilize these observations, technologies, and data to address place-based (e.g., sanctuaries, reserves, protected areas, leasing blocks, etc) management, conservation and restoration needs.

NCCOS supports the Competitive Research Program (CRP) and the RESTORE Science Program that provide the critical information and predictive capabilities required to manage the nation's coastal resources in an ecosystem context. NCCOS addresses these issues via a stressor-based or regional ecosystem approach in support of investigations related to sea level rise, harmful algal blooms, hypoxia, coral reefs, and related to the long-term sustainability of the Gulf of Mexico. These issues typically require multidisciplinary research teams and a significant long-term commitment of resources because of their complexity and the effort required to reach a new level of understanding sufficient to support NOS priorities and drive future coastal management decisions. Applications for funding are submitted through Federal Funding Opportunity (FFO) notices posted on the Grants.gov website. Notices of specific Announcements of Opportunity posted on the NCCOS Funding Opportunities page are provided as a courtesy to the research community.

NGS has funded extramural grants in support of Height Modernization and Geospatial Modeling. The National Height Modernization Program was created to enable access to accurate, reliable, and consistent heights. Elevation information contributes to informed decision making and impacts a wide range of important activities including mapping and charting, flood risk determination, transportation, land use and ecosystem management. Height Modernization is currently being implemented through a combination of NGS activities and state and local efforts. The program began because of critical needs identified in California and North Carolina, and it grew to include nearly two dozen states across the nation. Many states have received funding through either Congressional

earmarks or competitive grants. In other states, local agencies and organizations have provided resources. NGS has also funded research in support of geospatial modeling on topics related to workforce development in the geospatial industry, national and regional outreach plans, subsidence monitoring in the Gulf of Mexico, improving the alignment of national and regional reference frames, remote sensing technology, and gravity and astronomical observations. The funding objectives of the Geospatial Modeling Grant are to modernize and improve the National Spatial Reference System (NSRS) in the Gulf Coast region and to improve the awareness, coordination, and use of geospatial data.

OCM provides multiple extramural funding opportunities and fellowships in support of coastal resilience and management. Opportunities include the National Coastal Resilience Fund, which supports projects that restore, increase, and strengthen natural infrastructure to ultimately protect coastal communities from storm and flooding impacts

and enhance fish and wildlife habitat. Additional programs fund projects of special merit, including those related to the Coastal and Estuarine Land Conservation Program, National Estuarine Research Reserves (NERRs) and their Collaborative Science Program, as well as on topics of coastal resilience, bay watershed education and training, and Great Lakes Areas of Concern land acquisition. The Coral Reef Conservation Program, a partnership between NOAA Line Offices, also oversees multiple funding opportunities in support of coral reef research and management. OCM provides support to graduate and post-graduate students through several fellowship opportunities, including the Coastal Management Fellowship to provide on-the-job education and training opportunities in coastal resource management and policy and project assistance to state coastal zone management programs. Additional fellowship opportunities include the Coral Reef Management Fellowship in support of state and territorial agencies, the Margaret A. Davidson Fellowship that provides the opportunity for graduate students to conduct



collaborative research at NERRs, and the [Digital Coast Fellowship](#), which provides on-the-job education and training opportunities in coastal resource management and policy for postgraduate students and to provide technical assistance to help advance the goals of the Digital Coast and its partner organizations.

OCS has begun a new pilot funding program for a Hydrographic Surveying Matching Fund opportunity. The purpose of this program is to encourage non-federal entities to partner with NOAA on jointly-funded hydrographic surveying, mapping, and related activities of mutual interest. The pilot program relates directly to the OCS Ocean Mapping Plan and a goal to expand U.S. EEZ mapping by also expanding use of OCS' hydrographic services contract vehicle. NOAA and partner(s) match funds to expand collaborative partnerships and mapping efforts while also serving to increase funds available for NOAA hydrographic contracts.

ONMS oversees and supports the NOAA Dr. Nancy Foster Scholarship Program, which provides tuition, stipends, training, and collaborative experiences for master's and doctoral degrees in oceanography, marine biology, maritime archaeology—including, but not limited to, ocean and/or coastal: engineering, social science, marine education, marine stewardship, cultural anthropology, and resource management disciplines. Research proposals in support of ONMS science priorities are funded through this opportunity, with an emphasis on ensuring greater diversity of marine scientists.

OR&R MARINE DEBRIS PROGRAM supports multiple funding opportunities related to marine debris removal, prevention, research, and through the joint NOAA-National Fish and Wildlife Foundation Fishing for Energy partnership. Marine Debris Removal Grants offer funding that supports locally driven, community-based marine debris removal projects. Prevention Grants offer funding that supports marine debris prevention projects that actively engage and educate a target audience in hands-on programs. These projects

raise awareness, reduce barriers to marine debris prevention, and encourage and support changes in behaviors to ensure long-term prevention of marine debris. OR&R also provides North America Marine Debris Prevention and Removal Grants for projects that address marine debris issues in the U.S.-Mexico and U.S.-Canada border areas. Marine Debris Research Grants offer funding for original, hypothesis-driven research projects focused on the ecological risk assessment, exposure studies, and fate and transport of marine debris.

NOS PUBLICATIONS STATISTICS:

PEER-REVIEWED ARTICLES, TECHNICAL MEMORANDA, AND DATASETS

Scientists and staff affiliated with NOS program offices, and those supported through extramural funding opportunities, regularly publish their findings in peer-reviewed journals, technical reports, and other outlets. NOS personnel also maintain comprehensive databases, archive datasets, and develop portals for disseminating key information. Below are trends in the numbers of reported peer-reviewed articles, technical reports, and archived datasets per program office from years 2015-2020 (Figures 1-3). Data are derived from annual reports produced by the NOS Data Management Working Group (DMWG). Publication values for 2021 are still forthcoming, and will be included in a joint 2021-2022 DMWG report.

Figure 1. Number of reported peer-reviewed articles published per program office from years 2015-2020. Articles published by NCCOS are shown on the primary axis, while those from the seven other program offices are depicted on the secondary axis. Values depicted per year are cumulative totals for each program office. *Note: NCCOS totals include publications from both intramural and extramurally funded research.*

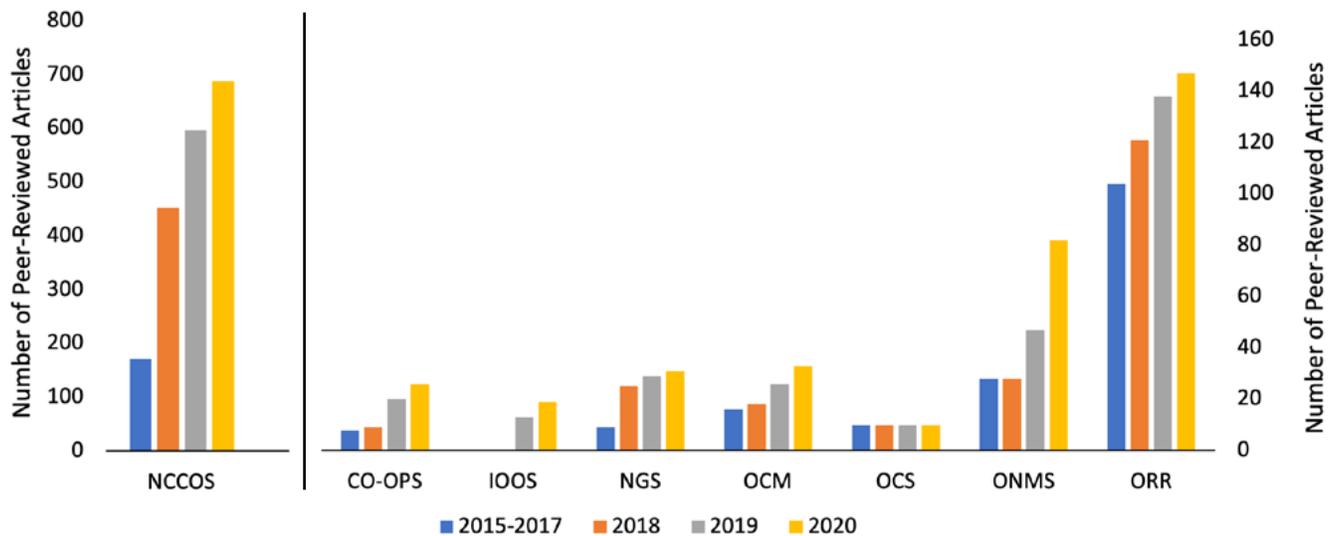


Figure 2. Number of technical reports published per program office from years 2015-2020.

Technical reports published by NGS and NCCOS are shown on the primary axis, while those from the six other program offices are depicted on the secondary axis. Values depicted per year are cumulative totals for each program office. *Note: NCCOS totals include technical reports from both intramural and extramurally funded research.*

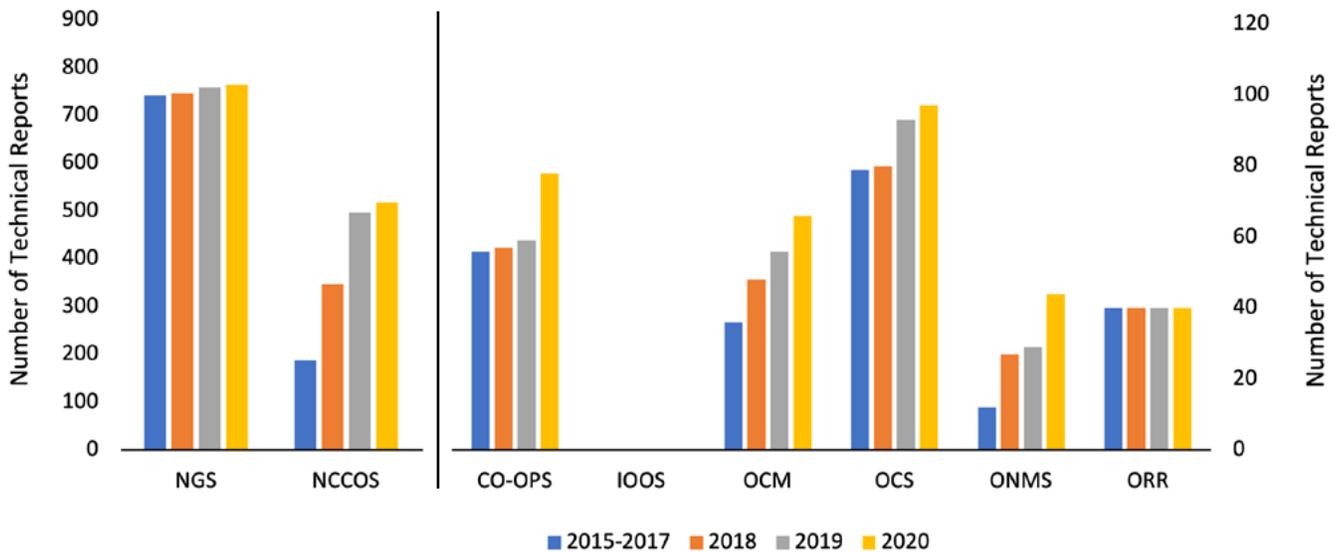
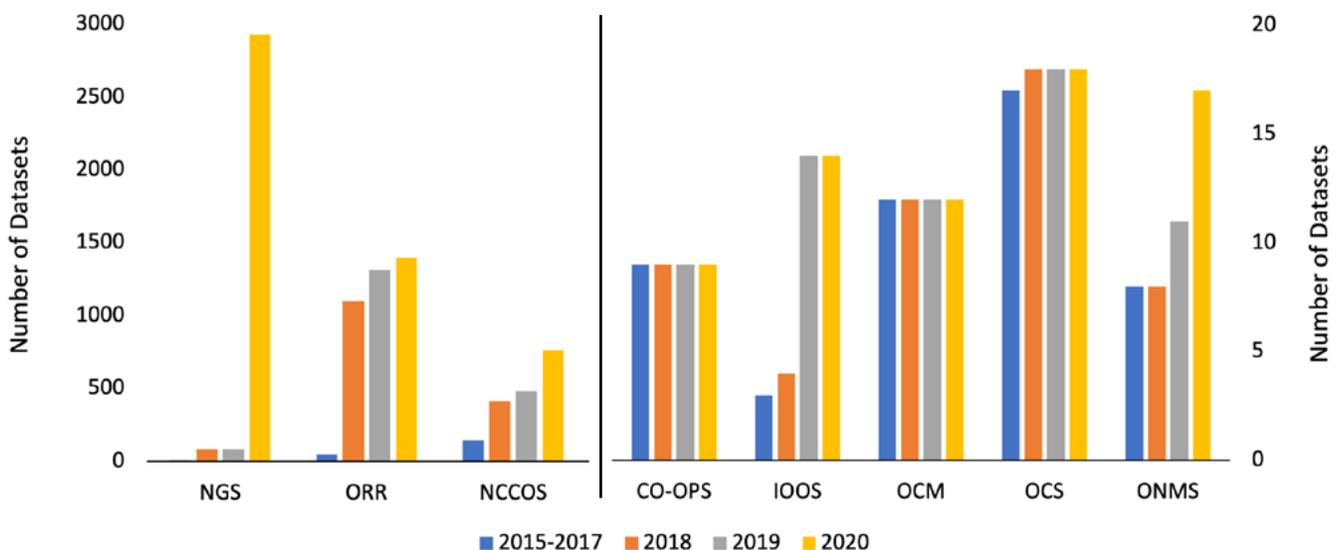


Figure 3. Number of archived datasets per program office from years 2015-2020.

Datasets produced by NGS, OR&R, and NCCOS are shown on the primary axis, while those from the five other program offices are depicted on the secondary axis. Values depicted per year are cumulative totals for each program office. *Note: NCCOS totals include datasets from both intramural and extramurally funded research.*



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