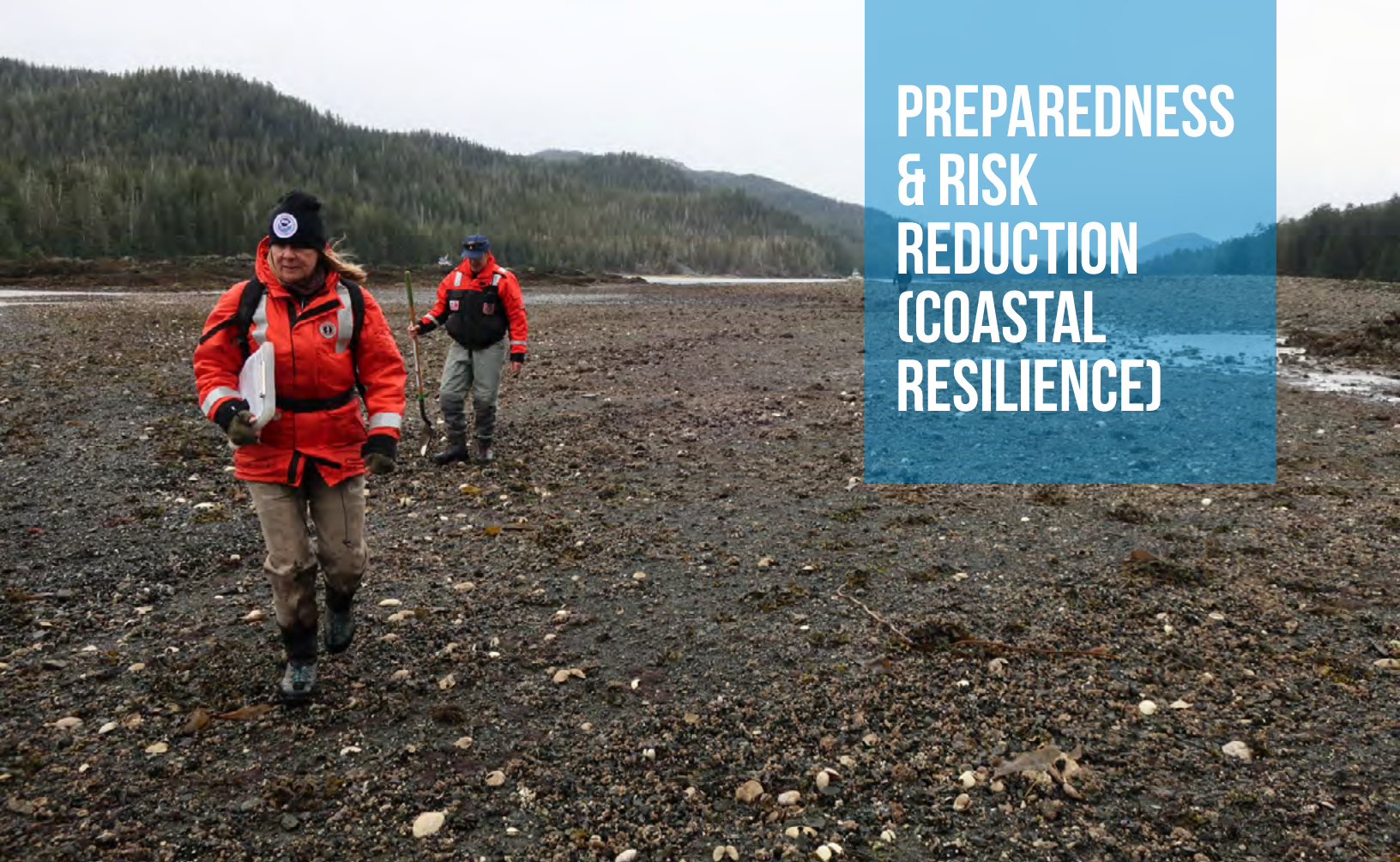# PREPAREDNESS & RISK REDUCTION (COASTAL RESILIENCE)

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
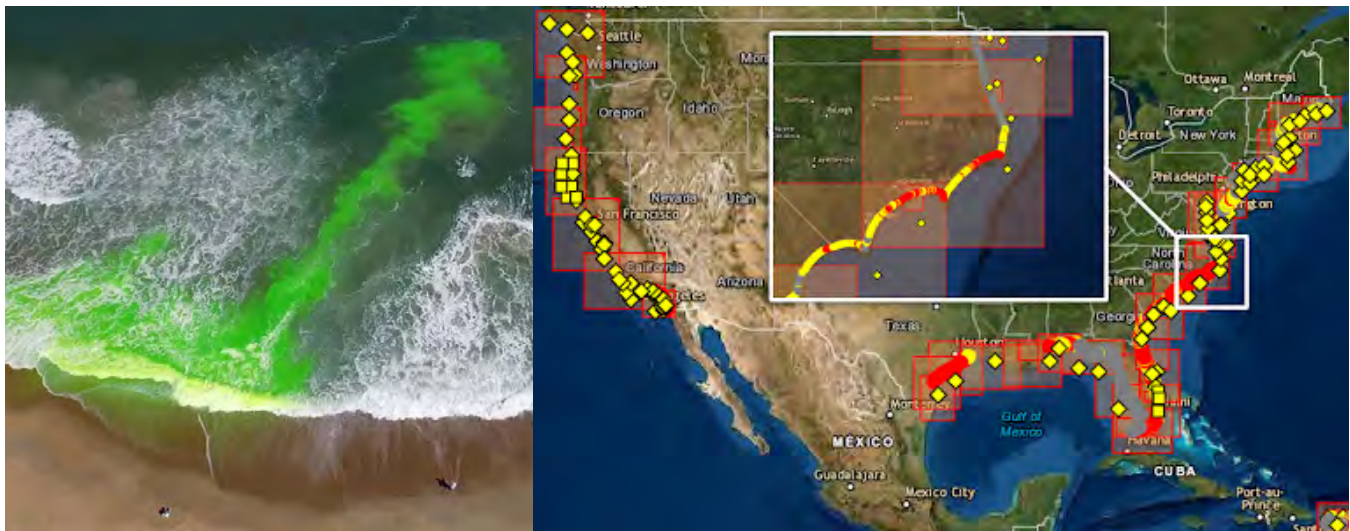
The left panel image shows a rip current using a harmless green dye. Rip currents are powerful, narrow channels of fast-moving water (at speeds up to 8 feet per second) that are prevalent along the east, Gulf, and west coasts of the U.S., as well as along the shores of the Great Lakes. The Nearshore 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.
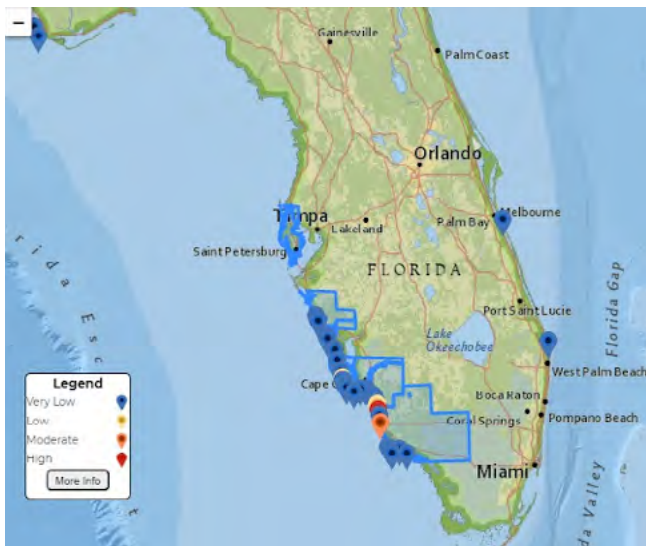
A screen grab of the Red Tide Respiratory Forecast on December 15, 2020. Image credit: GCOOS.

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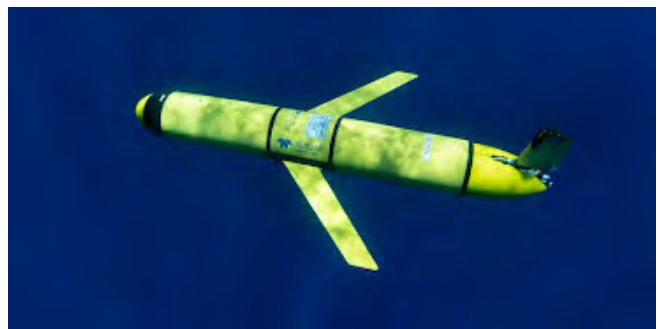
Deployed glider collecting profiles of water temperature and salinity during the 2020 hurricane season. Image credit: Dan Mele

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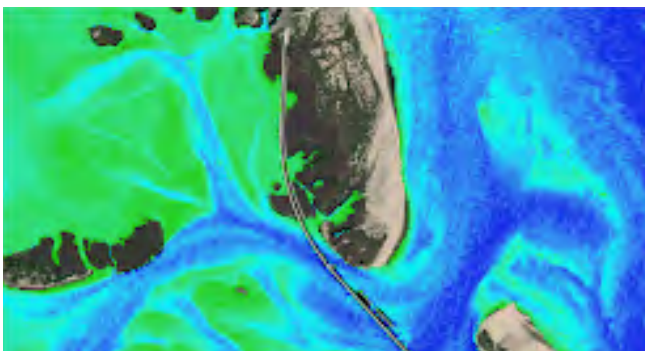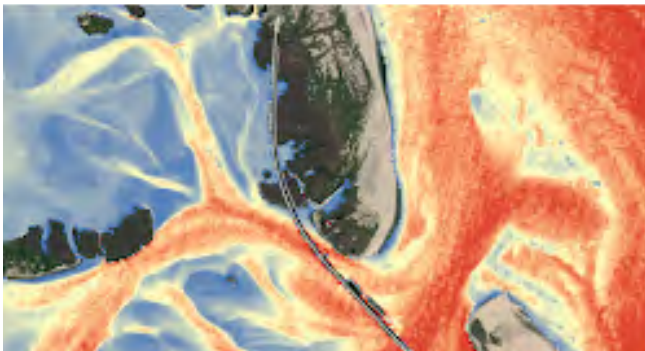
Oregon SDB created Inlet (Oct 2020) using NGS' new pre-alpha SatBathy tool v1.0 based on research from NCCOS. Image credit: NOAA/NOS/NGS.

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.
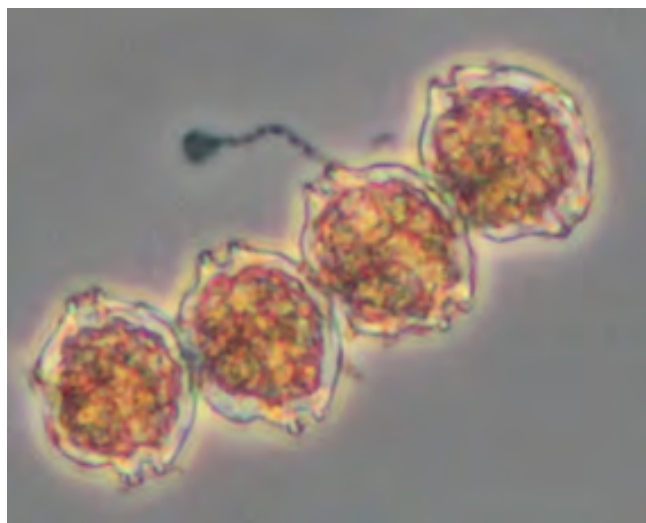
Chain of Alexandrium catenella cells.

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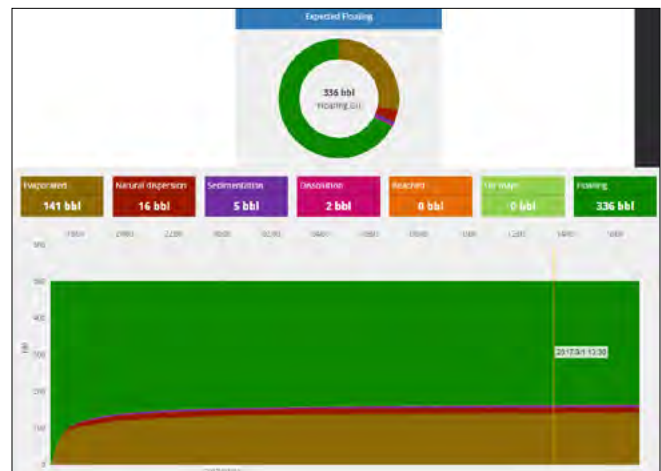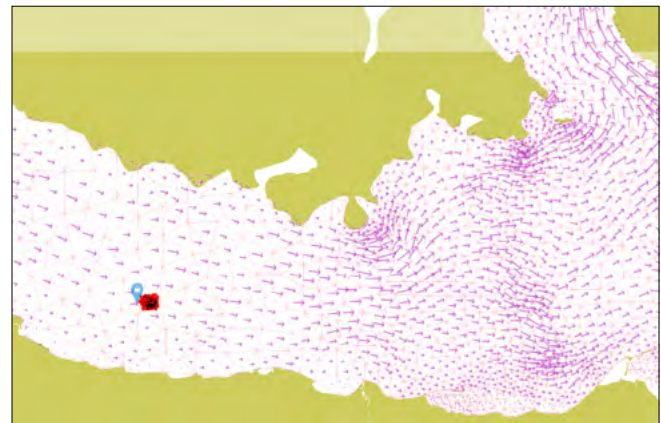
Top panel: A map view from WebGNOME, showing currents moving the oil in a simulated spill. Bottom panel: Oil fate (weathering) view from WebGNOME, showing an oil budget for a simulated spill.
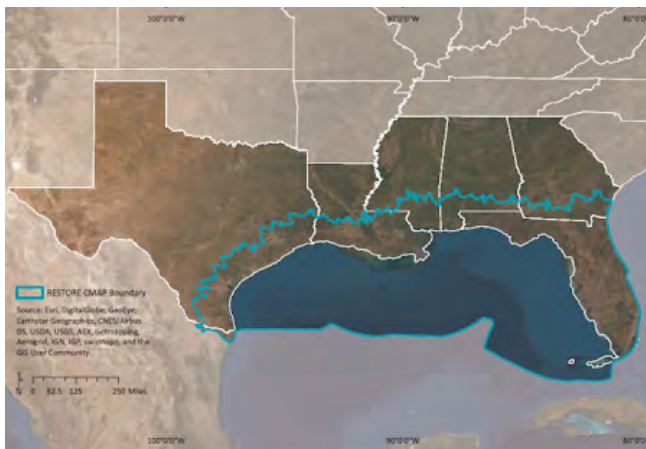
Image credit: NOAA/NOS/ORR.

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 Council[4] 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.

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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/
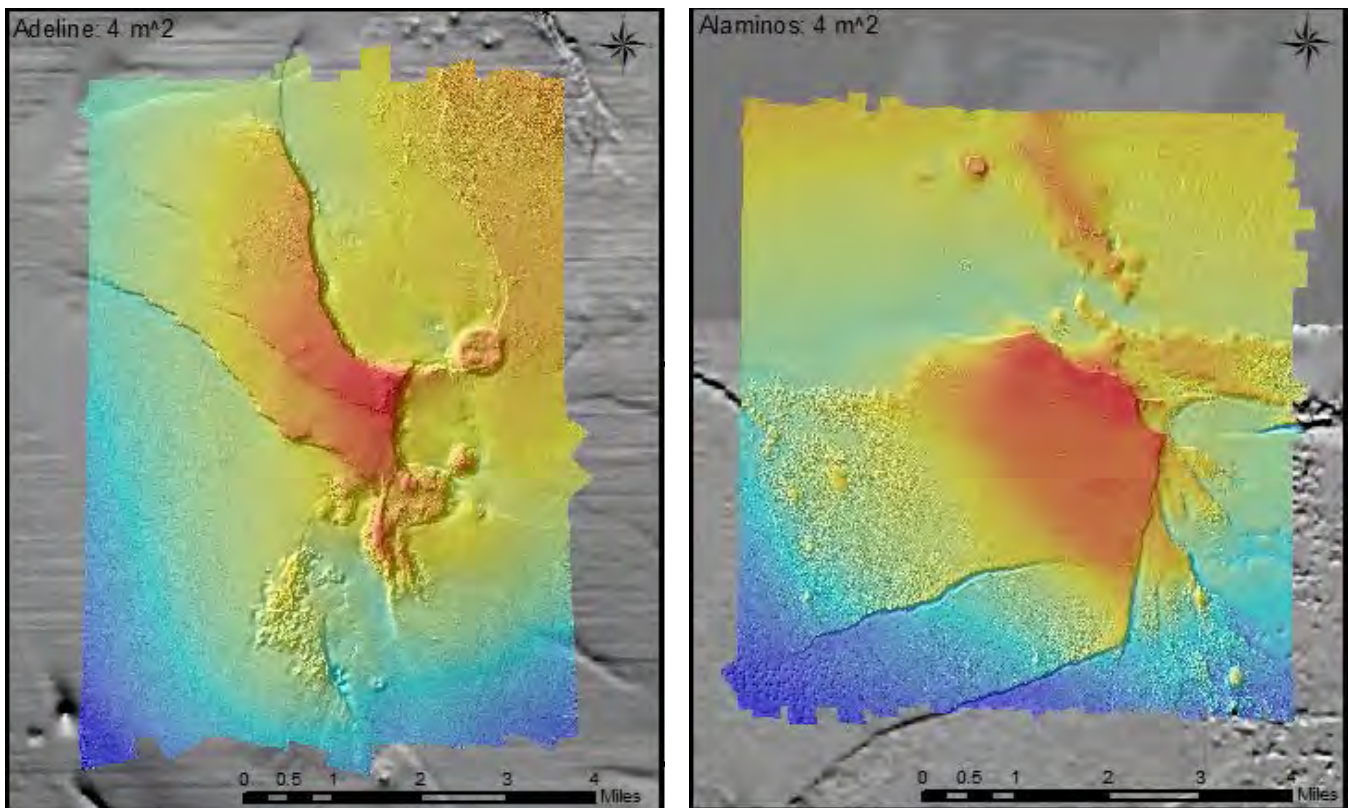
Multibeam Survey of Small Topographic Features to Determine Efficacy of Current "No Activity Zones"

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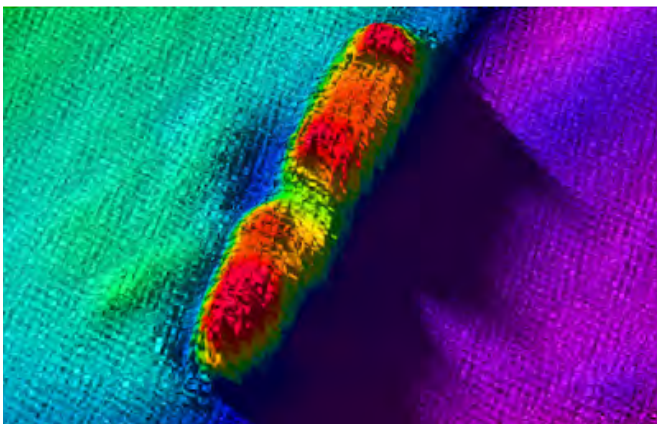
Left panel: An image of the Bluefields shipwreck (offshore, North Carolina seafloor) from the NCCOS Living Shipwrecks 3D Viewer. Right panel: A diver examines marine life along a North Carolina shipwreck. Image credits: NOAA/NOS/NCCOS; Tane Casserly, NOAA.

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
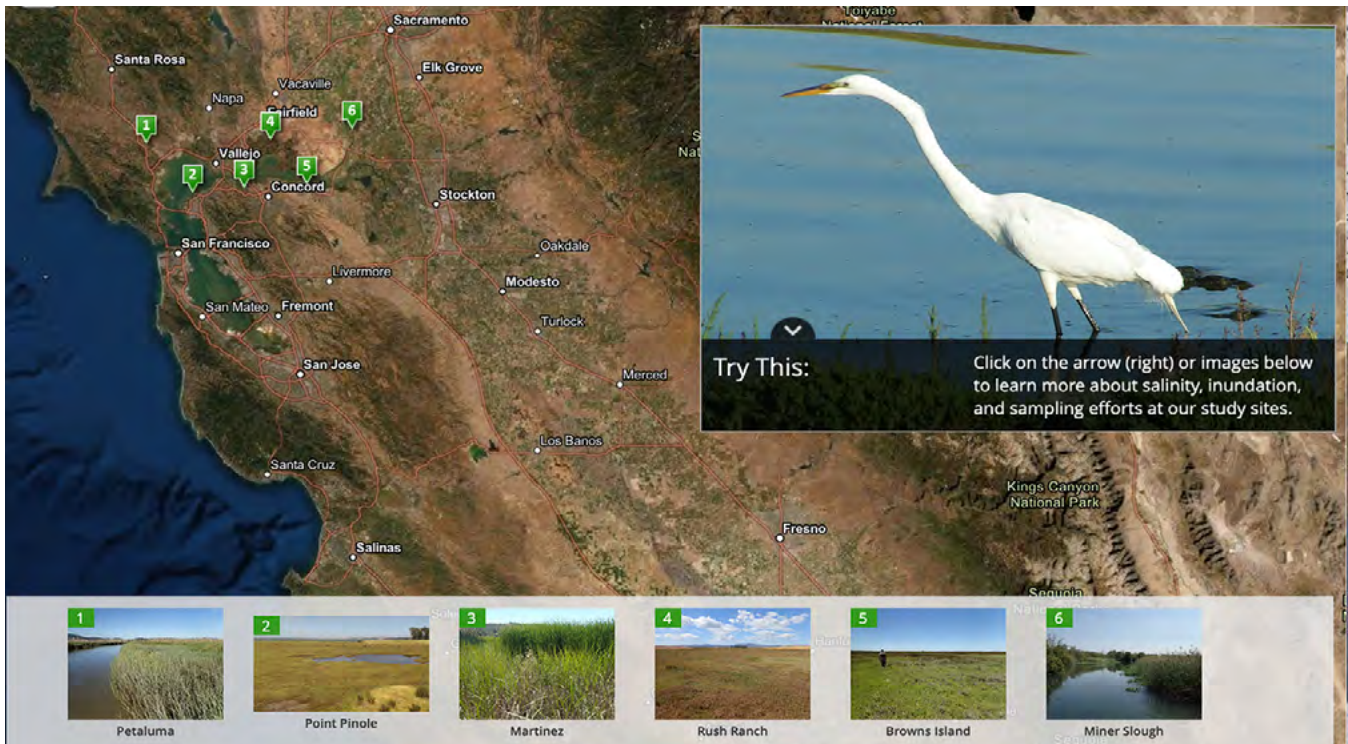
carbon sequestration. This project produced results at a regional scale that are assisting local partners in making natural resource management decisions. For example, the San Francisco Bay National Research Reserve is using these results to better understand impacts of SLR and other changing environmental 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.
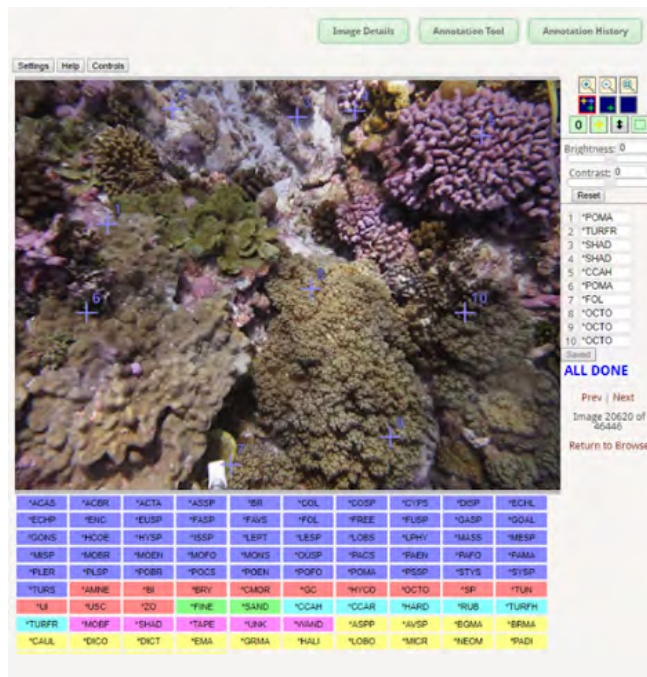
CoralNet is a software package that uses artificial intelligence to analyze benthic photos to classify corals. Image credit: NOAA Fisheries.

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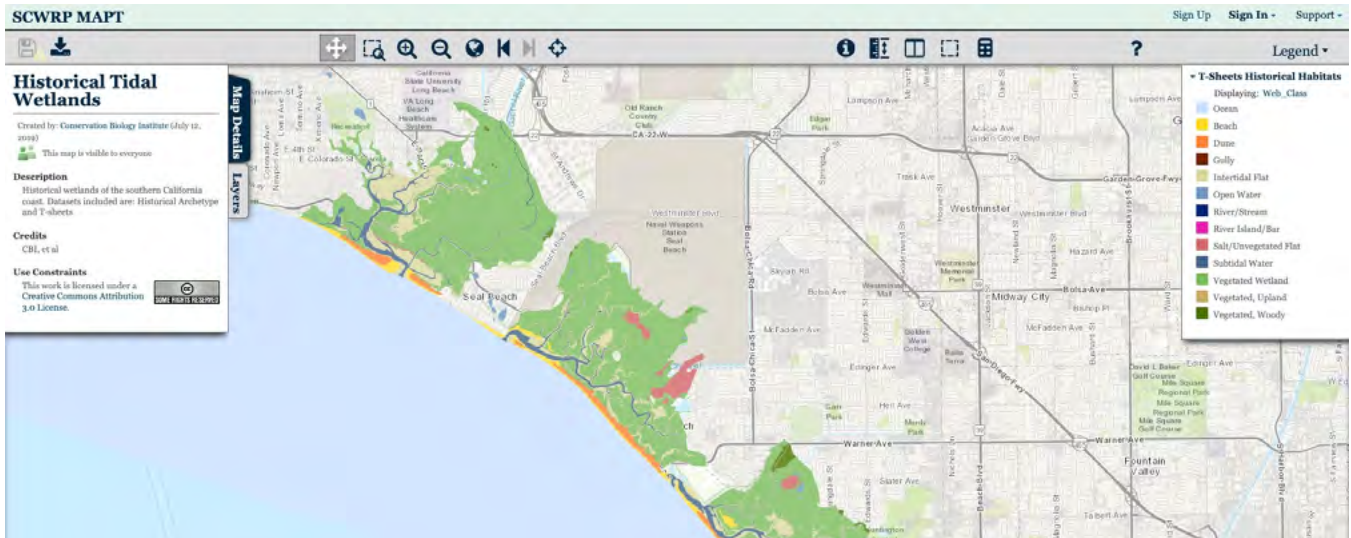
The Southern California Wetlands Recovery Project (SCWRP) Marsh Adaptation Planning Tool provides a platform for high-quality geospatial datasets, maps, and information to facilitate acquisition and restoration of rivers, streams, and wetlands in coastal Southern California. Image credit: SCWRP.

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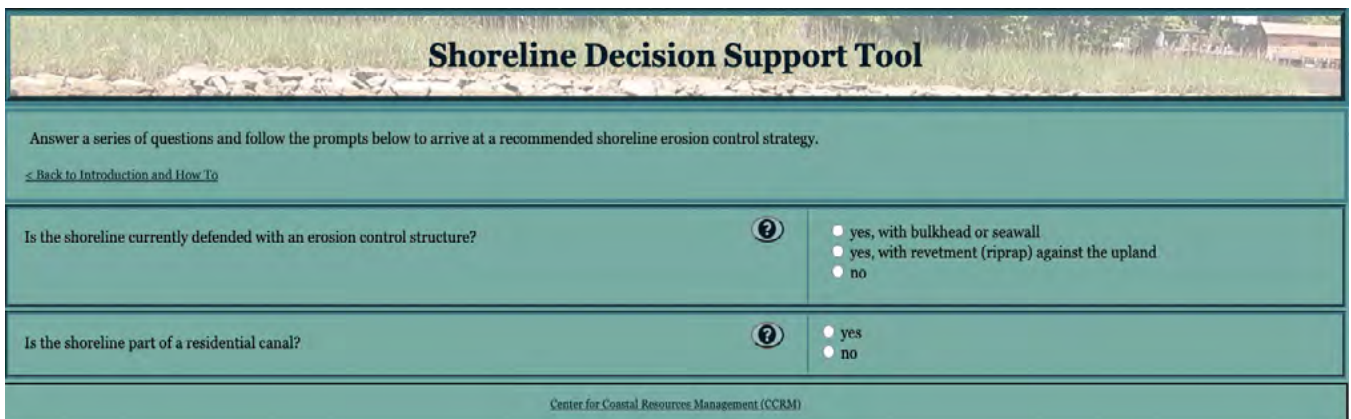
The Living Shoreline Decision Support Tool is a query-based tool designed to recommend shoreline best management practices. Image credit: Virginia Institute of Marine Science.

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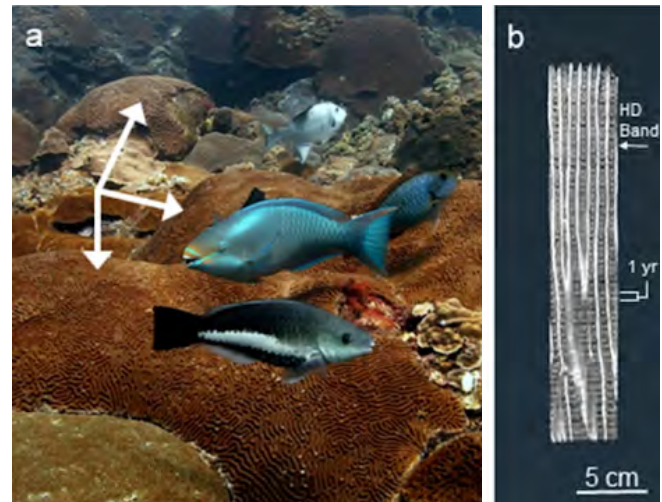
Photographs of (a) parrotfish and Pseudodiploria strigosa *coral colonies at east Flower Garden Bank and (b) computerized tomography (CT) images of cores for* P. strigosa. *CT images illustrate clear annual banding.*

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