Deep Sea Coral Research and Technology Program

2018 Report to Congress

NOAA FISHERIES

About This Report

The National Oceanic and Atmospheric Administration's (NOAA) **Deep Sea Coral Research and Technology Program** was established under the authority of Section 408 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), as reauthorized in 2007. This MSA-required a biennial report to Congress and the public summarizing the steps taken by NOAA to identify, monitor, and protect deep-sea coral areas, including the Program's research activities and results. The Program consults with the nation's eight regional fishery management councils and collaborates on research with other federal agencies, international partners, and non-governmental and academic scientists.

The Program collaborates with other NOAA programs and offices, such as National Marine Sanctuaries, Ocean Exploration and Research, Fisheries Science Centers and Regional Offices, National Centers for Coastal Ocean Science, and National Centers for Environmental Information. These programs and offices support exploration, research, analysis, and management activities critical to understanding and managing deep-sea corals and other ocean resources. The Program actively works to leverage their expertise.

This report describes the 2016 and 2017 research activities partially or fully funded by the Program to meet NOAA's mandate to identify, study, and monitor deep-sea coral areas. The report is supplemented with details of these activities: https://deepseacoraldata.noaa.gov/. The report also briefly describes progress during this period in MSA and other NOAA management actions that contribute to protecting deep-sea coral areas.

A subset of deep-sea coral research activities funded and executed by NOAA programs and offices other than the Deep Sea Coral Research and Technology Program is briefly discussed, as these activities are providing data that will be analyzed by our Program.

Chris Oliver, Assistant Administrator for Fisheries National Marine Fisheries Service National Oceanic and Atmospheric Administration

Tim Gallaudet, Ph.D., Rear Admiral, U.S. Navy (Ret.) Assistant Secretary of Commerce for Oceans and Atmosphere / Deputy NOAA Administrator, Acting Under Secretary of Commerce for Oceans and Atmosphere / NOAA Administrator

Deep Sea Coral Research and Technology Program
National Marine Fisheries Service

COVER PHOTO: Thorny tinselfish swimming above dense Lophelia pertusa coral mounds discovered at 500 m (1,600 ft) depth on the West Florida Slope. Image: NOAA, Pelagic Research Services.

Deep Sea Coral Research and Technology Program
2018 Report to Congress

Developed pursuant to Section 408 of the Magnuson-Stevens Fishery Conservation and Management Act, as Amended by Public Law 109-479

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Executive Summary

The deep sea is one of the last frontiers of marine research. Reaching extreme ocean depths requires committed scientists, innovative techniques, dedicated funding, and diverse partnerships. The National Oceanic and Atmospheric Administration (NOAA) Deep Sea Coral Research and Technology Program, administered by the Office of Habitat Conservation within NOAA Fisheries, meets these charges by working directly with resource managers to identify survey and research priorities for deep-sea coral communities. The Program then works with partners to survey and fund cutting-edge research to understand coral survival, growth, reproduction, genetic connections, and recovery from damage. As such, scientists are characterizing habitat created by deep-sea corals for commercially valuable fish and invertebrates on every expedition. In each region of the country, our work guides crucial protection for these animals to sustain the highly biodiverse and productive habitats the nation depends on.

With an investment of about $2.5 million per year and through extensive partnerships and leveraging of funds, the Program is measurably enhancing our understanding of deep-sea coral distribution, function, and vulnerability to human activities. In 2016 and 2017, the Program supported robust research to inform management decisions and improve public understanding of the deep sea. Materials referred to in this document are available at https://deepseacoraldata.noaa.gov/ or https://www.fisheries.noaa.gov/national/habitat-conservation/deep-sea-coral-habitat.

- ThePacific Islands Deep-Sea Coral Fieldwork Initiative (2015-2017) partnered with NOAA's Office of Ocean Exploration and Research to explore areas of our ocean never before seen by humans. Researchers described hundreds of new species during 187 remotely operated vehicle (ROV) dives comprising one of the largest ocean exploration efforts in U.S. history. Livestream ROV video feeds logged more than 16 million views, engaging audiences around the world in exciting discoveries.

- SoutheastDeep Coral Initiative (2016-2019) researchers and partners have explored canyon and slope habitats of interest to regional fishery management councils, and turned observations into predictions of productive deep-sea coral habitat in unexplored waters. Directly informed by Program research and broadly supported by the public, the Gulf of Mexico Fishery Management Council unanimously approved 21 new Habitat Areas of Particular Concern containing deep-sea corals in June 2018.

Empty egg case of a skate, ray, or shark attached to the octocoral Swiftia koreni. *Image: NOAA Office of Ocean Exploration and Research.*

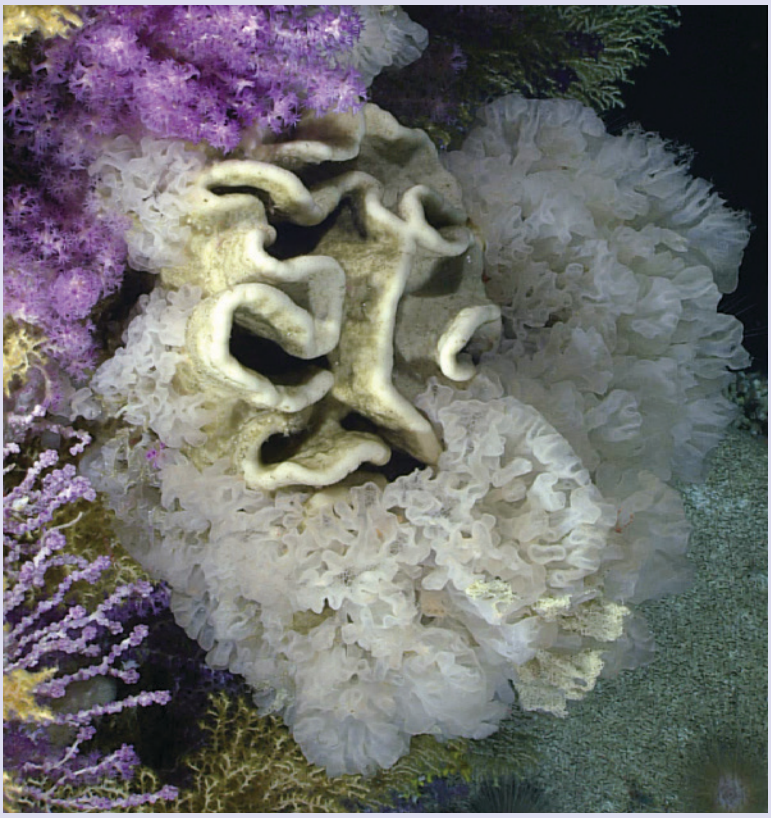
- A new deep-sea coral research initiative is beginning in the West Coast region (2018-2020). The Program has gathered priorities based on April 2018 essential fish habitat closures and reopenings designated by the Pacific Fishery Management Council. Many aspects of these updates were informed by past Program research on locations, impacts of fishing gear, and fish-habitat associations with deep-sea coral.

- Research with partners and data analysis has continued in the Alaska and Northeast regions, which are currently between research initiatives. The Program is working with the North Pacific Fishery Management Council to identify priorities for future research, and the New England Fishery Management Council voted in January 2018 to protect its entire exclusive economic zone deeper than 600 meters from most bottom-contact fishing gear to benefit vulnerable deep-sea coral habitats.

Recent research and resulting protections from certain fishing gear underscore the growing recognition of deep-sea coral's value, as Program data have informed decisions by most U.S. regional fishery management councils. This Report to Congress also describes updates to the Program's Deep-Sea Coral Data Portal, which includes a library, photo gallery, and searchable map displaying the distribution of more than 622,000 deep-sea coral and sponge records; and the recent *State of Deep-Sea Coral and Sponge Ecosystems of the U.S.* report, a major publication describing 10 years of research and management actions taken nationally.

None of these accomplishments would be possible without extensive contributions from collaborators within and outside of NOAA. The elements needed to make this Program such a success—including ship time coordination, predictive habitat modeling, underwater survey tool development, laboratory analysis, data management, and educational opportunities—are the result of multiple partners pooling resources for a shared mission. Critical collaborators include NOAA's National Centers for Coastal Ocean Science, Office of Ocean Exploration and Research, Office of National Marine Sanctuaries, the U.S. Geological Survey, the Bureau of Ocean Energy Management, academic scientists, and non-governmental organizations.

We are only beginning to understand where and how deep-sea corals grow and thrive. Further studies will improve our understanding of how these valuable and vulnerable communities contribute to robust fisheries and resilient ecosystems. In the coming years, the Program will continue to prioritize research that supports regional fishery management councils, national marine sanctuaries, and other resource managers as they develop management measures for deep-sea coral habitats around the nation.



Dense aggregation of corals and sponges near Jarvis Island. Numerous shrimp, crabs, brittle stars, and fish were also living within this structure. Image: NOAA Office of Ocean Exploration and Research.

About Deep-Sea Corals

Deep-sea corals can live for hundreds or thousands of years, creating remarkably complex communities in the depths of the oceans. Their habitat in the deep sea ranges from where the light is dim (around 150 feet or 50 meters deep) to more than 20,000 feet (6,000 meters) below the ocean's surface. Deep-sea coral habitats have been discovered in all U.S. regions on continental shelves and slopes, canyons, and seamounts. Their full geographic extent is still unknown, because most areas have yet to be adequately surveyed.

A few deep-sea coral species form reefs that, over millennia, can grow to more than 300 feet tall. Many other coral species are shaped like bushes or trees, and can form high-density assemblages similar to groves or forests on the seafloor. Along with sponges, these corals form the most important living habitats in the deep sea.

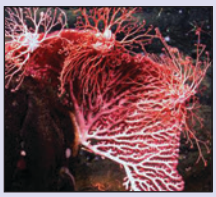
Nationwide, complex deep-sea coral structures provide habitat for many fish and invertebrate species, including commercially important grouper, snapper, sea bass, rockfish, shrimp, and crab. In addition to their value as habitat, sponges and octocorals that live in the deep sea can produce chemicals of great biomedical potential, and certain deep-sea coral species have commercial value as jewelry and art.

Most deep-sea corals grow extremely slowly. Once damaged, the corals and the communities they support may take centuries to recover—if they recover at all. Deep-sea corals are vulnerable to disturbance caused by fishing gear such as bottom trawls that contact the seafloor. They can also be damaged by activities associated with energy exploration and development, cable deployment, and other actions that disturb their habitat. In addition, ocean acidification—a result of the ocean absorbing increased levels of carbon dioxide—can adversely affect corals' ability to grow or maintain their structures.

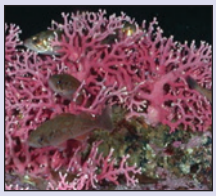
Black corals often resemble bushes or trees. Some black corals may be the world's oldest living marine organisms. This black coral off Hawaii was estimated to be more than 4,000 years old.

Deep-sea **stony corals** range from small individual cup corals to large, branching species, like this *Lophelia pertusa* colony off Eastern Florida, that form extensive deep-water reefs.

Gold corals, some of which have been harvested for jewelry, are unique in that they grow on the skeletons of other deep-sea corals and can live for thousands of years.



Gorgonians, like this fan-shaped colony of **red coral** (*Corallium* sp.) on Davidson Seamount, are among the most diverse deep-sea corals.



Lace corals, like these off California, are actually hydroids and only distantly related to other corals.

Sea pens are related to **gorgonians**. But unlike most other deep-sea corals they live in soft sediments where they can form large fields.

MSA Section 408:
Deep Sea Coral Research and Technology Program

(a) IN GENERAL—The Secretary, in consultation with appropriate regional fishery management councils and in coordination with other federal agencies and educational institutions, shall, subject to the availability of appropriations, establish a program—

(1) to identify existing research on, and known locations of, deep-sea corals and submit such information to the appropriate Councils;

(2) to locate and map locations of deep-sea corals and submit such information to the Councils;

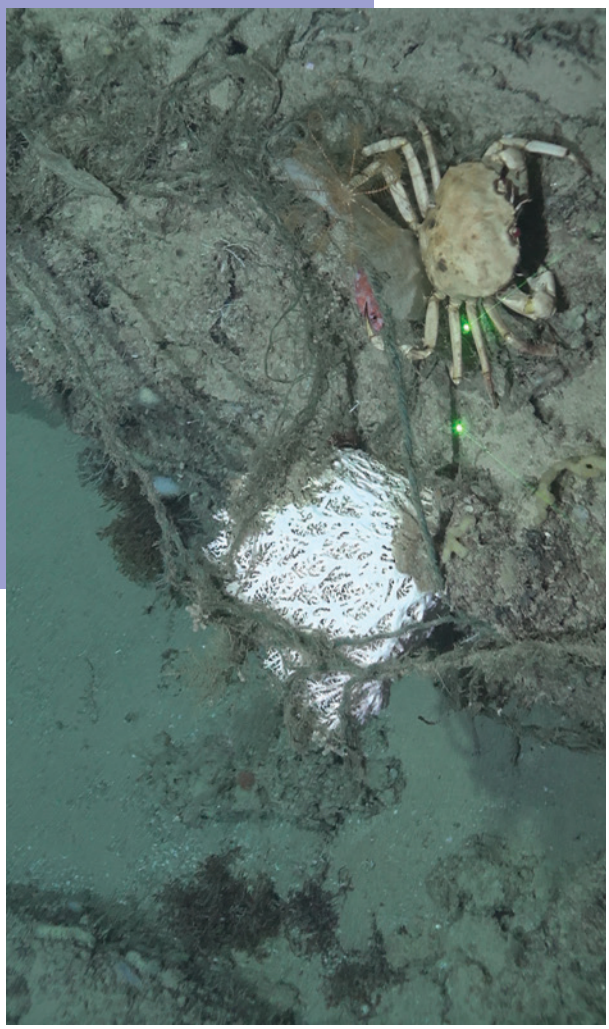
(3) to monitor activity in locations where deep-sea corals are known or likely to occur, based on best scientific information available, including through underwater or remote sensing technologies and submit such information to the appropriate Councils;

(4) to conduct research, including cooperative research with fishing industry participants, on deep-sea corals and related species, and on survey methods;

(5) to develop technologies or methods designed to assist fishing industry participants in reducing interactions between fishing gear and deep-sea corals; and

(6) to prioritize program activities in areas where deep-sea corals are known to occur, and in areas where scientific modeling or other methods predict deep-sea corals are likely to be present.

(b) REPORTING—Beginning 1 year after the date of enactment of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, the Secretary, in consultation with the Councils, shall submit biennial reports to Congress and the public on steps taken by the Secretary to identify, monitor, and protect deep-sea coral areas, including summaries of the results of mapping, research, and data collection performed under the program.



Lace coral entangled with discarded line on the West Florida Slope at 400 meters (1300 feet) depth. A golden crab, blackbelly rosefish, and crinoid are also visible to the right of the coral. Image: NOAA, Pelagic Research Services.

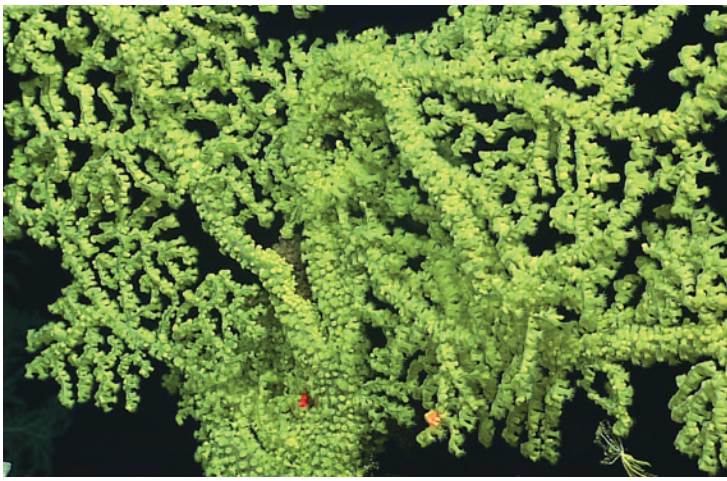
Discovering Deep-Sea Treasures of U.S. Pacific Island Marine National Monuments

Between 2015 to 2017, CAPSTONE efforts:

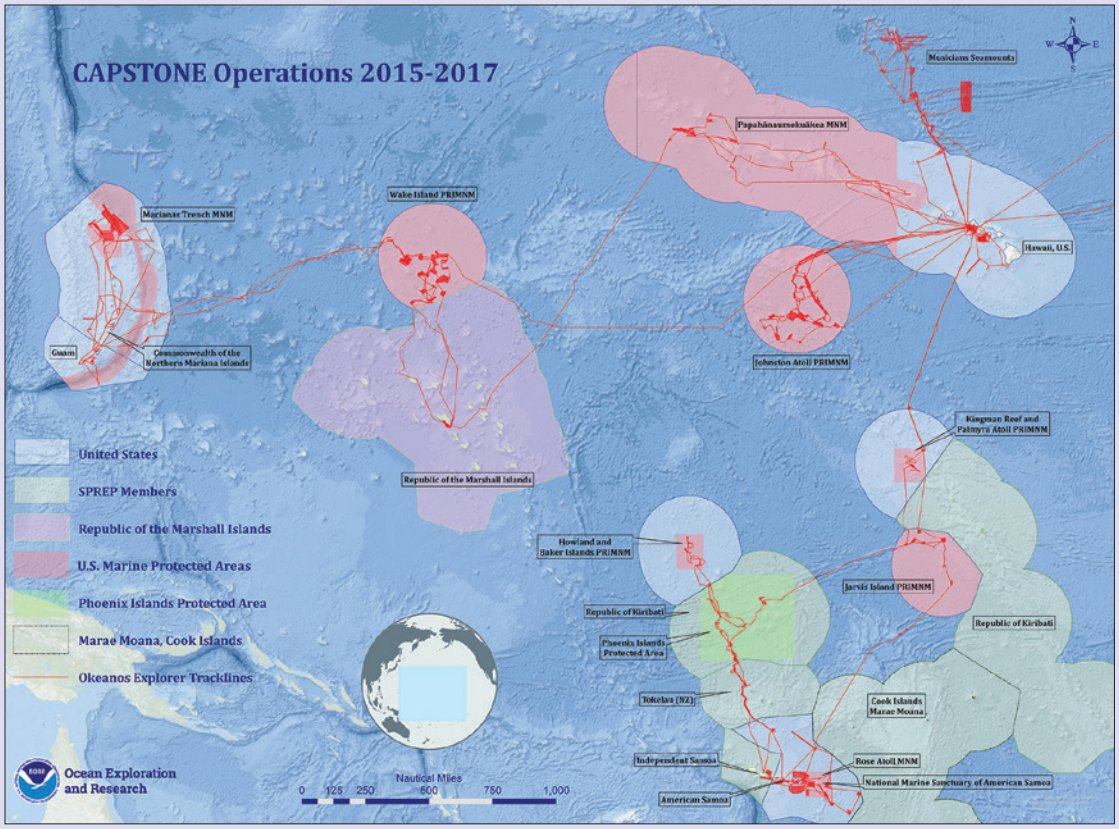
- Completed 24 cruise legs and 431 days at sea aboard NOAA Ship *Okeanos Explorer.*
- Conducted 187 remotely operated vehicle (ROV) dives between 250 and 6,000 meters (820-20,000 feet) deep.
- Mapped over 635,600 km^2 (245,000 mi^2) of seafloor.
- Collected 767 biological specimens to document and discover new species, new records, and range extensions.
- Engaged more than 260 scientists, students, and managers onboard and onshore in sharing knowledge.
- Loggedmore than 16 million views of live ROV video feeds.

The waters surrounding the Northwestern Hawaiian Islands and U.S. Pacific Island territories were the first U.S. marine national monuments established. The Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE) was a 3-year effort to collect deep-sea baseline information to support science and management decisions in and around U.S. marine protected areas in the central and western Pacific. This cross-NOAA initiative—led by NOAA's Office of Ocean Exploration and Research in partnership with the Deep Sea Coral Research and Technology Program—was one of the largest ocean exploration efforts in U.S. history. A major focus of CAPSTONE was the discovery of high-density deep-sea coral and sponge habitats that represent oases of biodiversity in the deep sea. The data collected will continue to be analyzed by scientists in the coming years and will provide countless discoveries, insight into biogeographic patterns, and a better understanding of regional biodiversity.

Vogt Seamount hosted one of the most diverse and dense communities of deep-sea coral and sponges of the 2016 Deepwater Exploration of the Marianas expedition. Image: NOAA Office of Ocean Exploration and Research.



*The Deepwater Exploration of the Marianas expedition successfully confirmed the presence of precious corals throughout the region with the first-ever in situ imagery of these organisms. This gold coral (*Kulamanamana haumeaae*) was observed at "Santa Rosa North." Image: NOAA Office of Ocean Exploration and Research.*



Completed in 2017, CAPSTONE was a multiyear foundational science initiative to collect deep-sea baseline information to support science and management decisions in and around U.S. marine protected areas in the central and western Pacific. In the map, the U.S. exclusive economic zone is shown in light blue, with protected areas and regions highlighted by color according to the legend on the left side. Red lines indicate the expedition path of NOAA Ship *Okeanos Explorer* over the entire CAPSTONE mission.

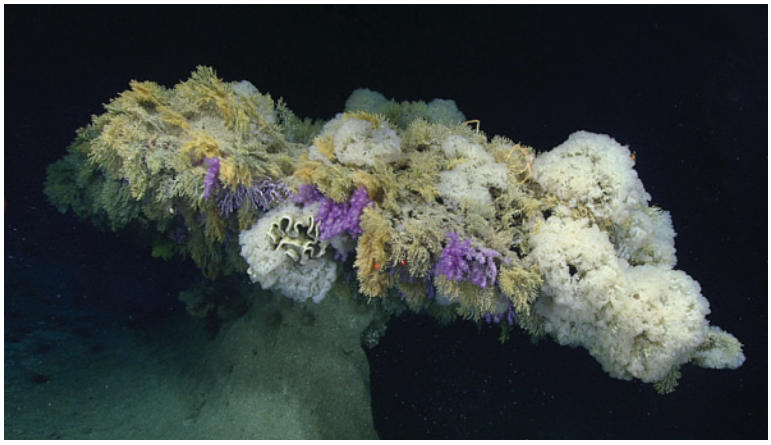
2016 Exploration of the Marianas Archipelago

The Deepwater Exploration of the Marianas expedition was the first to specifically search for deep-sea coral and sponge communities in the Mariana region. Ten impressively high-density and several medium-density coral and sponge communities were documented. Some of the corals and sponges, especially at Vogt Seamount, measured more than 3 feet in width, indicating healthy and stable communities. Despite the precious coral fishery being listed as a managed fishery in Guam and the Commonwealth of the Northern Mariana Islands, no precious coral beds had been identified prior to this expedition, and only anecdotal accounts of their presence in this region existed. The search for precious corals was successful, with observations of pink and red precious corals (*Hemicorallium* spp.), long-lived black corals (*Leiopathes* spp.), bamboo corals (*Acanella* spp.), and gold corals (*Kulamanamana* sp.). There appeared to be little overlap between bottomfish and precious coral habitats, as bottomfish were found at shallower depths, but there was overlap between bottomfish and other coral habitat.

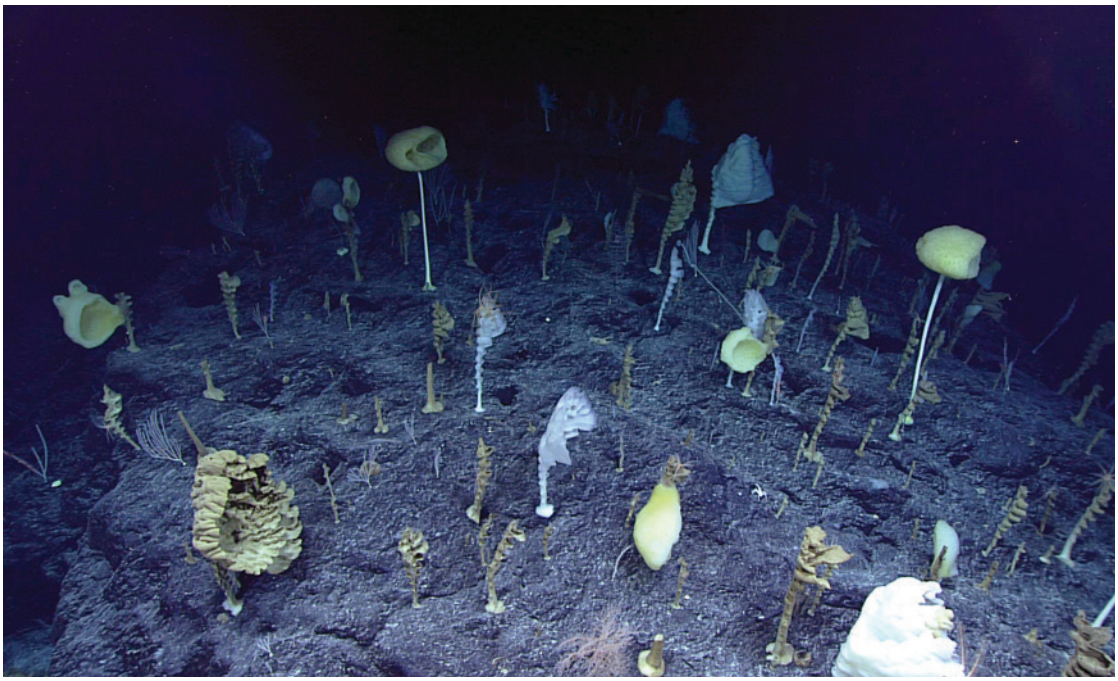
2016-2017 Exploration of the Pacific Remote Islands Marine National Monument

The Pacific Remote Islands Marine National Monument (PRIMNM) consists of Wake, Baker, Howland, and Jarvis Islands; Johnston Atoll; Kingman Reef; Palmyra Atoll; and surrounding waters. Prior to the start of CAPSTONE, the vast majority of the monument was unexplored, and the deep-sea habitats within were largely a mystery. However, by the conclusion of CAPSTONE expeditions, NOAA and partners had visited every unit of the monument, greatly expanding our knowledge about what exists within the monument boundaries and making critical data publicly available for managers and scientists. For example, 21 high-density deep-sea coral and sponge communities were documented for the first time, with at least one new community discovered in every Island Unit. Precious corals (*Hemicorallium* spp.) were confirmed to exist around Johnston Atoll at 400-550 meters (1,300-1,800 feet) depth in very low oxygen conditions, suggesting commercially harvested shallower coralliid species can tolerate a wide range of oxygen levels and potentially colonize a relatively wide latitudinal range in the central Pacific. Hundreds of observations were made of new or yet to be described species, new records, and novel behaviors and associations.

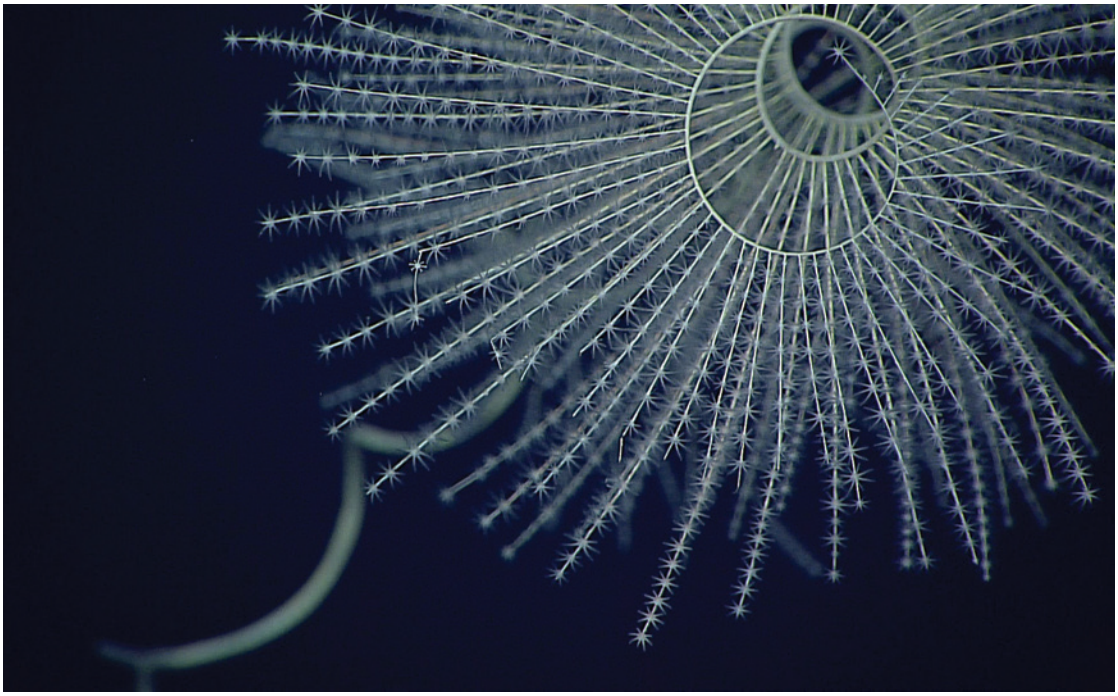
Several large deep-sea corals and a sponge grow in a high-density community in the Wake Island Unit. Image: NOAA Office of Ocean Exploration and Research.



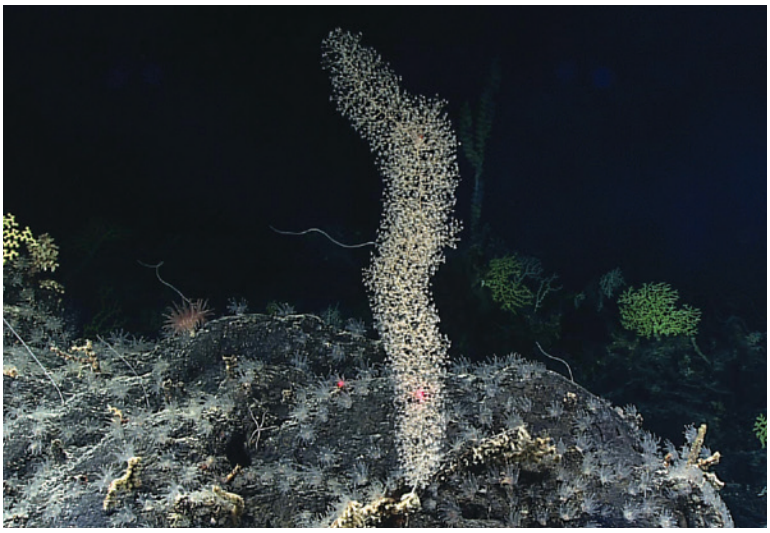
One of the priorities for each of the five ROV expeditions in the PRIMNM was to locate deep-sea coral and sponge habitats. A highlight of the exploration of the Jarvis Island Unit was this unusual umbrella-shaped pillar feature covered in deep-sea corals and sponges. Image: NOAA Office of Ocean Exploration and Research.



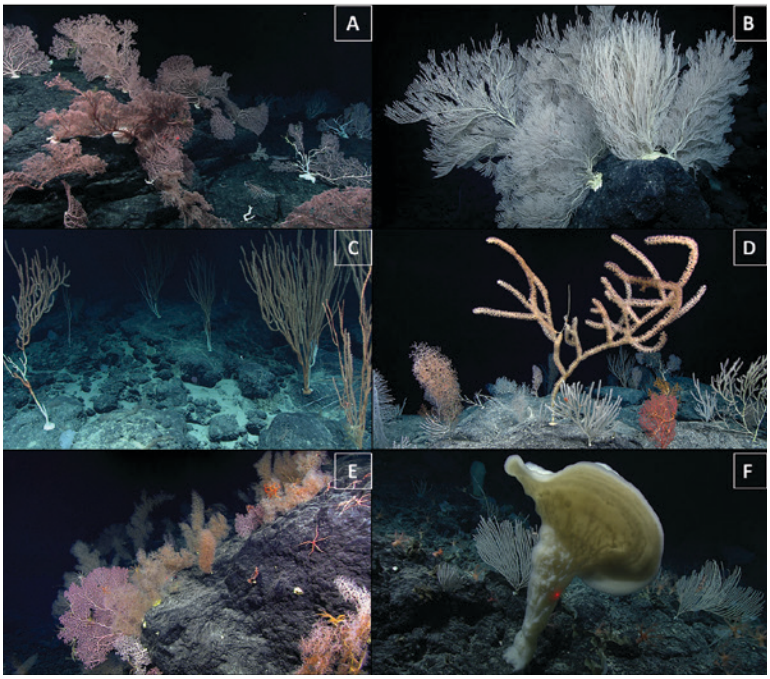
Nine high-density deep-sea coral and sponge communities were documented in the Johnston Atoll Unit of the PRIMNM. Here, a high-density community dominated by sponges in the families Euplectellidae and Farreidae were encountered on "Ridge" seamount. Image: NOAA Office of Ocean Exploration and Research.



The Wake Island unit of the PRIMNM is home to numerous species of deep-sea coral like this Iridogorgia magnispiralis*. Image: NOAA Office of Ocean Exploration and Research.*



*This deep-sea coral garden at Swains Island hosts numerous species of corals. The dive revealed a higher diversity and abundance of corals, sponges, and other taxa compared to other ROV dives in the region, including high densities of scleractinian coral colonies (*Enallopsammia *sp. and* Madrepora *sp.) around 1,100 meters. Image: NOAA Office of Ocean Exploration and Research.*



*Diverse coral and sponge communities of the Musicians Seamounts. A) Dense precious coral (*Hemicorallium *sp.) community at Mendelssohn Seamount (U.S. exclusive economic zone); B) large primnoid colonies at Paganini Seamount; C) 3 meter (10 feet) bamboo coral colonies at Shostakovich Seamount; D) diverse community at Debussy Seamount; E) a coral community dominated primarily by chrysogorgiid gorgonians at Sibelius Seamount; F) high densities of deep-sea coral and glass sponges at Beethoven Ridge. Image: NOAA Office of Ocean Exploration and Research.*

2017 American Samoa Expedition

Knowledge of fauna populating the deep waters of the central Pacific, including American Samoa, is extremely scarce. Thirteen ROV dives during the American Samoa expedition explored the distribution of seafloor habitats, identifying distinct communities on seamounts, including one high-density community. The passage north of the islands is a major circulation gateway for deep water flowing from the South Pacific into the North Pacific, and may also pose a significant barrier for larval dispersal. Consistent with this hypothesis, coral communities discovered between 250 and 4,000 meters (820-13,000 feet) in the American Samoan region were distinct from those north of the passage.

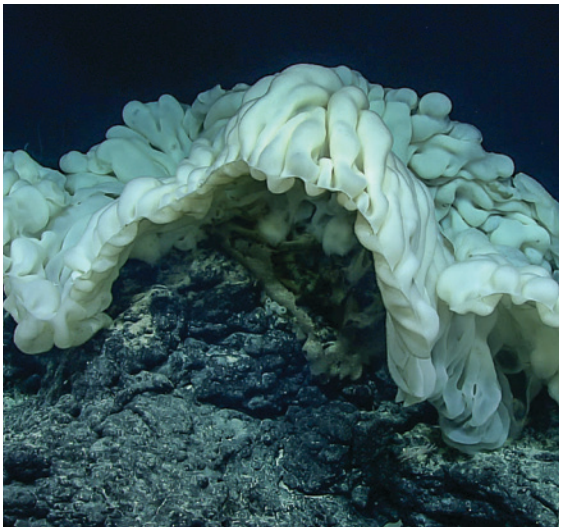
2017 Exploration of the Hawaiian Islands and Musicians Seamounts

Of the regions explored throughout CAPSTONE, the greatest number of high-density coral and sponge communities was observed in the Musicians Seamounts, a 650-nautical-mile-long chain that begins just inside the U.S. exclusive economic zone, north of Hawaii. Each site was unique in both relative abundance of species and unexpected findings. For example, Shostakovich Seamount was home to huge bamboo corals measuring 3 meters (10 feet) tall and 2 meters (6.5 feet) wide. Mendelssohn Seamount, the closest Musicians Seamount to Hawaii, hosted a pink precious coral garden (*Hemicorallium* sp.) composed of colonies more than 1 meter (3 feet) wide. Other locations exhibited mixed groups of high densities of precious coral (bamboo coral, pink coral, and black coral).

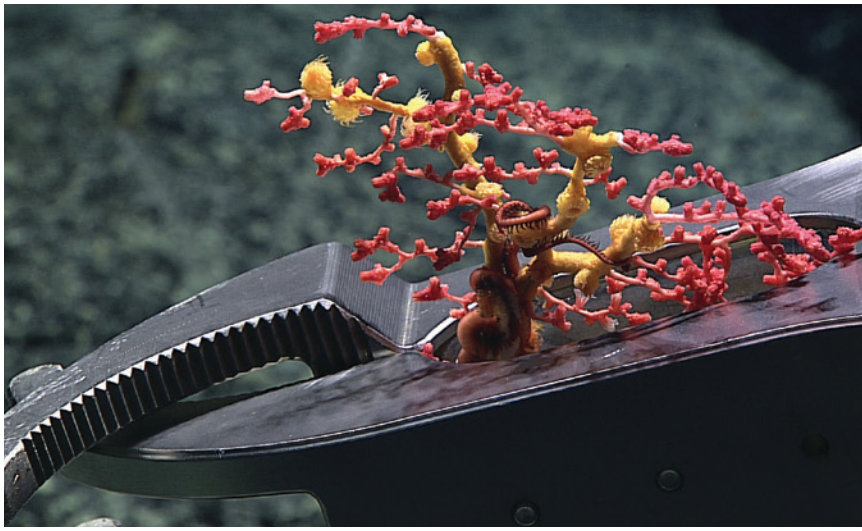
International Collaboration

As NOAA prepared to explore the Howland, Baker, and Jarvis Island Units of the PRIMNM, CAPSTONE's 2017 expeditions offered the opportunity to partner with neighboring countries to investigate deep-sea habitats in their waters. Working in partnership with marine resource managers of the Republic of Kiribati, Cook Islands, New Zealand, Samoa, the Pacific Regional Environment Programme, and the Big Ocean network, regional exploration priorities complemented overarching CAPSTONE themes. Telepresence ROV surveys discovered four high-density deep-sea coral communities, the first documented in Kiribati's Phoenix Islands Protected Area. Just north of the Cook Islands, a large-scale high-density community of old bamboo coral colonies that extended the entire length of the dive was discovered.

While exploring the Central Pacific Basin, a large-scale high-density bamboo coral (subfamily Keratoisinae) community was discovered north of the Cook Islands. Some corals observed were over 3 meters (10 feet) tall. Image: NOAA Office of Ocean Exploration and Research.



A rare sponge in the subfamily Lanuginellinae, observed at Schumann Seamount. This species, nicknamed the "minivan" sponge, reaches the largest size of any known sponge and was first discovered on a CAPSTONE cruise in the Papahānaumokuākea Marine National Monument (Wagner and Kelley 2017). Image: NOAA Office of Ocean Exploration and Research.



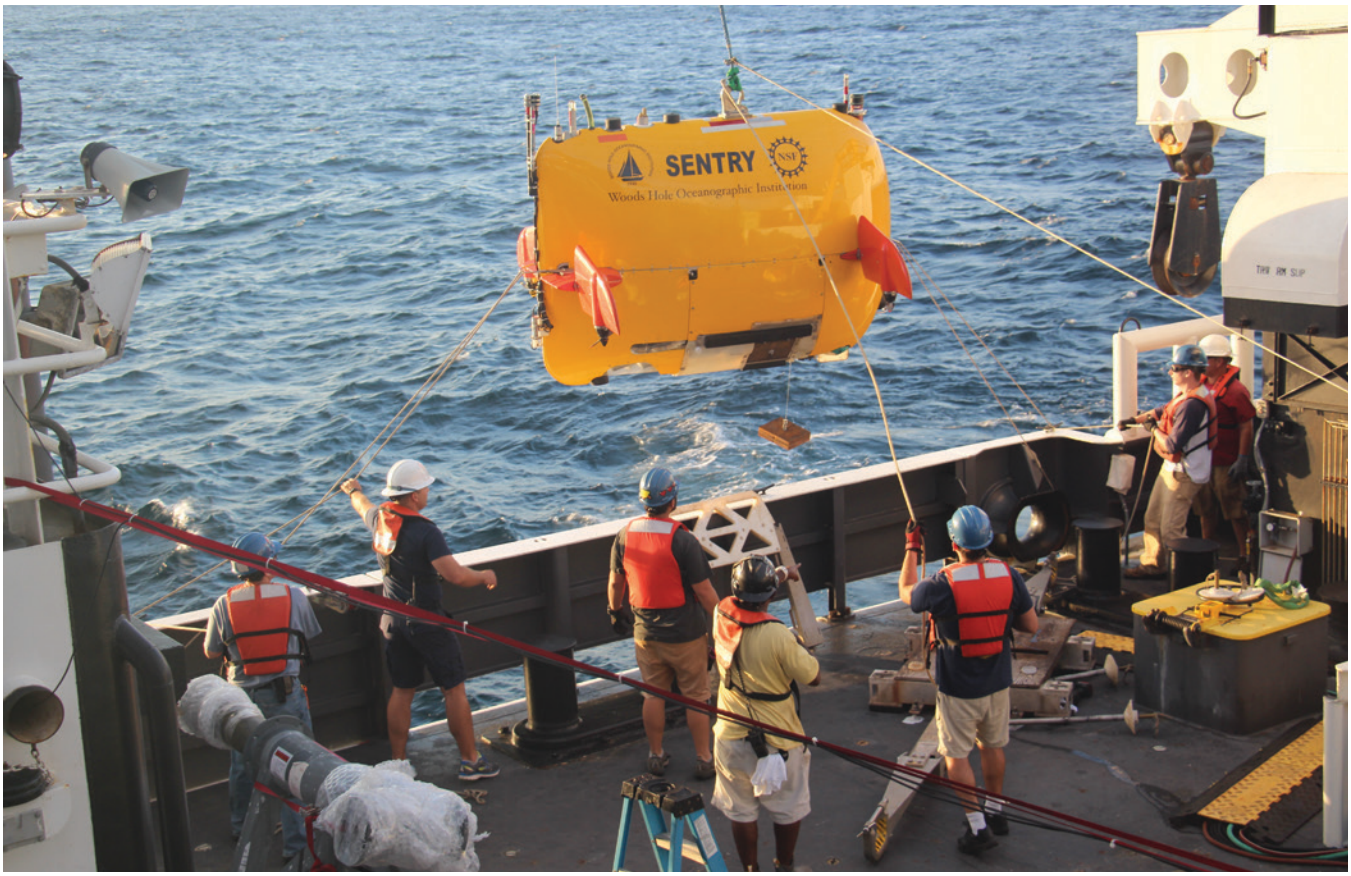
*ROV Deep Discoverer collected bubblegum coral (*Paragorgia *sp.) with an encrusting yellow zoanthid in the Phoenix Islands Marine Protected Area. Image: NOAA Office of Ocean Exploration and Research.*

Southeast Deep Coral Initiative: Exploring Ecosystems off the Southeast United States

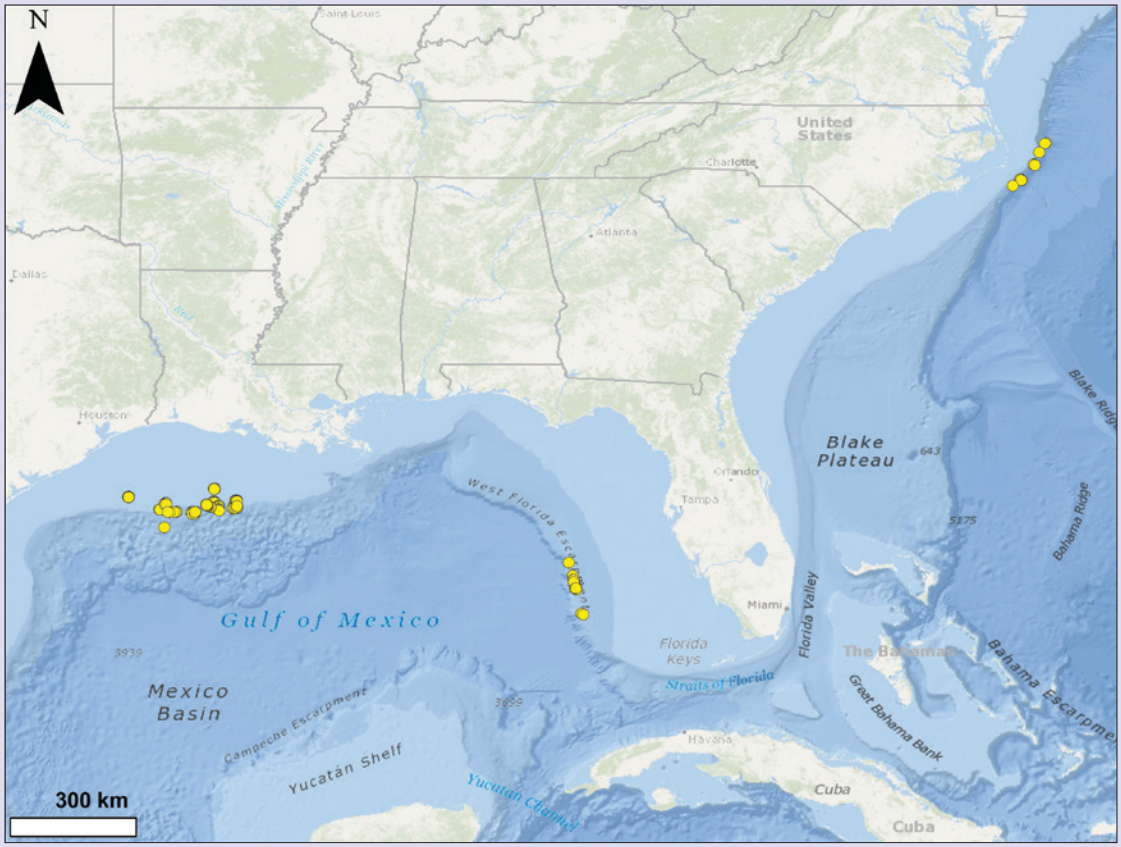
In 2016, the Deep Sea Coral Research and Technology Program launched a 4-year initiative to study deep-sea coral and sponge ecosystems in the South Atlantic Bight, Gulf of Mexico, and U.S. Caribbean. This multidisciplinary effort, known as the Southeast Deep Coral Initiative (SEDCI), builds on previous cross-agency collaborations aimed at increasing our understanding of the deep sea. The Initiative's goals are to collect and provide data to support science-based decision-making and to ensure public access to this information. Research priorities were developed in consultation with regional fishery management councils and national marine sanctuaries, as well as partners from the Bureau of Ocean Energy Management, U.S. Geological Survey, and a number of academic institutions (Schull et al. 2016).

SEDCI's fieldwork has included the following highlights.

- **North Carolina Canyons**—During 2016–2017, NOAA's Office of Ocean Exploration and Research and SEDCI supported exploration of five submarine canyons off North Carolina. Using an autonomous underwater vehicle (AUV), the research team conducted 10 dives between 700 and 2,000 meters (2,300-6,500 feet), high-resolution mapping, oceanographic data collection, and sample recoveries to better characterize canyon habitats. Preliminary analyses have revealed deep-sea corals in each canyon surveyed, although diversity and abundance vary widely.
- **Gulf of Mexico Northwestern Banks**—With support from the Deep Sea Coral Research and Technology Program, Flower Garden



AUV Sentry deployment. Image: NOAA Office of Ocean Science and Technology.



Map showing areas surveyed using deep-sea ROVs and AUVs during SEDCI expeditions in 2016-2017.

Banks National Marine Sanctuary undertook four surveys of mesophotic and deep-sea banks in the northwestern Gulf of Mexico in 2016-2017.

- **WestFlorida Slope** —The West Florida Slope has been relatively poorly explored, but surveys have shown some of the most extensive and pristine deep-sea coral habitats of the Gulf. In 2017, 13 ROV surveys focused primarily on four sites under consideration by the Gulf of Mexico Fishery Management Council as new coral habitat areas of particular concern (HAPCs), and discovered large aggregations of deep-sea corals within each site. Additionally, 53 biological samples were collected for studies on deep-sea coral population connectivity, taxonomy, growth rate, and reproduction. Images and videos were shared with the public, and collected data were used by the Council to further inform proposed protections.

In 2017, NOAA Ship *Okeanos Explorer* returned to the Atlantic to target exploration of proposed management areas in the Gulf of Mexico and along the U.S. East Coast. Program participation and co-funding of these expeditions supported SEDCI leaders, National Centers for Coastal Ocean Science and Office of National Marine Sanctuaries. The Bureau of Ocean Energy Management, U.S. Geological Survey, and researchers and graduate students from Texas, Mississippi, Florida, North Carolina, and South Carolina all contributed to SEDCI missions as well. Given the vast expanses of unexplored seafloor, collaboration will continue to be essential for advancing our understanding of

"The United States is a world leader in research and conservation of diverse deep-sea coral ecosystems, which are remarkably fragile and critically important to a number of commercially and recreationally harvested species." — Pat Montanio, Director of the Office of Habitat Conservation in NOAA Fisheries

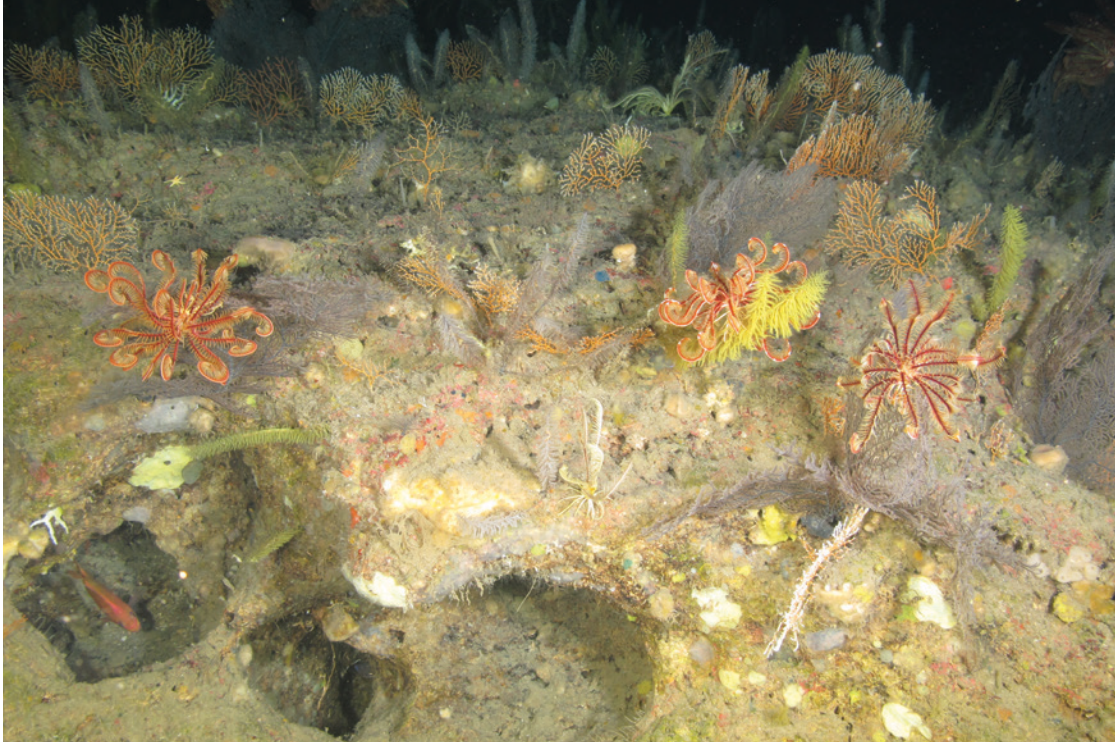
the deep sea. SEDCI sponsored expeditions in 2018 and 2019 will again focus on the South Atlantic Bight and Gulf of Mexico, as well as expand to U.S. Caribbean waters to improve our understanding of unknown and potentially vulnerable habitats.

In addition to major expeditions, SEDCI is supporting smaller, targeted activities including species identification guides, environmental monitoring, habitat suitability modeling, and fisheries studies. For example, the Program is working collaboratively with Puerto Rican fishermen to deploy low-cost underwater video cameras with fishing gear to identify deep-sea coral and sponge habitat associated with deep-sea snapper fisheries. The project has been well received, affording fishermen the first views of bottom-habitats where they fish. It will also help focus more detailed research in the future, especially by collecting information on fishing intensity and potential bycatch of corals and sponges in deep-water fisheries.

SEDCI has also sponsored creation of a regional geodatabase describing information from previous deep-sea explorations, including submersible/ROV dives, mapping surveys, collected specimens, observations of deep-sea corals and sponges, habitat suitability model outputs, and boundaries of existing and proposed marine protected areas. This geodatabase is being used to synthesize past research in the region, and assess areas remaining to be sampled, surveyed, and mapped to meet current initiative objectives. Given how effective the geodatabase has become, the Program will likely prioritize similar projects as part of other regional initiatives.

Among the most cutting-edge activities sponsored by SEDCI is development of new habitat suitability models that can predict the probability of occurrence for deep-sea corals. These models combine known coral occurrence with data on temperature, depth, substrate, and bathymetry to characterize the habitat of different types of corals. The models are tested and verified by surveys, some relying on scientists viewing remotely from shore through telepresence (see Modeling section of this report).

A rare sighting of orange Lophelia pertusa *located at 500 meters (1,640 feet) depth at Many Mounds on the West Florida slope. The vast majority of* L. pertusa *in North American waters are stark white, like the colony to the right in the picture. Image: NOAA, Pelagic Research Services.*



Diverse and dense mesophotic community at Elvers Bank in the Northwest Gulf of Mexico. Image: University of North Carolina Wilmington – Undersea Vehicles Program, Flower Garden Banks National Marine Sanctuary.

Flower Garden Banks National Marine Sanctuary

2016-2017 Highlights:

- Threeexpeditions with ROV *Mohawk* at depths between 50 and 200 meters (165-650 feet).
- 12 banks surveyed, 10 under consideration for expansion of sanctuary boundaries.
- 120biological specimens collected during 77 ROV dives.
- >75hours of video collected.
- >10,000 images captured.

Since 2016, Flower Garden Banks National Marine Sanctuary, with funding from the Deep Sea Coral Research and Technology Program, has conducted three missions to survey areas within proposed sanctuary boundary expansion areas. Seafloor surveys were conducted to better understand species diversity and abundance in the area, and to support taxonomic and phylogenetic studies. Expeditions have also documented marine debris, discovered previously unknown fragile glass sponge communities, identified locations of rare or native species, and sampled several black corals that are potentially new to science. Many banks host dense communities of corals and other invertebrates, highlighting the importance of these surveys to support informed management decisions. These discoveries have been especially valuable for sanctuary boundary expansion discussions on how to best protect these unique and valuable resources.

ROV pilots from University of North Carolina at Wilmington Undersea Vehicle Program prepare the Mohawk*, owned by the National Marine Sanctuary Foundation, for missions aboard NOAA's R/V* Manta*. Image: Mercer Brugler, City University New York.*

West Coast Prepares for Upcoming Deep-Sea Coral Initiative

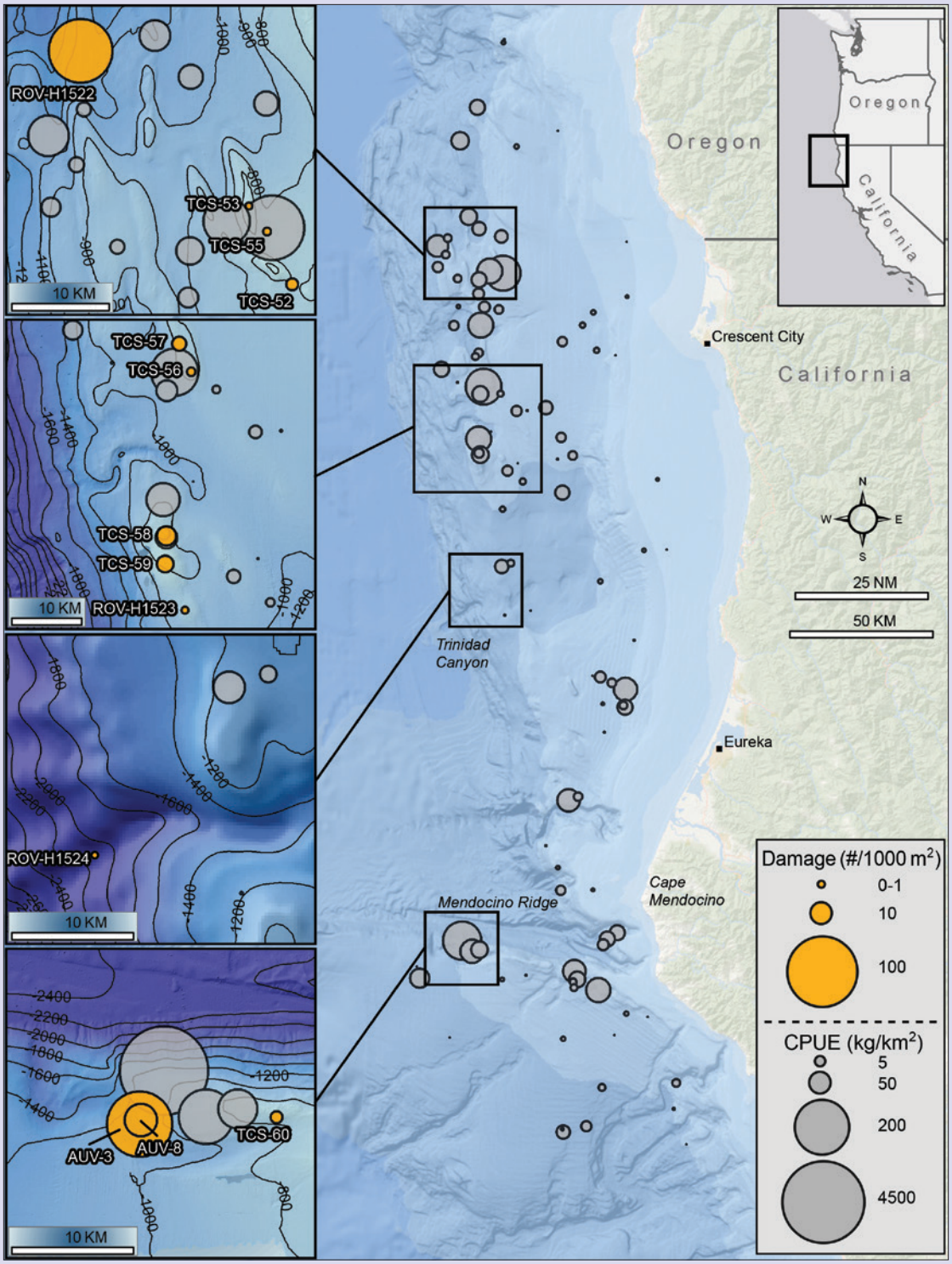
The Program's first West Coast Research Initiative (2010-2012) engaged new partners and excitement regarding the region's deep-sea living habitats. In 2018, the Program returns to coordinate and expand ongoing research:

- Coral and sponge distribution, abundance, density, and diversity throughout the region.
- Associations between managed fish species and corals/sponges.
- Coral and sponge damage in areas of high fishery bycatch.
- Descriptionof new species.
- Innovation of genetic identification techniques for corals.
- Habitatsuitability modeling.
- Analysis of pre-existing data.

Surveys of ecological damage in areas with the highest measured levels of coral bycatch in groundfish fisheries counted, measured, and assigned condition status (healthy, unhealthy, or dead). While most animals surveyed were undisturbed, damaged communities were documented, and corals generally experienced a higher rate of damage than sponges. Bamboo corals, in particular, suffered the highest rate, with up to 45 percent of colonies damaged in some places that remain unprotected after 65 years of bottom-contact fishing gear history.

The Program has also conducted groundbreaking research using environmental DNA (eDNA). This technique addresses the high cost of deep-sea research, sparse locations of coral communities, and challenge of precise taxonomic identification with only photographs and video. With the progression of eDNA technology, water sampling can add confidence to visual identifications and eliminate the need to collect coral specimens. Building an eDNA library could eventually save considerable time and resources by relying on

Dr. Meredith Everett, holding a specimen of coral, Swiftia spauldingi. *Coral genetic analysis has allowed discrimination of coral populations, as well as the first successful field detection of deep-sea corals using eDNA (Everett and Park 2017). Image: Seattle Aquarium.*

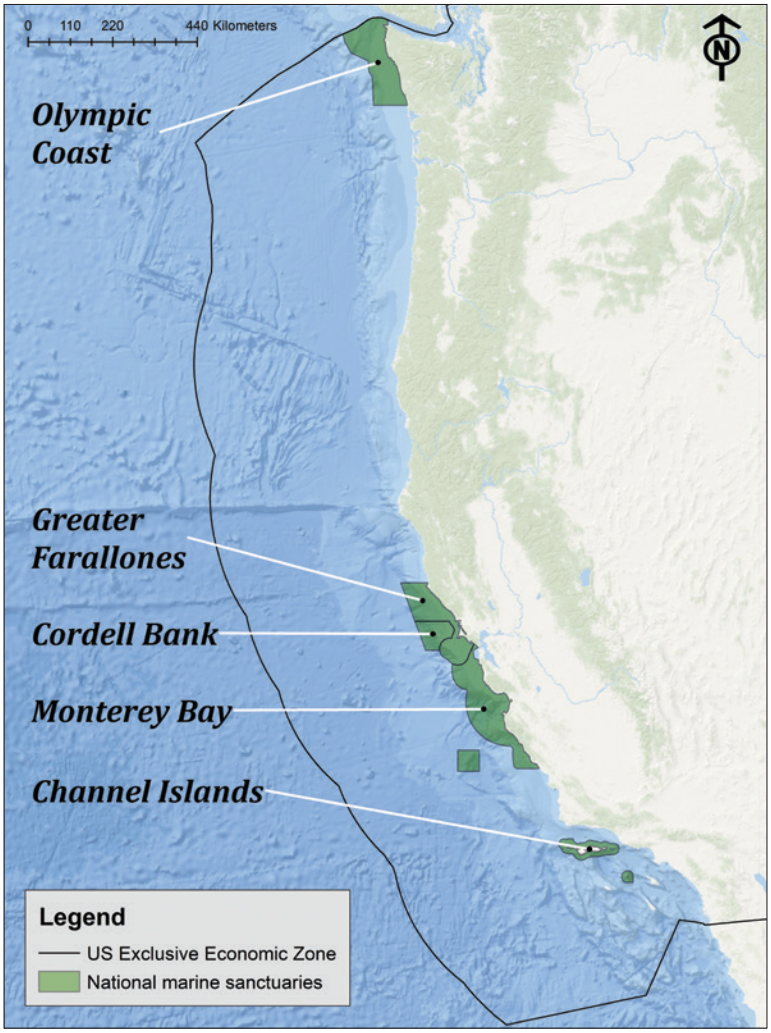


Study sites off southern Oregon and northern California surveyed for fishing damage between 600 and 2,100 meters (2,000-6,900 feet) depth by Yoklavich et al. (2017). The size of orange circles (located at centroid of each dive) is proportional to average density of disturbed or damaged deep-sea corals and sponges observed during transects on dives conducted with a towed camera system, autonomous underwater vehicle, and remotely operated vehicle. The size of gray circles is proportional to catch per unit effort (CPUE) of corals as bycatch in NOAA Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey (2001–2015).

water samples alone to characterize deep-sea coral communities.

The Program has communicated research results to the Pacific Fishery Management Council to inform the process of designating essential fish habitat (EFH). Minimizing damage to deep-sea coral and sponge habitats from West Coast groundfish fisheries has been an important consideration in revising EFH. In preparation for 2018 final action on EFH review, the Council used Program-funded research to propose major revisions to groundfish conservation measures. If approved, these measures would protect important habitat while reopening less vulnerable habitats to increase fishing opportunities.

The next initiative focused on supporting collaborative deep-sea coral and sponge research off the coast of California, Oregon, and Washington is beginning with a planning year in 2018. Funding will then be increased in 2019 and 2020 to support habitat mapping, coral and sponge location identification, and targeted research. In 2021, researchers will complete analyses of data collected during the initiative.



Map of the five West Coast national marine sanctuaries, all of which contain deep-sea coral and sponge resources.

Deep-Sea Coral Research in West Coast National Marine Sanctuaries

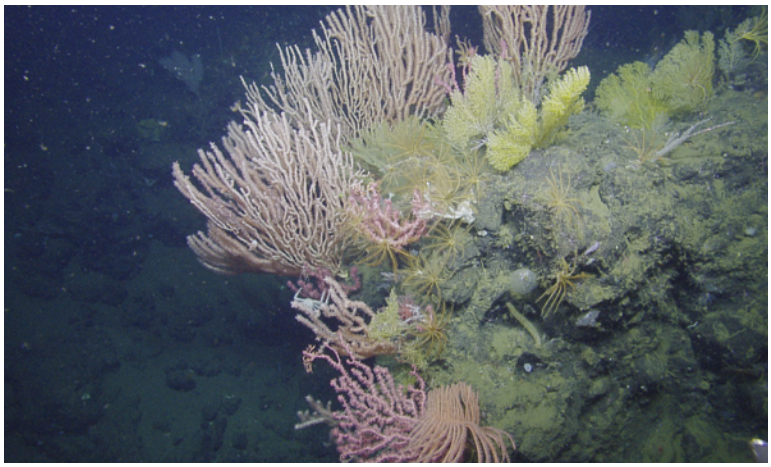
NOAA's Office of National Marine Sanctuaries protects some of the most important and iconic underwater cultural and natural resources in the United States. While past research has focused on nearshore habitats, a number of sanctuaries are increasingly investing in mapping and monitoring their deep-sea ecosystems, and have documented deep-sea coral and sponge habitats as part of ongoing research programs. The Deep Sea Coral Research and Technology Program is collaborating with the five West Coast sanctuaries to better understand their resources, and when applicable, to inform sanctuary expansion processes.

Channel Islands

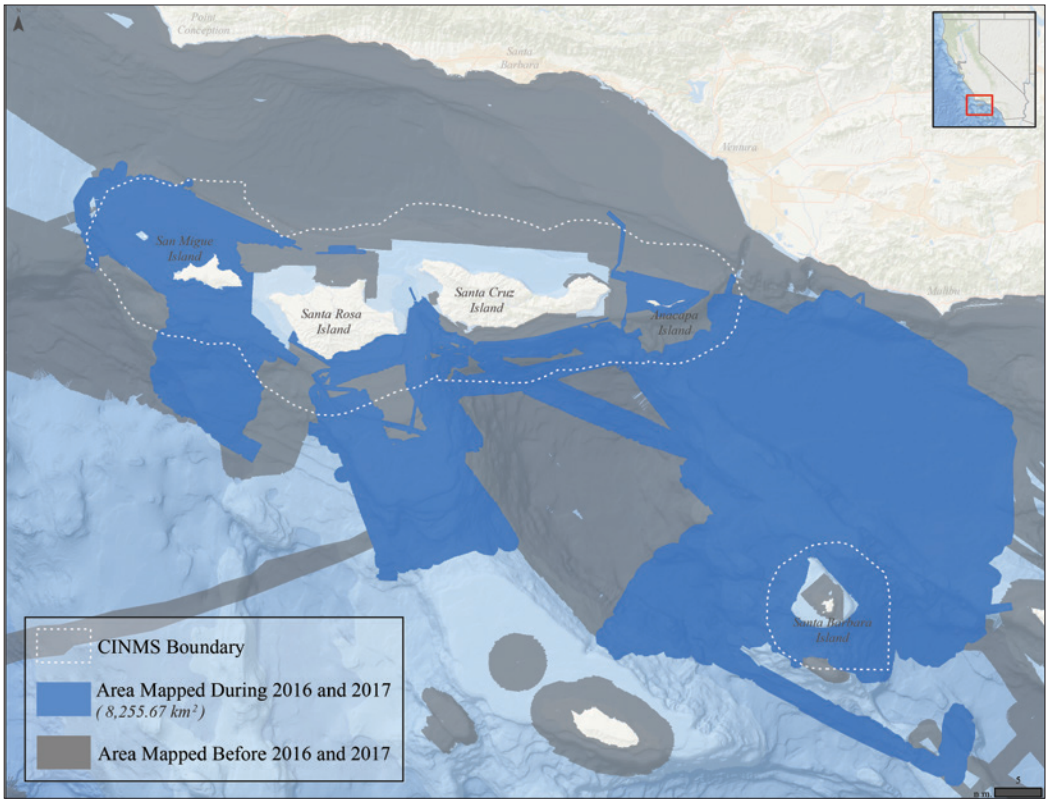
2016-2017 Highlights:

- Eleven mapping missions covered 8,255 km^2 (3,190 mi^2) of seafloor.
- Morethan 100 ROV dives were conducted within and around the sanctuary.
- More than 60 hours of video captured deep-sea coral and sponge distributions.

Prior to this reporting period, less than 15 percent of the seafloor in federal waters off Southern California had been mapped, which presented challenges to decision-makers and potential hazards to navigation. The Channel Islands National Marine Sanctuary and National Centers for Coastal Ocean Science compiled all available seafloor data from state and federal agencies, academic institutions, and non-governmental organizations to identify gaps and prioritize areas for future research. Throughout 2016-2017, with partial support from the Deep Sea Coral Research and Technology Program, sanctuary percent area mapped rose from less than 50 percent to nearly 80 percent. Among other benefits, mapping the seafloor in high resolution contributes integral information to deep-sea coral habitat prediction. Informed by significant mapping progress, remotely operated vehicle (ROV) surveys have produced new coral, sponge, and eDNA records. Acquired in partnership with the Ocean Exploration Trust, video surveys have captured evidence of invertebrate and fish associations, coral colonies damaged by fishing gear, and a new species awaiting taxonomic description. These results update nautical charts and inform management decisions regarding fish habitat, fishery productivity, ecological conservation, renewable energy opportunities, etc. Mapping and survey data also improve predictions of coral and sponge presence and densities. Combined with other data, such as vessel monitoring, predictive habitat suitability models will help managers identify likely deep-sea coral and sponge locations, and assess the overlap of human activities within sanctuary boundaries.



An image taken by the ROV Hercules *off Ocean Exploration Trust's E/V* Nautilus *showing multiple coral colonies near Arguello Canyon, just north of the Channel Islands National Marine Sanctuary. Image: Ocean Exploration Trust, NOAA.*



Northern Channel Islands region highlighting (in blue) the area of seafloor mapped in 2016-2017. Image: NOAA.

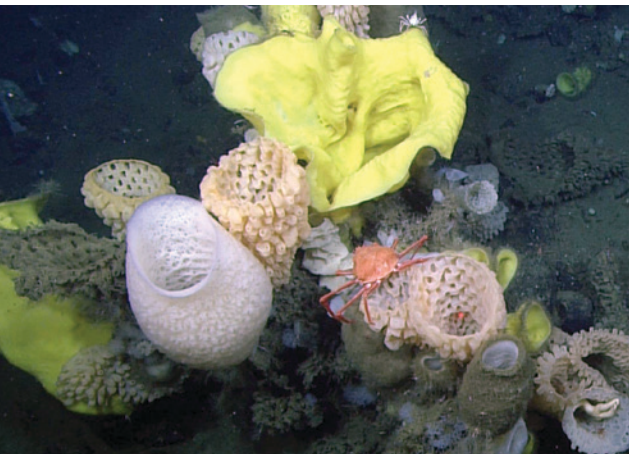
Monterey Bay

2016-2017 Highlights:

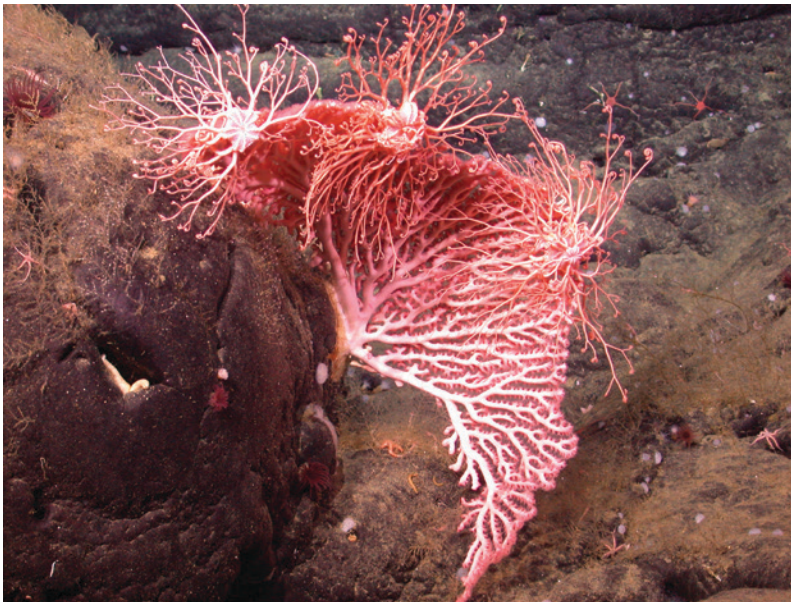
- ROV surveys within the sanctuary documented more than 260 species of deep-sea organisms on and above the seafloor (including 19 species of sponges, 21 species of corals, and a number of anemone, jelly, octopus, crab, shrimp, sea star, and fish species).
- Anew field guide has been produced to aid taxonomic identification of deep-sea species.

Deep-sea coral research in Monterey Bay National Marine Sanctuary is undertaken by sanctuary partners, most notably the Monterey Bay Aquarium Research Institute. ROV surveys have documented a rich diversity of marine life inhabiting the sanctuary seafloor and created a baseline taxonomic characterization, essential for understanding community composition and monitoring changes. In one particularly rich focal area, Sur Ridge, researchers created a detailed benthic and midwater field guide documenting picturesque habitat full of yellow Picasso sponges and pink bubblegum corals rising more than 6 feet tall off the seafloor (Burton et al. 2017). Sur Ridge has yielded valuable information that can improve our understanding of local deep-sea coral distribution, age, growth, productivity, and predation impacts. These structure-forming species provide islands of protection, nurseries, and feeding grounds for a variety of sea life such as crabs and fishes.

In 2018, deep-sea exploration will take center stage in an expedition on Ocean Exploration Trust's E/V *Nautilus* to map and explore seafloor habitats of Monterey Bay National Marine Sanctuary in depths of up to 4,000 meters (13,000 feet). The Deep Sea Coral Research and Technology Program did not fund these sanctuary efforts in 2016-2017, but will incorporate new deep-sea coral and sponge data records into its database. These efforts have well-positioned the Program to support work in this diverse and productive area during its 2018-2021 West Coast Deep-Sea Coral Research Initiative.



A crab and several different types of sponges inhabit a rock on Sur Ridge. Image: Monterey Bay Aquarium Research Institute.



*Basket stars and precious coral (*Corallium *sp.) like these were observed at Sur Ridge off central California, in Monterey Bay National Marine Sanctuary. Image: NOAA, Monterey Bay Aquarium Research Institute.*

Close view of the eight tentacles on each polyp of a bamboo coral, from Pioneer Canyon (in the northern portion of Monterey Bay administered by the Greater Farallones National Marine Sanctuary). Image: Ocean Exploration Trust, NOAA.

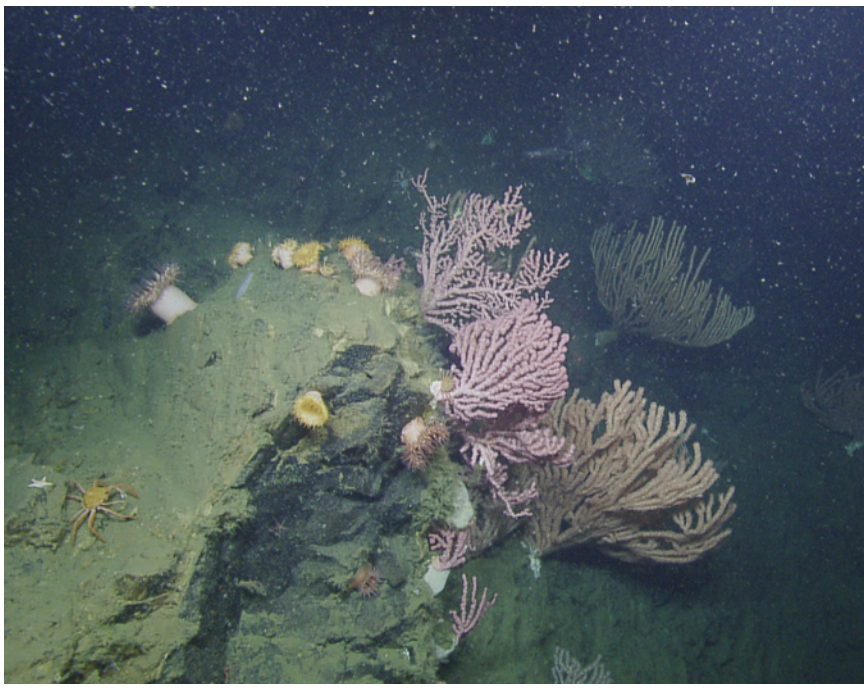
Greater Farallones

2016-2017 Highlights:

- 2,457 km^2 (950 mi^2) of sanctuary seafloor mapped in high resolution.
- Four ROV surveys in unexplored deepwater targeted habitat characterization and five surveys explored shipwrecks.
- At least two new species of sponges discovered in sanctuary waters.

NOAA recently expanded the boundary of Greater Farallones National Marine Sanctuary from approximately 1,280 mi^2 to 3,295 mi^2 to include new areas surveyed by the Deep Sea Coral Research and Technology Program. In 2016-2017, mapping by the E/V *Nautilus*—in collaboration with the NOAA Office of Ocean Exploration and Research, Office of National Marine Sanctuaries, and the Ocean Exploration Trust—more than doubled the amount of sanctuary seafloor mapped in high definition. These maps will be used to plan research over the next several years and to better define management zones for protection and sustainable commercial fishing.

In 2016, ROV dives illuminated extensive deep-sea coral communities featuring a variety of bamboo, bubblegum, black, and mushroom corals. A number of these animals were sampled for museum collections and taxonomic identification, including using innovative eDNA identification techniques. Surveys of the deeper portions of the Farallon Escarpment revealed long-lived black corals (aging analysis still in progress). Taxonomists are working to classify the specimens and quantify associated video data to expand our understanding of where corals are located. Two species of sponges that are new to science were also collected from the deep shipwreck, USS Independence, and a third collected sponge species was renamed with an expanded known range.



An aggregation of bamboo and bubblegum corals on a rocky outcrop on the northern wall of Arena Canyon in Greater Farallones National Marine Sanctuary. Image: Ocean Exploration Trust, NOAA.

Cordell Bank

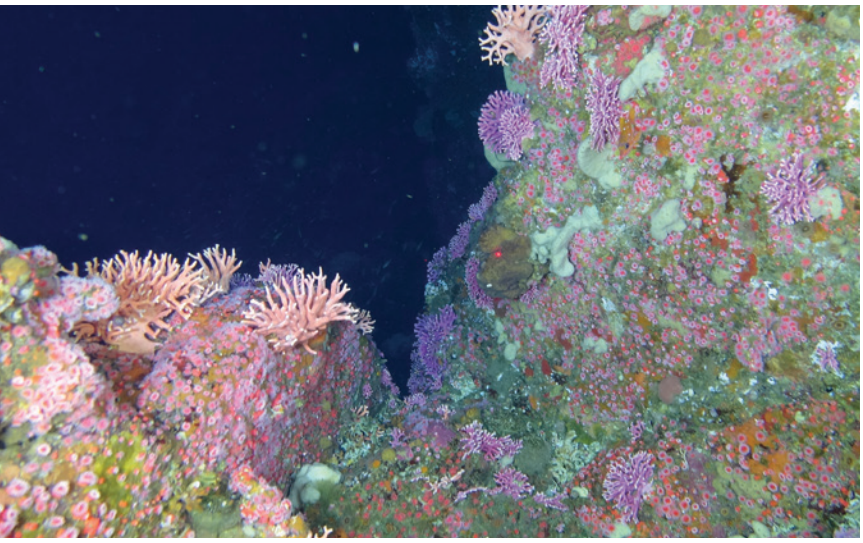
2016-2017 Highlights:

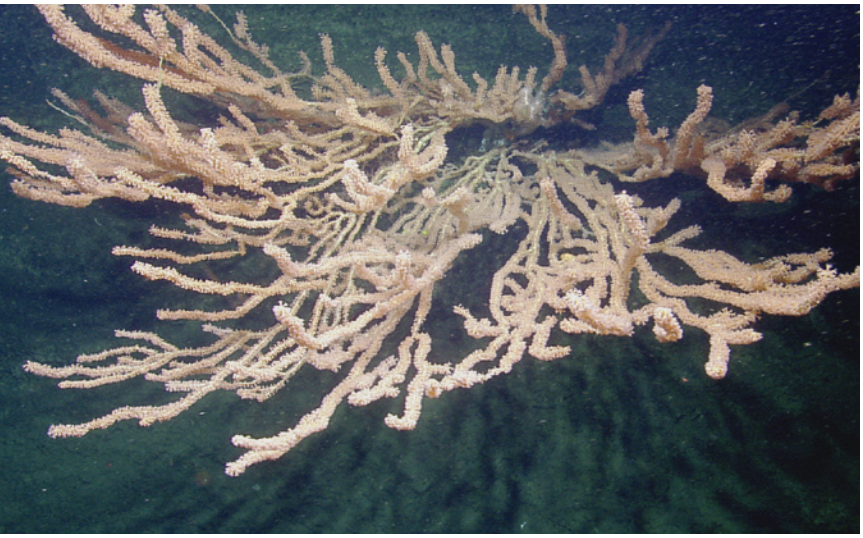
- Six exploratory ROV dives ranged from 740 to 2,700 meters (2,400-8,800 feet) depth.
- Fourteen seafloor monitoring surveys during six ROV dives ranged from 70 to 120 meters (230-400 feet).
- Atleast 16 new types of corals were recorded in sanctuary waters.

The boundaries of Cordell Bank National Marine Sanctuary were also recently expanded from approximately 529 mi^2 to 1,286 mi^2 to include new deep-sea areas. Corals, sponges, and other invertebrates that had never been recorded in Cordell Bank were found during a 2017 ROV expedition to the deepest depths of the sanctuary yet surveyed. Scientists on board the Ocean Exploration Trust's E/V *Nautilus* collected the first records of black corals and bamboo corals in the sanctuary, as well as new species of sponges, sea cucumbers, anemones, and fish, and supplemental information on habitat and environmental conditions. This information significantly expands our knowledge of deep habitats in the sanctuary, and opens new topics for future research and outreach. Scientists from multiple sanctuaries, the California Academy of Sciences, University of California Davis, and NOAA Fisheries collaborated on the expedition.

Sanctuary staff and collaborators also surveyed the sanctuary seafloor in 2017 to implement long-term monitoring supported by the Office of National Marine Sanctuaries and the Cordell Marine Sanctuary Foundation. Observations along 14 transects documented the habitats on and around the bank from soft sediment to high relief rock, which support diverse and abundant invertebrate communities. The surveys were part of the sanctuary's plan to characterize the sanctuary and monitor for changes over time.

Typical Cordell Bank reef top habitat is completely covered with colorful invertebrates like lace corals and strawberry anemones. Image: Cordell Bank National Marine Sanctuary, NOAA.





China rockfish inside a sponge and pink lace corals on Cordell Bank. Image: Cordell Bank National Marine Sanctuary, NOAA.

Large bamboo coral observed growing horizontally off the steep walls of Bodega Canyon during surveys on E/V Nautilus. *Image: Ocean Exploration Trust, NOAA.*

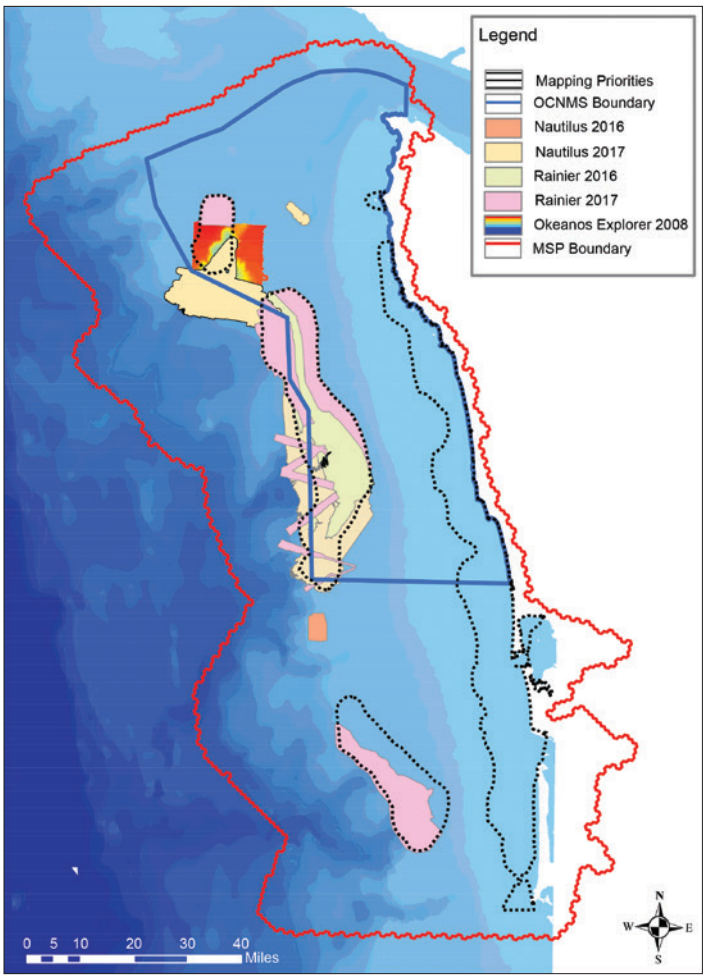
Olympic Coast

2016-2017 Highlights:

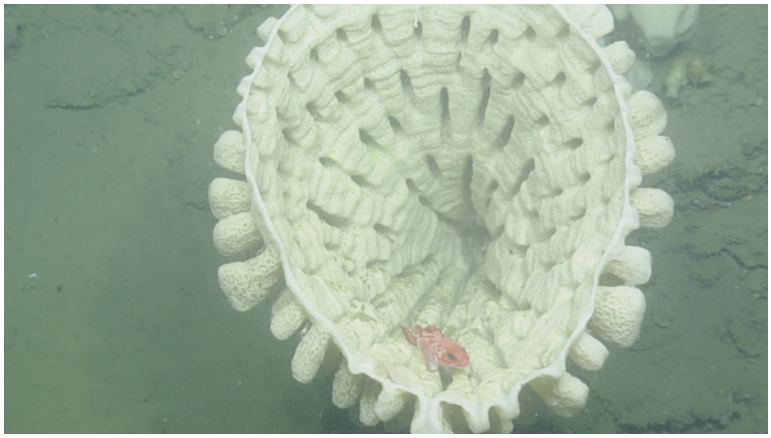
- 2,531 km^2 (977 mi^2) of sanctuary seafloor was mapped in high resolution.
- Sixteen ROV dives and 14 AUV dives provided approximately 200 hours of video footage and tens of thousands of still images.

Olympic Coast National Marine Sanctuary has made considerable progress toward mapping offshore areas of the seafloor classified as "high priority" by a multi-agency spatial prioritization workshop sponsored by the State of Washington in 2015. Ocean Exploration Trust's vessel, E/V *Nautilus*, mapped 1,300 km^2 (500 mi^2) of canyon and shelf break habitats within and adjacent to the sanctuary in 2016-2017. NOAA Ship *Rainier* then mapped another 1,200 km^2 (460 mi^2) of seafloor in 2017 to significantly advance high-resolution habitat maps for Washington's coast, including critical offshore habitats within and adjacent to sanctuary boundaries.

The E/V *Nautilus* expedition also yielded a dazzling array of new deep-sea habitat information, including coral and sponge range extensions, specimens collected for identification, and discovery of undescribed species that may be new to science. ROV surveys explored hard-bottom sites with high vertical relief and complexity, primarily within submarine canyons that may provide persistent stable habitat for long-lived species. These hard bottom habitats comprise only about 3 percent of the sanctuary seafloor, but are believed to have a disproportionate value to deep-sea ecosystems. The NOAA Northwest Fisheries Science Center's autonomous underwater vehicle (AUV) *Popoki* surveyed low-relief habitats surrounding canyon rims to characterize seafloor dominated by soft sediments, which comprise more than 95 percent of sanctuary seafloor. Video data and images will help sanctuary staff quantify composition, abundance, and distribution of deep-sea communities while supporting future efforts of the NOAA Deep Sea Coral Research and Technology Program.



Recent seafloor mapping progress for areas of Washington's Pacific coast within and adjacent to Olympic Coast National Marine Sanctuary blue outline). Black dotted outlines indicate areas of the seafloor designated as "high priority" for mapping. Other labeled shapes indicate mapping from specific cruises. The MSP boundary is the extent of the planning area for Washington State's new Marine Spatial Plan, finalized in 2018. Image: NOAA.



The ROV Hercules *encountered several large goiter sponges, measuring more than 3 feet tall and 3 feet wide, in deep areas of Quinault Canyon inside Olympic Coast National Marine Sanctuary. This photo documents an ancient sponge with tiny shrimp and a thornyhead rockfish perched inside. Image: Ocean Exploration Trust, NOAA.*

Alaska: The role of Deep-Sea Coral and Sponge Communities as Habitat for Marine Fishes

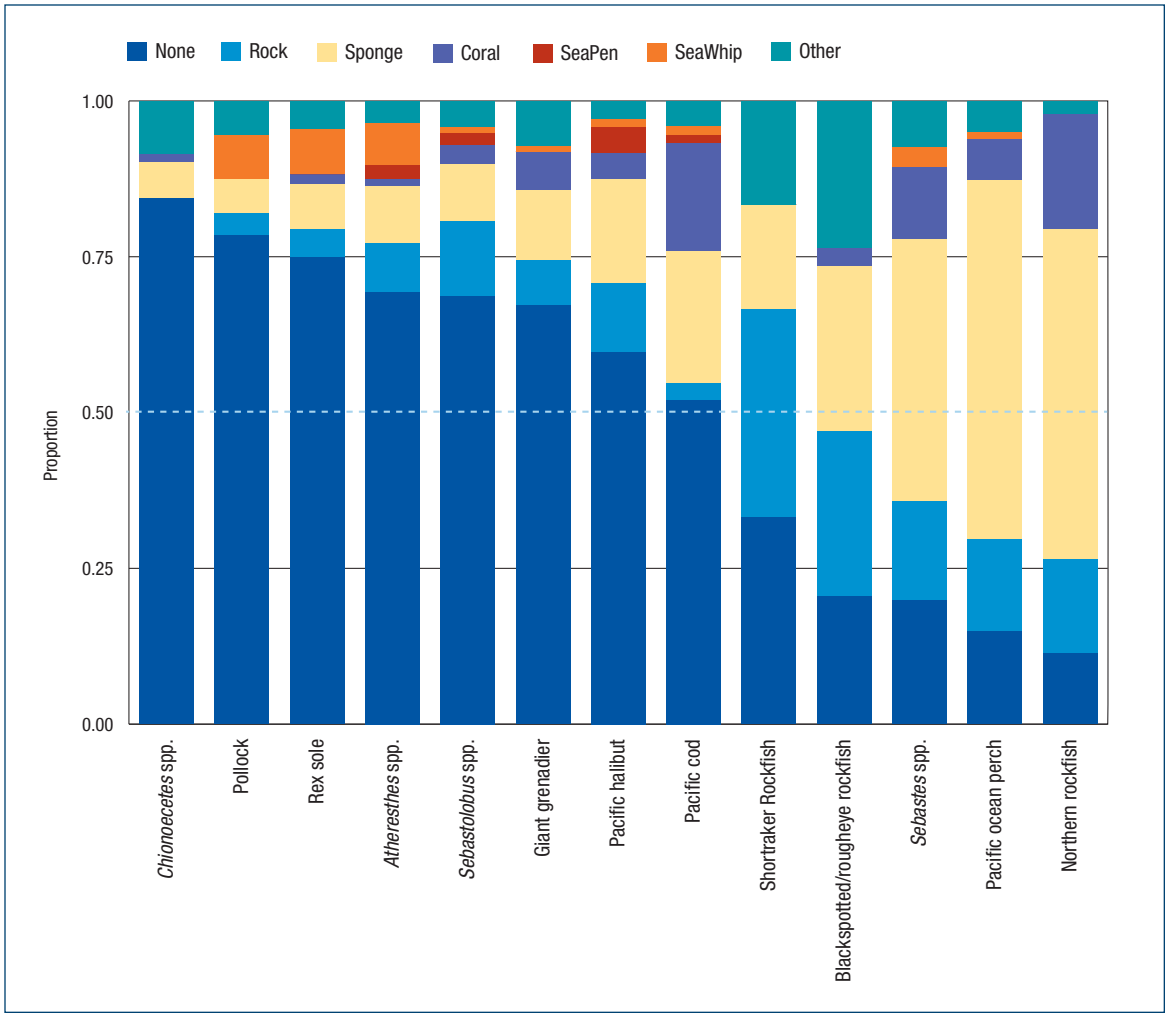
2016-2017 Highlights:

- Analysesconducted for more than 450 underwater camera transects surveyed in the eastern Bering Sea and Aleutian Islands during the past Alaska Deep-Sea Coral Fieldwork Initiative.
  - 500,000+ images examined.
  - 200,000+ fish and invertebrates identified.
  - 25,000+animal size measurements collected.
- Analysis conducted for 79 underwater acoustic-optic survey locations in the western and central Gulf of Alaska to document rockfish and deep-sea coral/sponge associations.
- Analysis conducted for 73 more locations in areas closed to fishing on the Gulf of Alaska slope.
- 120new records of deep-sea corals and sponges added to the National Database, with more to come in the next year.

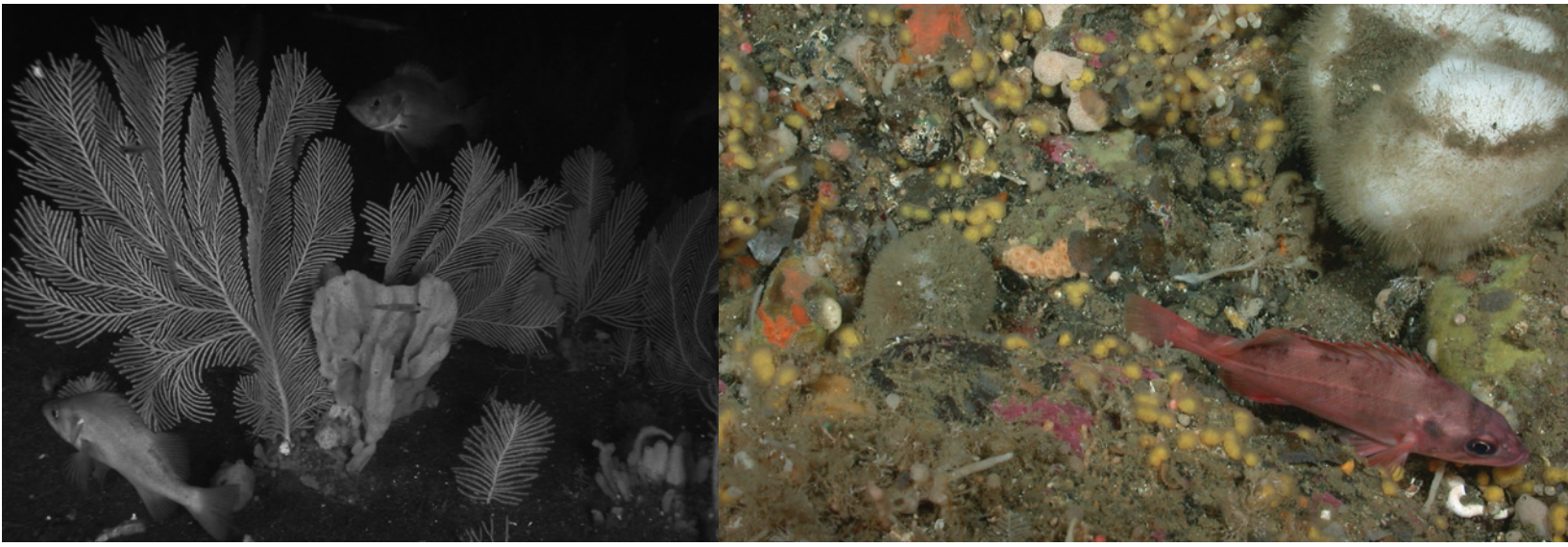
Data from camera surveys have provided the first broad-scale distribution and abundance estimates of deep-sea corals and sponges in the eastern Bering Sea canyons and slope (Goddard et al. 2016, Rooper et al. 2016), Aleutian Islands (Goddard et al. 2017), and Gulf of Alaska (Wilborn et al. 2017) ecosystems. These measurements have informed management decisions affecting commercial fisheries. For example, image analyses documented coral and sponge presence at all three closed areas surveyed on the Gulf of Alaska slope with densities comparable to other slope ecosystems in Alaska and elsewhere in the United States. Now that we have more information about their locations and densities, a key question is the role of deep-sea coral communities in supporting healthy and sustainable fisheries.

In Alaska, almost all studies on associations of fish (especially rockfishes) with corals and sponges have found significantly positive coexistence. Scientists in Alaska recently compared the association of fish and crab species with deep-sea corals and sponges, as well as other seafloor structure across different areas of the eastern Bering Sea and Aleutian Islands. This project built on the significant data and images collected during the Program's Alaska Deep-Sea Coral Fieldwork Initiative of 2012-2015. Densities of fish and crabs were positively correlated to the amount of rocky habitat and density of deep-sea corals and sponges. However, abundance of corals and sponges was much different across ecosystems, with Aleutian Islands densities roughly three orders of magnitude higher than in the eastern Bering Sea.

Researchers also examined images with commercially important fishes and crabs to determine their association strength with seafloor structure. At broad scales, rockfish species and Pacific cod were significantly correlated to structured seafloors. At the smaller scale of individual fish, Pacific cod, northern rockfish, and Pacific Ocean perch were significantly associated with structure. Fish were documented in association with both small and large seafloor structures, but the strength of association with structure was weak for large fish. Researchers also found rockfish to prefer sponges to other structures, even when all types were available. These relationships were consistent across ecosystems, indicating that even though rockfish densities and coral and sponge abundances were very different between the eastern Bering Sea and Aleutian Islands, the ecological processes guiding habitat use by rockfish were consistent.



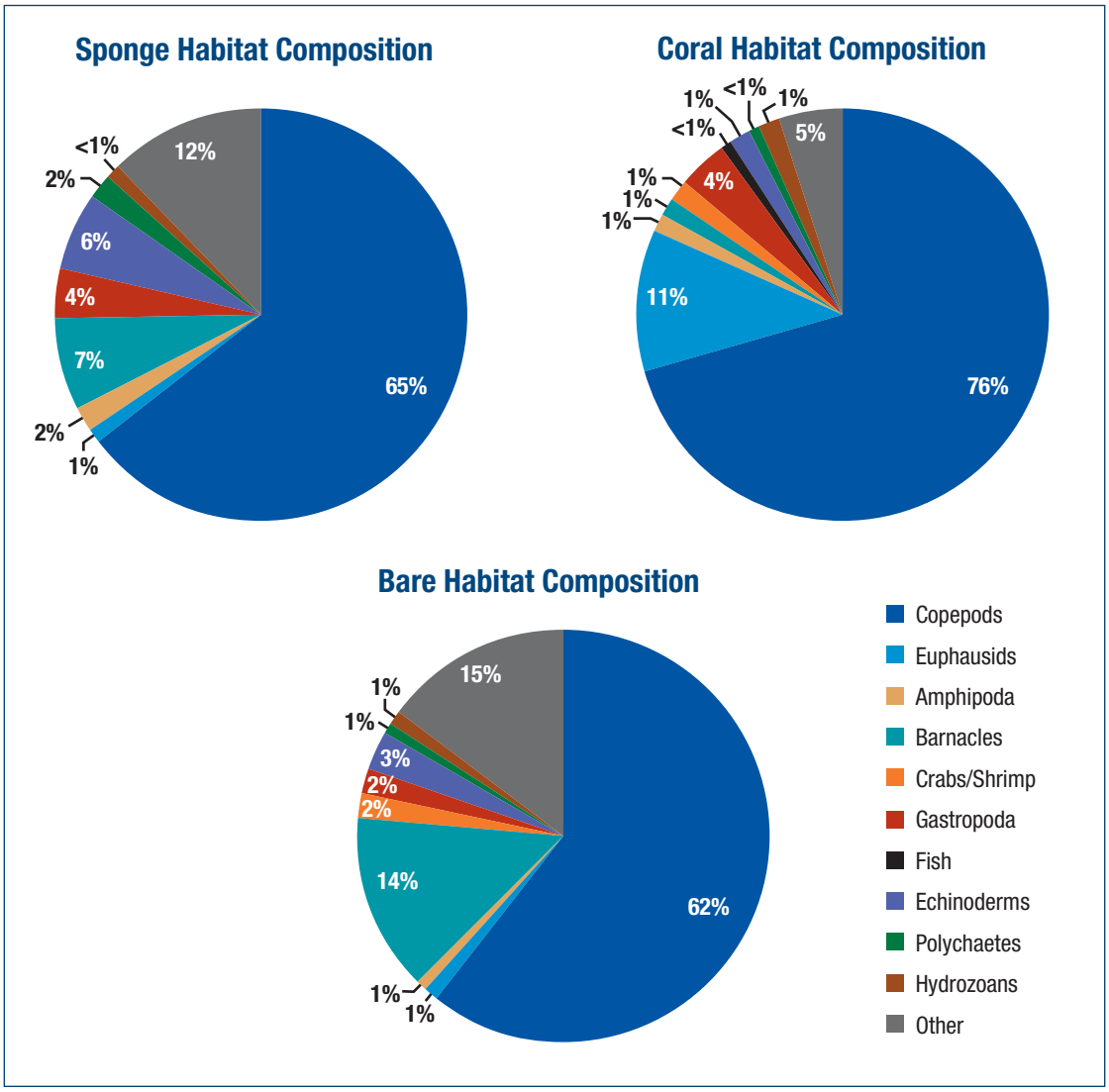
Association of fishes and different types of bottom structure across the eastern Bering Sea and Aleutian Islands.



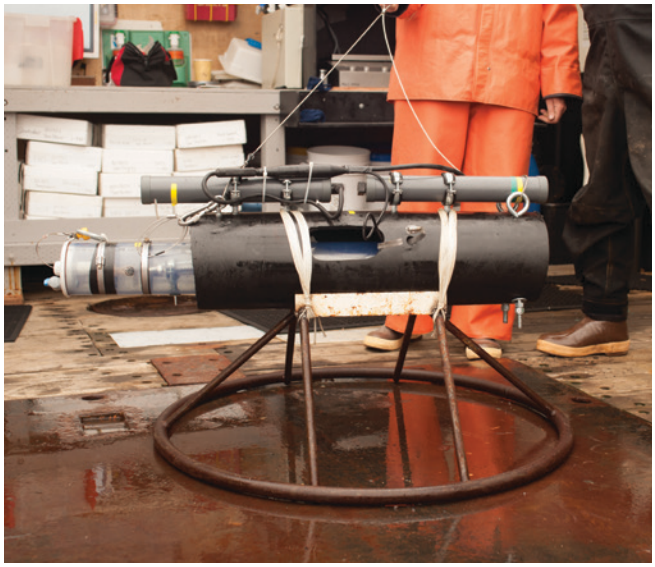
*Pacific Ocean perch (*Sebastes alutus*) in coral and sponge habitat. Images: Alaska Fisheries Science Center.*

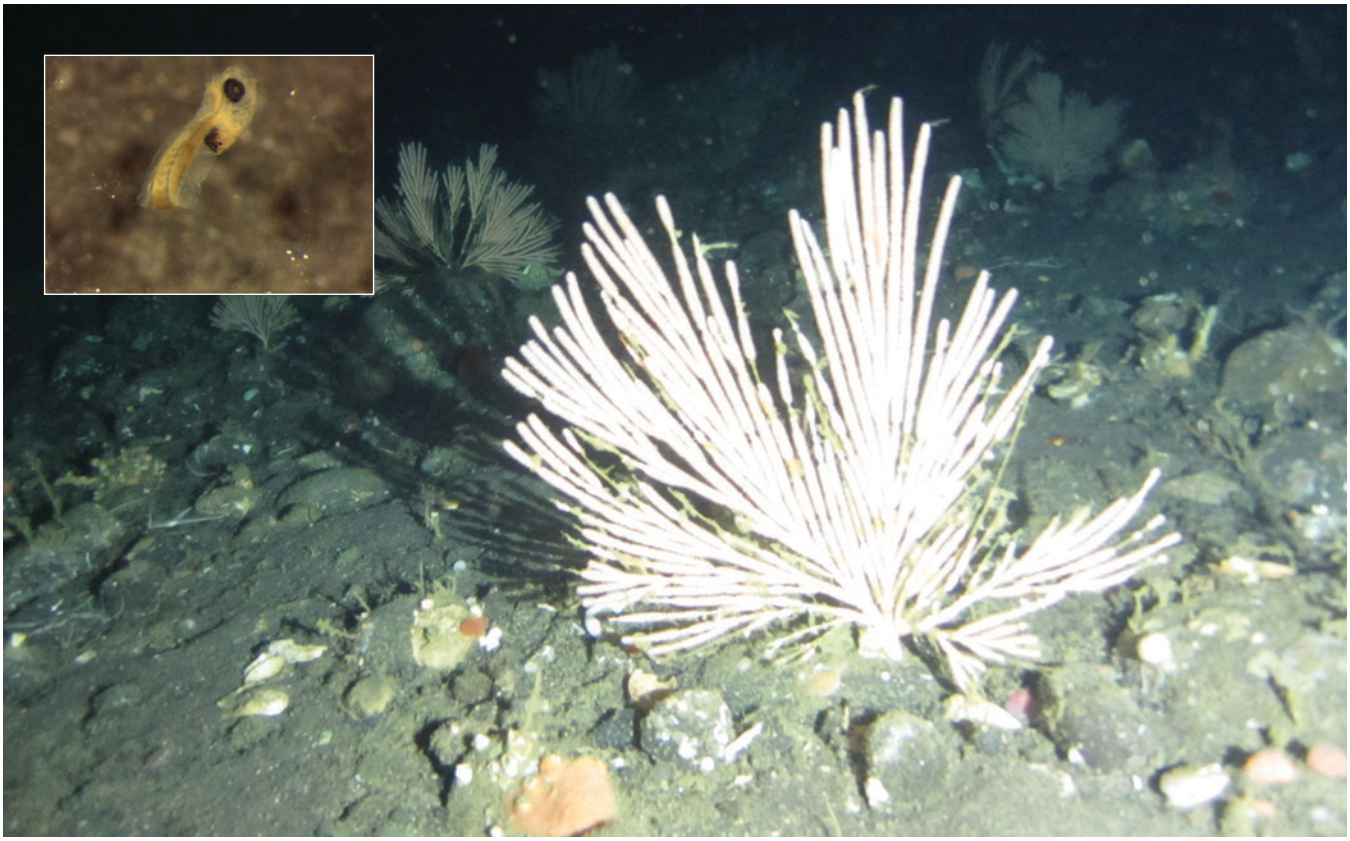
Researchers in Alaska also completed a pilot project to examine the occurrence of fish and other larvae in deep-sea coral habitat, sponge habitat, and bare seafloor habitat. A unique feature of this study was the tool used to collect plankton samples—a robotic larval fish pump relying on a propeller to draw water through the plankton net. This innovative design allowed the pump to limit larval fish collection to its time spent on the seafloor, avoiding contamination during transit, and to capture photographs of the collection site. Initial data collection using this novel device has captured larval rockfish in rocky coral habitat, an intriguing result begging further data collection.

Government-driven deep-sea coral and sponge research would simply not happen without the partnerships and collaborative efforts of the larger deep-sea research and management community.



Percent composition of larval animals identified at three different habitat types (sponge, coral, and bare rock).





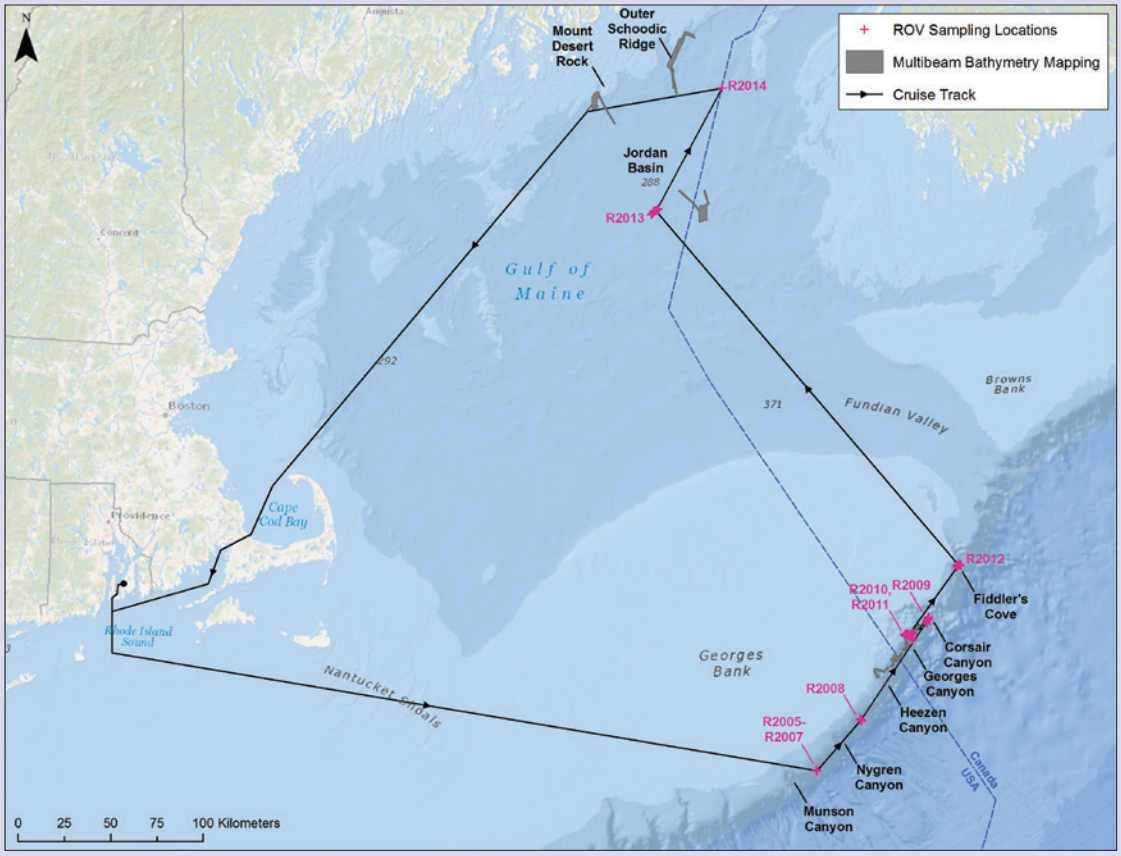
Larval fish pump and habitat where larval rockfish were collected in 2017 in the Gulf of Alaska. Images: Alaska Fisheries Science Center.

Northeast: Data to Inform Deep-Sea Coral Management

Since the close of fieldwork supported by the Deep-Sea Coral Research and Technology Program (2012-2015), research in the Northeast U.S. region continues. NOAA scientists and partners are analyzing the extensive image, video, and physical data collected during the nine Northeast Deep-Sea Coral Initiative cruises, 52 remotely operated vehicle (ROV) dives, and 151 camera tows. Samples of corals, sponges, and associates have been processed and curated. Taxonomic, genetic, and reproductive analyses are ongoing. These data continue to enhance our regional knowledge of deep-sea coral diversity, distribution, and habitat characteristics.

A strong example of collaborative research conducted to address remaining data gaps and key research priorities after 2012-2015 fieldwork is the transboundary exploration of deep-sea communities between the United States and Canada, known as *Northern Neighbors: Transboundary Exploration of Deepwater Communities*. An international team of scientists used a Canadian ROV and NOAA ship to collect mapping data, high-definition video, images, and coral samples in submarine canyons and the northern Gulf of Maine. Surveys conducted in poorly known areas led to discovery of diverse coral gardens. Likely the largest and most extensive colonies of *Lophelia pertusa* discovered to date were also recorded in the region. Physical samples were collected for taxonomic, genetic, and reproduction research. Video and photographs will be used to assess coral abundance, diversity, distribution, size, and species associations.

A variety of deep-sea corals found on a ledge in an unnamed canyon between Heezen and Nygren Canyons, including the stony coral Lophelia pertusa*, a large white gorgonian* Paragorgia *(bubblegum coral) and a small red* Paragorgia *(upper left), and the gorgonian* Primnoa *(orange, center). Image: Northern Neighbors: Transboundary Exploration of Deepwater Communities.*



Map of NOAA Ship *Henry Bigelow* cruise track from June 2017 with remotely operated vehicle sampling stations and high-resolution bathymetry mapping.

Data were shared with both the New England Fishery Management Council and Fisheries and Oceans Canada to inform conservation and management measures. The public was engaged throughout this expedition thanks to outreach initiatives by the NOAA Office of Ocean Exploration and Research (http://oceanexplorer.noaa.gov/explorations/17gulfofmaine/welcome.html) and Oceana Canada (http://www.oceana.ca/en/expeditions/gulf_of_maine/gulfofmaine/overview). To learn more about deep-sea coral research and management in the region, see the NOAA story map Exploring Deep-Sea Corals in the Gulf of Maine.

Preliminary image analyses have revealed coral and sponge abundance, diversity, and distribution in U.S. Northeast waters to be greater than previously thought, particularly in offshore canyons. Results also show that these canyons have distinct biological and geological signatures, which can genetically isolate certain species. Closer to shore, research shows that coral gardens are more widespread in Gulf of Maine waters than previously realized. Seafloor mapping, in partnership with NOAA's Office of Coast Survey, revealed hard-bottom slopes that could potentially support deep-sea coral habitats, as well as evidence of disturbance likely due to bottom-tending fishing gear.

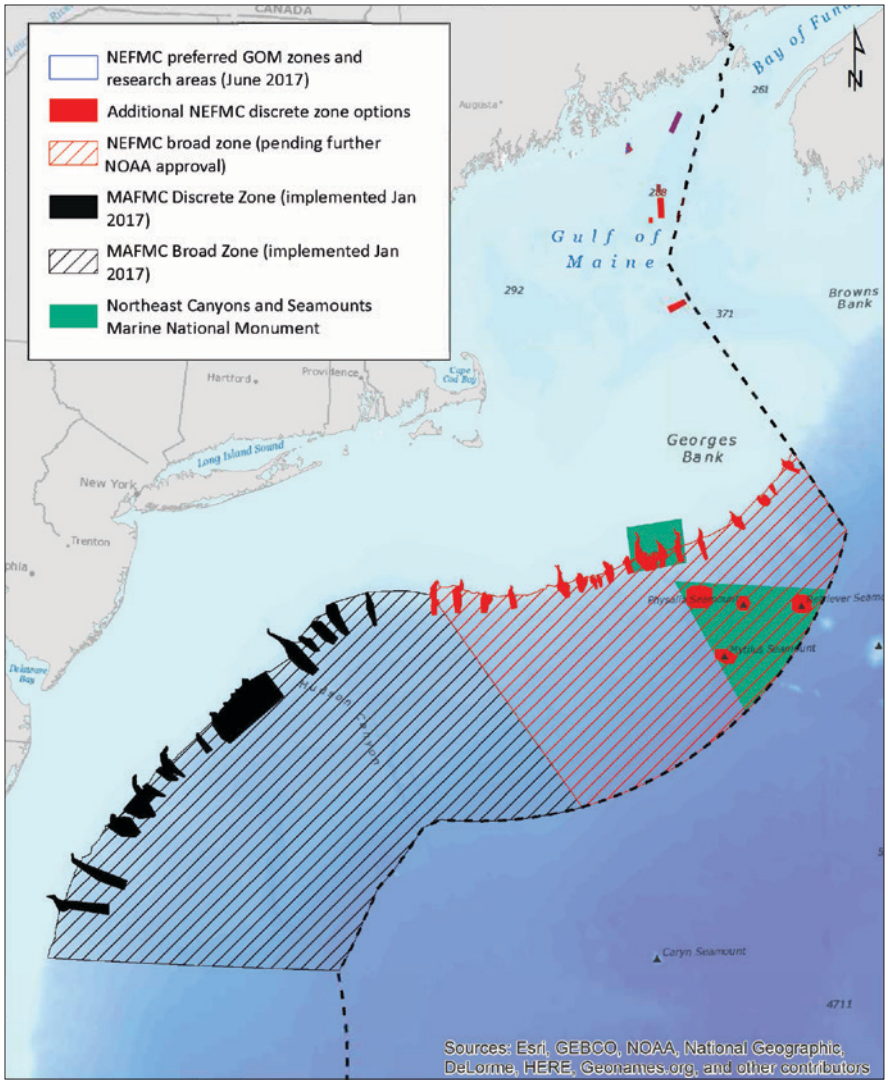
Deep-sea coral data and predictive habitat suitability models continue to inform regional fishery management council decision-making with respect to defining essential fish habitat and deep-sea coral management alternatives. The New England Fishery Management Council recently took a similar approach to that of the Mid-Atlantic Council by using Program-supported surveys, historical data, and habitat

suitability models. This information was used to generate options to designate expansive deep-sea coral protection zones in the first and second implementation of the deep-sea coral discretionary authority (MSA section 303(b)(2)(B)) nationally. In 2016, the Canadian government also protected 9,600 km^2 (3,700 mi^2) of coral and sponge habitat based on data collected during the Northeast Deep-Sea Coral Initiative. These areas were revisited and further explored by the *Northern Neighbors: Transboundary Exploration of Deepwater Communities* expedition in 2017.

Information collected throughout the Northeast Regional Deep-Sea Coral Initiative was also instrumental to the designation of the first marine national monument in the Atlantic Ocean, the Northeast Canyons and Seamounts Marine National Monument, in 2016. The monument consists of two units representing distinct geological features that support vulnerable ecological communities, including deep-sea coral and sponge habitats. The presidential proclamation specifically referenced deep-sea corals, along with "other structure-forming fauna such as sponges and anemones," as resources that "create a foundation for vibrant deep-sea ecosystems." The Department of the Interior and NOAA will jointly manage the monument.

In addition to recent research and management actions, the Northeast Fisheries Observer Program has also benefited from the expertise of NOAA deep-sea coral scientists to improve observer training materials and guidance on documenting corals obtained as commercial fishery bycatch. Since protocol updates, observers are now collecting data on structure-forming gorgonians and sea pens, among other previously unreported groups. Continuing to improve observations of commercial deep-sea coral bycatch will lead to a better understanding of their interactions with fisheries, and guide habitat conservation efforts in the Northeast.

Bubblegum coral, Acadian redfish, and sea anemones on a large boulder in Georges Canyon (Canada). Image: Northern Neighbors: Transboundary Exploration of Deepwater Communities.



Deep-sea coral protection zones for the Northeast region enacted in the Mid-Atlantic and being considered for New England. Broad zones are shaded; discrete zones on seamounts, in canyons, and in the Gulf of Maine are outlined. New England zone boundaries have not yet been approved by NOAA.

A diverse assemblage of deep-sea corals and sponges in Kinlan Canyon, located between Heezen and Nygren Canyons (United States). This canyon was named in 2018 for Dr. Brian Kinlan, a NOAA scientist who significantly advanced predictive habitat modeling. Image: Northern Neighbors: Transboundary Exploration of Deepwater Communities.

State of Deep-Sea Coral and Sponge Ecosystems of the United States Report

Cover of the 2017 State of Deep-Sea Coral and Sponge Ecosystems of the United States *report.*

NOAA's new report, *State of Deep-Sea Coral and Sponge Ecosystems of the United States* (Hourigan et al. 2017), reviews advances in deep-sea coral research over the past decade and how this new information is shaping deep-sea conservation. Each of the report's 13 peer-reviewed chapters was written by leading U.S. researchers. Six regional chapters summarize new research—much of it led by NOAA—and explain how results have led to improvements in deep-sea management as well as understanding of coral and sponge taxonomy, species distributions, fisheries habitats, and the effects of human activities. These chapters serve as a 10-year update to the first *State of Deep Coral Ecosystems of the United States* report, published in 2007, and provide the first look at U.S. deep-sea sponge ecosystems. Discoveries since the first report have also led to the description and increased understanding of 62 new species of deep-sea corals in U.S. waters, which are included in peer-reviewed species lists as an online supplement to the report.

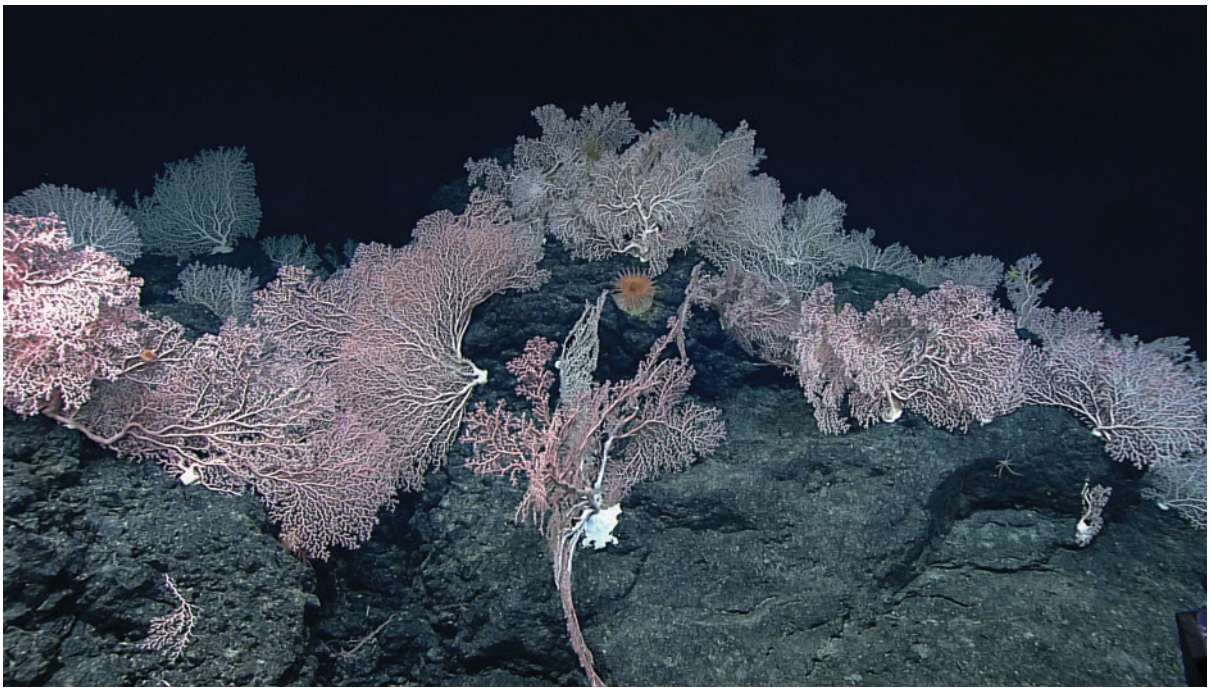
Six additional articles focus on cross-cutting topics including species discovery, interactions between fishing gear and deep-sea corals/sponges, management of black coral harvests, improvements in habitat modeling, advances in coral ageing and growth rate research, and current knowledge of coral population connectivity. Research presented in this report consolidates our understanding of how deep-sea corals and sponges contribute to resilient ecosystems and sustainable fisheries.

Highlights of the report include the following:

- Deep-sea corals and sponges create the most important biogenic habitats in deep U.S. waters.
- Sixty-two new species of deep-sea corals described since 2007.
- New diverse and dense deep-sea coral "gardens" discovered in every U.S. region, especially Alaska, where new evidence points to their role as habitat for fisheries of national and international importance.
- Expansion of national marine sanctuaries along the West Coast to include deepwater habitats that contain deep-sea corals and sponges.
- Results of a major 3-year exploration and research campaign in previously unexplored U.S. Pacific Island slopes, oceanic ridges, and seamounts.
- Deep-sea coral damage and management responses after the 2010 Deepwater Horizon oil spill in the Gulf of Mexico.
- Use of habitat suitability models to aid protection of 38,000 square miles of the Northeast deep sea, which has helped make the United States a leader in deep-sea conservation.
- Enhanced protection in the Southeast for areas containing one of the most substantial concentrations of deep-sea coral reefs in the world.
- Updated conservation status and threat analysis for U.S. deep-sea coral and sponge ecosystems, progress in conservation, and potential implications of emerging industries such as deep-sea mining.

Deep-sea corals and sponges are extremely vulnerable to human activities that damage the seafloor or alter the surrounding environment, and may take centuries to recover—if they recover at all. The report serves as a baseline for continued research to further understand and conserve these ecosystems.

Newly described species of stylasterid coral, Crypthelia kelleyi*, discovered on a CAPSTONE expedition to the Northwestern Hawaiian Islands. This and other newly described species were highlighted in the 2017* State of Deep-Sea Coral and Sponge Ecosystems of the United States *report as part of the first U.S. peer-reviewed deep-sea coral species list. Image: NOAA Office of Ocean Exploration and Research.*



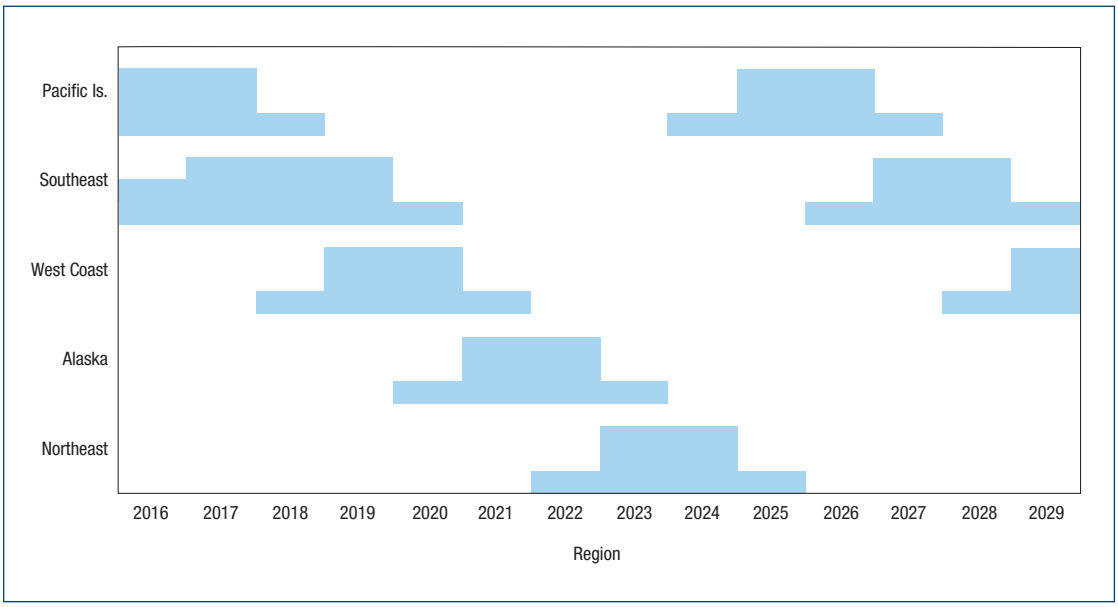
Dense pink coral garden discovered at nearly 1,800 meters (5,900 feet) on Mendellsohn Seamount in the Pacific Islands. Image: NOAA Office of Ocean Exploration and Research.

Deep Sea Coral Research and Technology Program Review

The mission of NOAA's Deep Sea Coral Research and Technology Program is to provide sound science to protect and manage vulnerable deep-sea ecosystems. These ecosystems support our nation's fisheries and provide other valuable services, and NOAA scientists aligned with the Program have worked closely with resource managers to ensure that data collected are relevant to their needs and priorities. During its first 8 years, the Program increased our understanding of deep-sea coral and sponge habitats in U.S. waters, and provided information to protect these critical resources. In order to build on these successes and improve effectiveness, the Program conducted a review in 2017 (https://spo.nmfs.noaa.gov/sites/default/files/TM-OHC-5.pdf). The review solicited feedback and evaluated accomplishments to date with the goal of better engaging partners and leadership, addressing stakeholder needs and challenges, effectively informing resource managers, promoting new ideas, and increasing operational cost efficiency. This review included presentations by principal investigators and regional fishery management councils, broad perspectives gathered from surveys and interviews, and a workshop convened to discuss approaches to address Program and partner objectives, priorities, and opportunities.

Past successes and needed improvements were major themes discussed during the review. Valuable Program contributions have included improving knowledge of deep-sea coral and sponge habitat distribution in U.S. waters, maintaining and disseminating this information in a world-class database and portal, translating research results to inform management by regional fishery management councils and other entities, and fostering partnerships and leveraging funds to enhance cost-effectiveness of these activities. Program-funded research has been instrumental in catalyzing national deep-sea conservation actions since 2010. Based on recommendations from the review, the Program has begun a plan of action to further improve its effectiveness, including the following key elements.

- **Update the operational model for field research:** The Program has begun to move from funding two concurrent regional fieldwork initiatives to funding one at a time. Each region will now receive enhanced support for research activities during 2 core years (up to $1 million each year), supplemented by smaller amounts for planning and preparation during the preceding year, and for analyses and project wrap-up during the following year. This model with non-overlapping and enhanced core regional support provides more flexibility for regions not currently in a focused initiative year to maintain data analysis teams and to capitalize on opportunities and partnerships with remaining Program funds.
- **Partnerships are key:** Strengthening existing partnerships and building new collaborations within NOAA and with other federal agencies, academia, foundations, and industry was highlighted as central to successful deep-sea research and exploration.
- **Continuing and new research:** Emphasis was especially placed on surveys and habitat characterization, mapping, genetics, better understanding coral and sponges as habitat for managed fisheries species, recovery from damage, predictive habitat suitability modeling, and data mining and annotation to support complementary partner efforts.
- **Database and reporting:** The Program was advised to continue improvements to quality



The revised regional field research initiative funding schedule will provide 1 year of planning ramp-up funds, 2 years of full initiative funding, and 1 year of ramp-down funds for data analysis. This approach will result in a 5-year cycle before the Program returns to a particular region for a new initiative. Implementation of this model is beginning in FY 2018 with Pacific Islands ramp-down and West Coast ramp-up.

control of National Database records, simplify researcher reporting requirements, and create data submission templates to improve the process of making Program-supported and partner-collected data publicly available.

- **Communication:** More effectively telling the story of deep-sea coral and sponge research in support of management actions by councils and sanctuaries was highlighted as a valuable area for Program growth. Deep-sea corals are among the slowest growing and oldest animals in the ocean, with some species living more than 4,000 years. Along with deep-sea sponges, they may represent sources for new medicines, and support ecosystems of incredible variety, diversity, and often commercial value. The habitats they create are also captivatingly beautiful, and the Program would benefit from enhancing communication efforts.

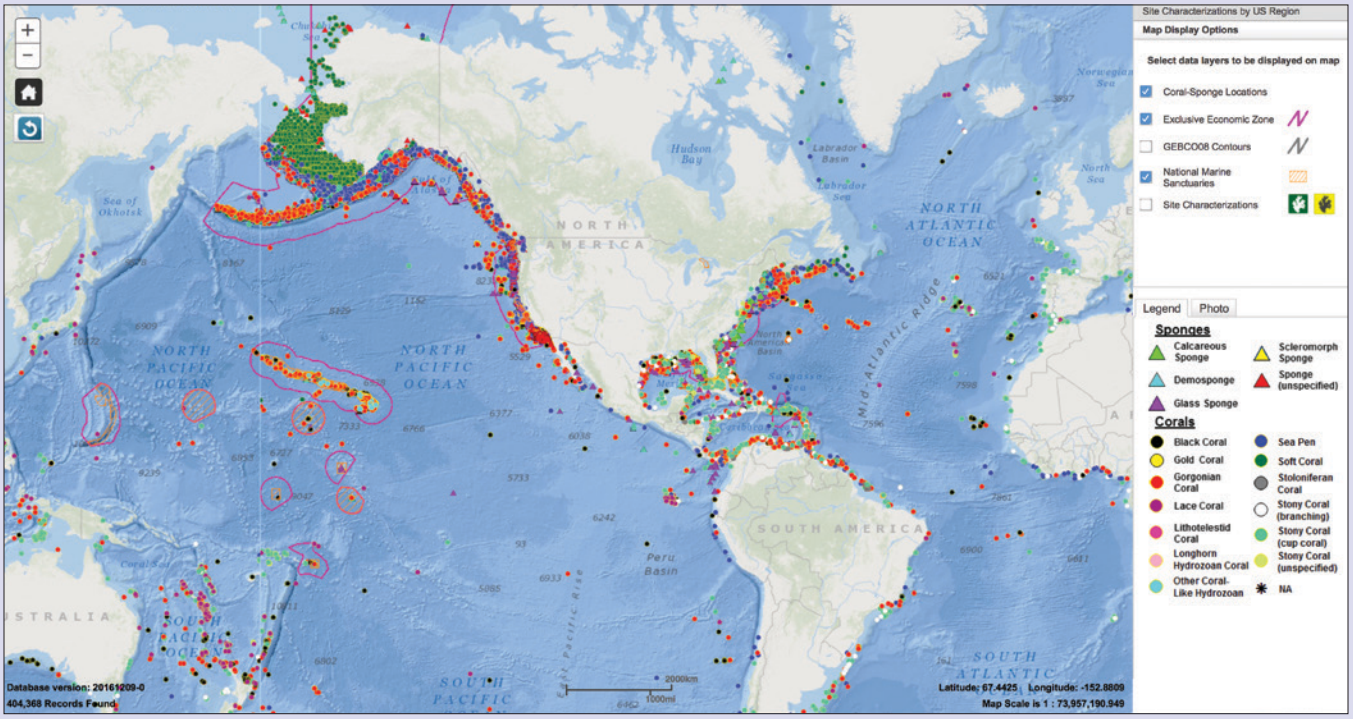
Program researchers, managers, and partners concluded that from a national perspective, the outcomes most critical to Program success include advancing the understanding of deep-sea coral and sponge habitat distribution and developing and maintaining a world-class database and data portal. These outcomes are enabled by supporting excellence in a set of priority research areas: surveys and habitat characterization, mapping (largely in partnership), genetic studies, determining coral and sponge associations with managed species productivity, and recovery from damage. Models, image and video annotation, and data analysis (including partner efforts) are key tools for interpretation of research results. These results then feed into the National Database to inform management decisions made by regional fishery management councils, national marine sanctuaries, marine national monuments, and regional ocean planners. Collaboration, sharing data/expertise/methods/equipment/communications, and leveraging funds across and beyond NOAA are critical elements to achieving desired outcomes. Government-driven deep-sea coral and sponge research would simply not happen without the partnerships and collaborative efforts of the larger deep-sea community.

World-class Deep-Sea Coral Database Advances

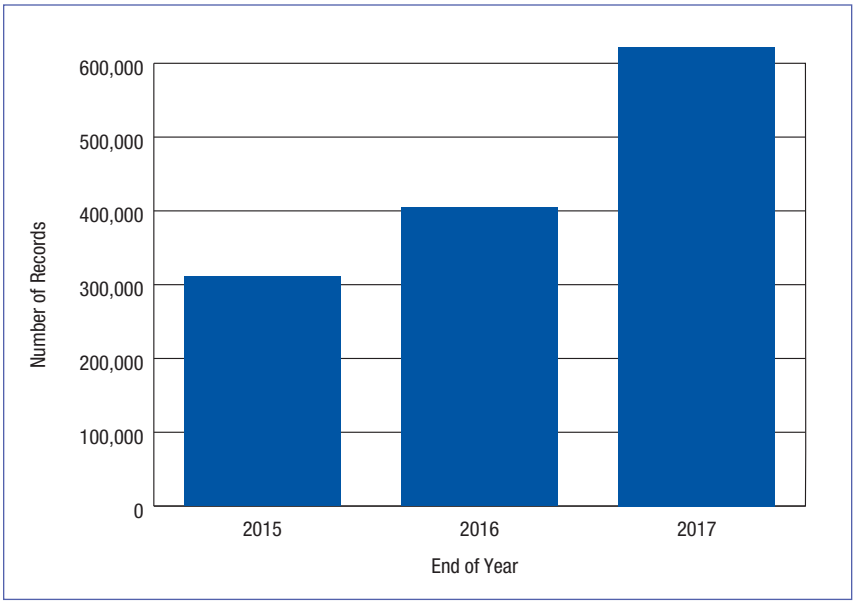
The Deep Sea Coral Research and Technology Program's research and data visualization needs are supported by a data portal that provides access to the National Database for Deep-Sea Corals and Sponges. The National Database and portal debuted in 2015 to serve the data needs of regional fishery management councils, other ocean resource managers, and scientists. The map displays known deep-sea coral and sponge locations along with taxonomic identification, survey information, depth, oceanographic variables, and often accompanying photographs. In 2016-2017, the database has been updated quarterly with new records and corrections or enhancements to existing records. In this timeframe, the number of coral and sponge records in the database more than doubled, from 309,000 records in January 2016 to more than 622,000 records in December 2017, contained in 119 data sets. The portal now also provides access to deep-sea coral habitat suitability model information, as well as story maps, publications, and other valuable resources. By providing known coral and sponge locations along with relevant metadata, the National Database for Deep-Sea Corals and Sponges provides resources to answer questions such as whether a particular species has been observed in a particular region or depth range. Uses of the National Database have included the following:

- Proposingareas to protect from bottom-contact fishing gear, in conjunction with a number of regional fishery management councils.
- Siting areas appropriate for finfish aquaculture, in conjunction with the NOAA National Centers for Coastal Ocean Science.
- Recommending avoidance areas for fishing fleets using bottom-contact gear, in conjunction with councils and NOAA Fisheries Regional Offices.
- Planningexpeditions on NOAA Ship *Okeanos Explorer* to maximize the likelihood of discovering new deep-sea coral and sponge communities, in conjunction with the NOAA Office of Ocean Exploration and Research.
- Planningexpeditions on a variety of vessels to areas with past coral/sponge observations to learn more about poorly understood ecosystems, and in some cases to monitor community changes, in conjunction with other NOAA offices, the Bureau of Ocean Energy Management, U.S. Geological Survey, Fisheries and Oceans Canada, Ocean Exploration Trust, Schmidt Ocean Institute, and a variety of academic institutions and NGOs.

Furthermore, deep-sea coral and sponge location records, metadata, and/or habitat suitability model results are fed directly from the National Database into a number of spatial planning portals and tools. These data visualization platforms exist to inform ocean planning and management decisions, providing a tangible return on investment in ocean research and exploration. National and regional examples include the Marine Cadastre and companion Ocean Reporting Tool, which will soon allow users to draw a box around an area of interest and receive a report of resources (including deep-sea coral), activities, and cautions relevant for that area; Northeast Ocean Data Portal; Mid-Atlantic Ocean Data Portal; South Atlantic Fishery Management Council Habitat and Ecosystem Viewer; Gulf Council Coral Portal and Gulf AquaMapper (developed for aquaculture planning), and West Coast Ocean Data Portal. These tools provide known deep-sea coral locations (and/or predicted locations) in the spatial context of other natural resources, seafloor type, oceanographic information, jurisdictional boundaries, protected areas, fishing regulations, lease blocks, hazards, existing infrastructure, and areas of high energy potential, for example.



Known locations of deep-sea corals (circles) and sponges (triangles), with a focus on those within the U.S. exclusive economic zone (200 nm limit outlined in pink). Locations of taxonomically different corals and sponges are shown in different colors (see legend at right). National marine sanctuary boundaries are also shown in hatched orange areas. Since most of the deep sea is unexplored and coral/sponge absence data are not currently included in the National Database, areas on the map without records do not necessarily lack corals and sponges.

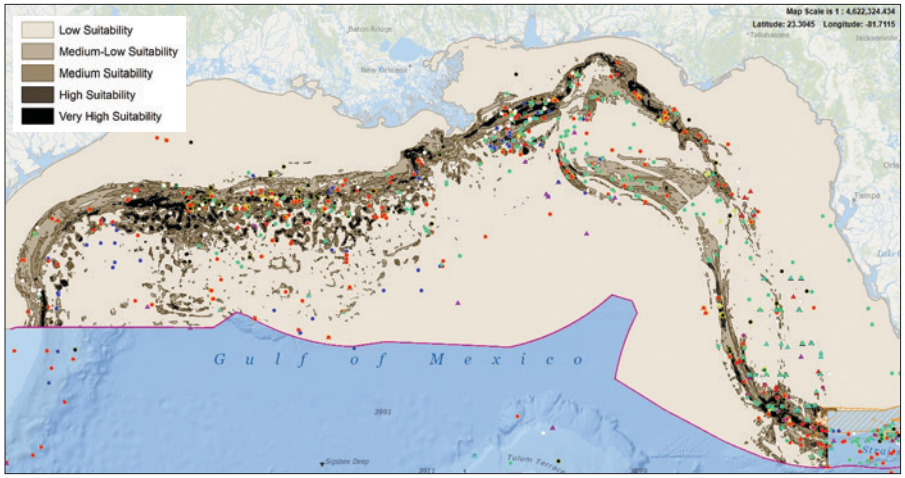


Growth in the number of deep-sea coral and sponge records contained in the National Database at the end of 2015 (the year the map portal for the database was initiated), and cumulatively at the end of calendar years 2016 and 2017. Deep-sea coral and sponge data records may represent discrete observations, or multiple coral/sponge observations over a larger area integrated into a single value (e.g., for trawl catches).

Deep-Sea Coral Predictive Habitat Suitability Modeling

The Deep Sea Coral Research and Technology Program supports predictive habitat suitability modeling, conducted by NOAA's National Centers for Coastal Ocean Science and the Alaska Fisheries Science Center, that is revolutionizing deep-sea coral and sponge exploration and conservation. Based on past observations, historical deep-sea coral locations, seafloor type, depth, slope, temperature, and other variables, models predict locations likely to be productive coral and sponge habitat. Since gaps between survey areas can be vast, model results help researchers make informed decisions about where to search for corals and sponges in the largely unexplored deep sea. In turn, exploration with a remotely operated vehicle or autonomous underwater vehicle captures visual features of the seafloor that can confirm or refute model predictions. With visual surveys providing information such as coral and sponge species identity, number of colonies, and colony size, modelers will be able to refine outputs to improve model accuracy. Deep-sea coral and sponge habitat predictions for many regions of the United States are publicly available on the National Database for Deep-Sea Corals and Sponges.

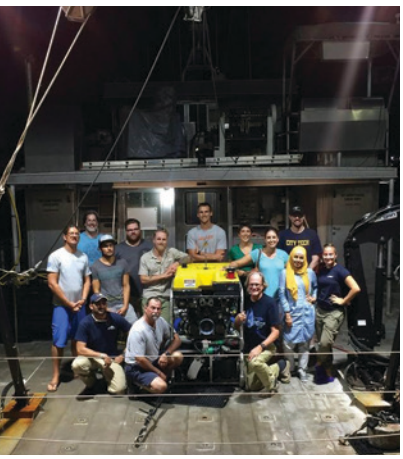
Habitat suitability models have informed deep-sea coral surveys in a number of locations. In 2017, New England model predictions of areas most likely to support deep-sea coral habitat became targets of video survey locations. Researchers were then led to discover abundant and diverse colonies of deep-sea corals. In another example, the Deep Sea Coral Research and Technology Program is partnering with the National Centers for Coastal Ocean Science and the Bureau of Ocean Energy Management to review nearly 40,000 video transect and still images covering more than 200,000 m^2 (50 acres) of seafloor in the Gulf of Mexico. Resulting records of deep-sea coral presence and absence in the region will be used to develop new models that will more accurately predict the probability of occurrence for a number of types of deep-sea coral. This interagency collaboration is being expanded to support modeling in the Southeast U.S. waters and off the West Coast. Learn more about deep-sea coral habitat suitability modeling by visiting the story map created by NOAA's Office for Coastal Management: Discovering Deep-Sea Corals—Predictive Habitat Modeling.



Habitat suitability model output for soft corals and sea fans in the Gulf of Mexico, overlaid with known locations of deep-sea corals and sponges from the NOAA National Database for Deep-Sea Corals and Sponges (multi-colored dots). Darker areas of the model output indicate higher likelihood of suitable habitat. The U.S. exclusive economic zone (200 nm limit) is outlined in pink.

Education and Engagement

The Deep Sea Coral Research and Technology Program has expanded outreach efforts in recent years, especially in response to feedback from our 2017 program review calling for enhanced communications. To more effectively tell the stories behind deep-sea coral and sponge research in support of management, the Program sponsored a webinar series of 12 presentations, many viewed live by more than 100 people. Topics included recent coral and sponge species discoveries, response to environmental conditions, response to oil pollution, next-generation genetic techniques, habitat suitability modeling, and applications of research to fisheries management. Program staff also presented results at four conferences and an aquarium in 2016 and 2017, and hosted a special session at the International Symposium on Deep-Sea Corals to highlight chapters of the *State of Deep-Sea Coral and Sponge Ecosystems of the United States* report with author presentations.



Throughout the Program's operation, NOAA deep-sea coral scientists have worked closely with regional fishery management councils to ensure that data collected are relevant to council needs and priorities. In 2017, the Deep Sea Coral Research and Technology Program engaged staff from all eight councils in its program review and regional research planning workshops. Staff presented Program information and solicited research priorities and general feedback during North Pacific, Pacific, South Atlantic, Caribbean, and Gulf of Mexico Fishery Management Council meetings. Staff were also consulted to inform the process of protecting deep-sea habitat overseen by the New England Fishery Management Council. Additionally, the Program engaged council staff from the South Atlantic and Gulf of Mexico in research cruises in 2017 to inform habitat protection decisions in each region.

Participants in 2017 Deep Sea Coral Research and Technology Program–funded expeditions mapped deep-sea coral ecosystems in the South Atlantic Bight using multibeam systems of NOAA Ship Nancy Foster *(top), and surveyed deep-sea coral ecosystems in the areas surrounding Flower Garden Banks using ROV* Mohawk *deployed off NOAA R/V* Manta *(bottom). Nine students participated in these two expeditions, and gained valuable hands-on experience conducting research in the field.*

Students have become increasingly engaged in deep-sea coral and sponge research and outreach during this reporting period as well. The Program sponsored a student through the NOAA Educational Partnership Program with Minority-Serving Institutions in 2017 to research the social impetus and policy-making sides of deep-sea coral and sponge protection. At the close of her internship, Danielle Olive from the University of Virgin Islands produced a story map, "History of Deep-Sea Coral Protection in U.S. Waters," highlighting her findings. In the field, the Southeast Deep Coral Initiative (SEDCI) has involved 16 students on deep-sea coral and sponge research expeditions in the Gulf of Mexico and South Atlantic Bight in 2016-2017. SEDCI also consistently engages students from the College of Charleston in coral and sponge data analysis activities, which has resulted in five masters theses.

SEDCI expeditions in 2017 were also particularly successful at engaging the public through pre-cruise background stories, on-the-ship blogging, and post-cruise video outreach. The 4-minute "Living in the Dark" video was created by Green Fire Productions to document the discovery of deep-sea corals, sponges, and associated species living 1,000 feet under the ocean surface, as well as how results are used to inform management decisions.

Appendix 1: Budget Information

Fiscal Year 2016

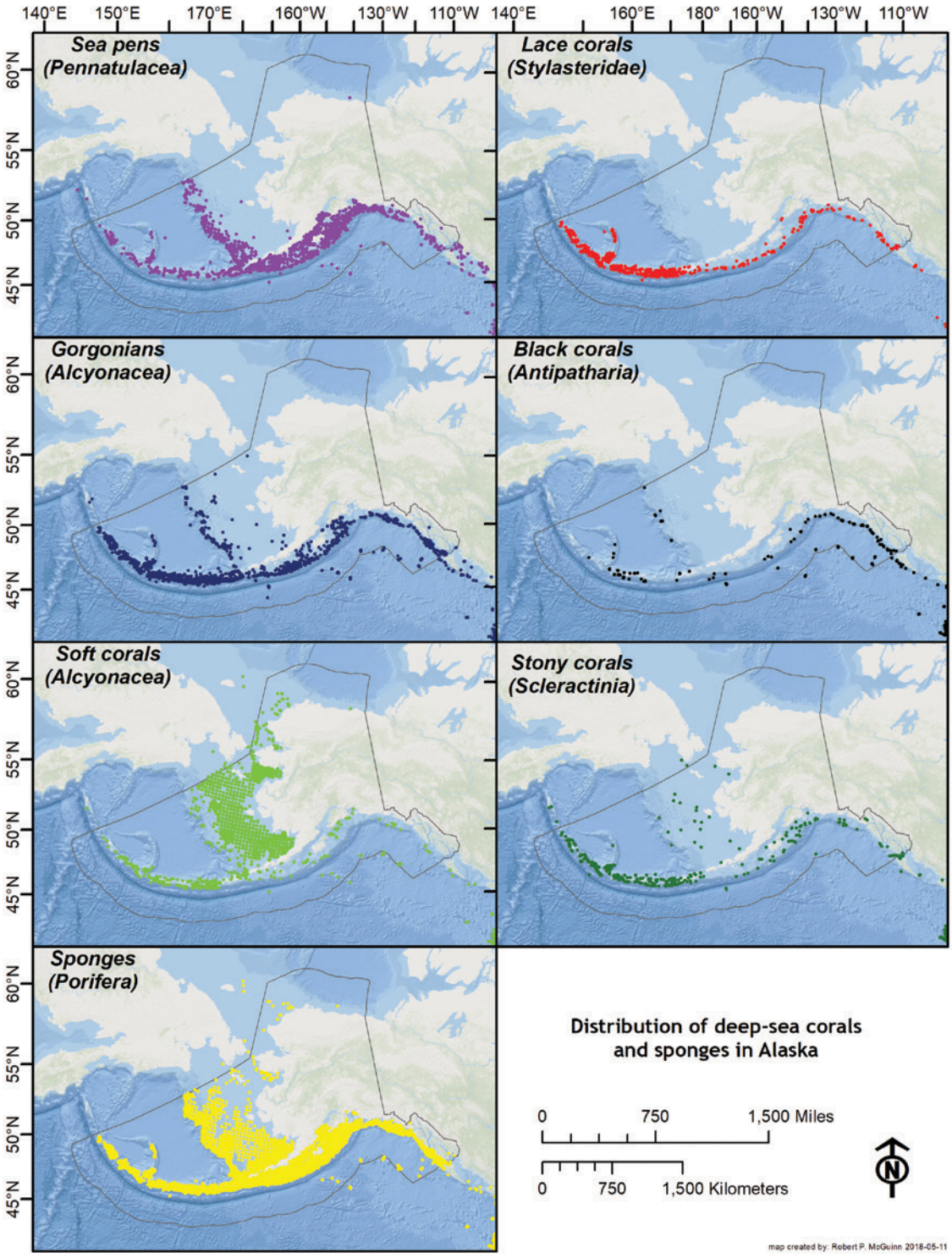
Project	Fishery Management Council Region	Funding
Pacific Islands Fieldwork Initiative, Year 2 of 3	Western Pacific	$800,000
Southeast Fieldwork Initiative, Year 1 of 4	South Atlantic, Gulf of Mexico, Caribbean	$376,969
Northeast research, mapping & data analysis	New England, Mid-Atlantic	$18,130
Data-mining deep-sea coral records from NCCOS ROV video missions in the U.S. Caribbean	Caribbean	$25,000
Research expedition data management	National	$125,000
Taxonomic and genetic identification of fisheries bycatch of deep-sea corals and sponges	Pacific, North Pacific	$100,000
National Bycatch Reduction Engineering Program's (BREP) project to develop techniques to reduce interactions between fishing gears and corals/sponges	Mid-Atlantic	$50,000
Northeast Fisheries Observer Program (NEFOP) deep-sea coral and sponge identification and program analysis	New England; Mid-Atlantic	$15,000
Reconnaissance survey of glass sponge bioherms in the Santa Catalina Basin of the Southern California Bight	Pacific	$61,355
Deep sea characterization and assessment within the Channel Islands National Marine Sanctuary	Pacific	$25,000
Distribution of deep-water coral and sponge habitats off Washington and Oregon and their functional links to demersal fishes	Pacific	$38,918
Enhancement of a coral and sponge field guide for the Pacific region	Pacific, North Pacific	$23,620
Coral and sponge diversity in the eastern Bering Sea of Alaska	North Pacific	$25,000
Analyses to assess habitat associations for rockfish and coral, summarize new research on Bowers Bank and Ridge and create a story map for the eastern Bering Sea Canyons	North Pacific	$118,000
Extended analyses of deep-sea corals and sponges from past AFSC surveys	North Pacific	$26,509
Seafloor mapping and exploration of the Southern California borderlands	Pacific	$40,000
Deep-sea coral survey image analysis	Pacific	$25,000
Deep-sea coral data management	National	$165,000
Improvements to the DSCRTP data management system	National	$44,000
Program coordination	National	$160,928
NMFS management and administration	National	$199,657
Total		**$2,463,086**

Fiscal Year 2017

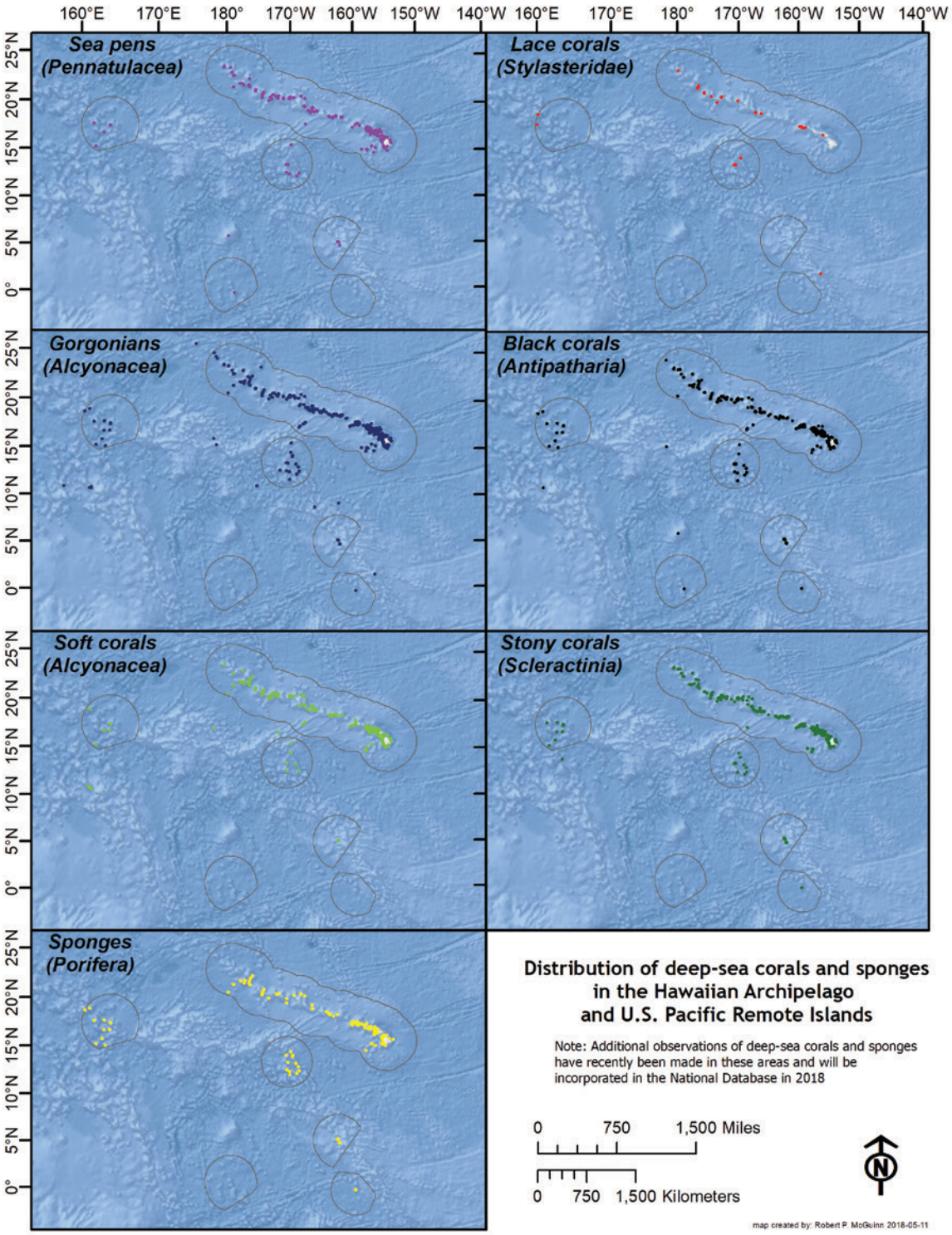
Project	Fishery Management Council Region	Funding
Pacific Islands Fieldwork Initiative, Year 3 of 3	Western Pacific	$754,000
Southeast Fieldwork Initiative, Year 2 of 4	South Atlantic, Gulf of Mexico, Caribbean	$720,907
Northeast research, mapping & data analysis	New England, Mid-Atlantic	$75,875
Internal program review	National	$4,050
Research expedition data management	National	$130,000
Taxonomic and genetic identification of fisheries bycatch of deep-sea corals and sponges, and development of population genetic and eDNA approaches	Pacific, North Pacific	$84,000
Video analysis of deep-sea corals and sponges in Cordell Bank National Marine Sanctuary	Pacific	$38,500
Deep-sea mapping off California in collaboration with NOAA Office of Coast Survey	Pacific	$49,500
Deep-sea coral data management	National	$165,000
Program coordination	National	$223,178
NMFS management and administration	National	$221,851
Total		**$2,466,861**

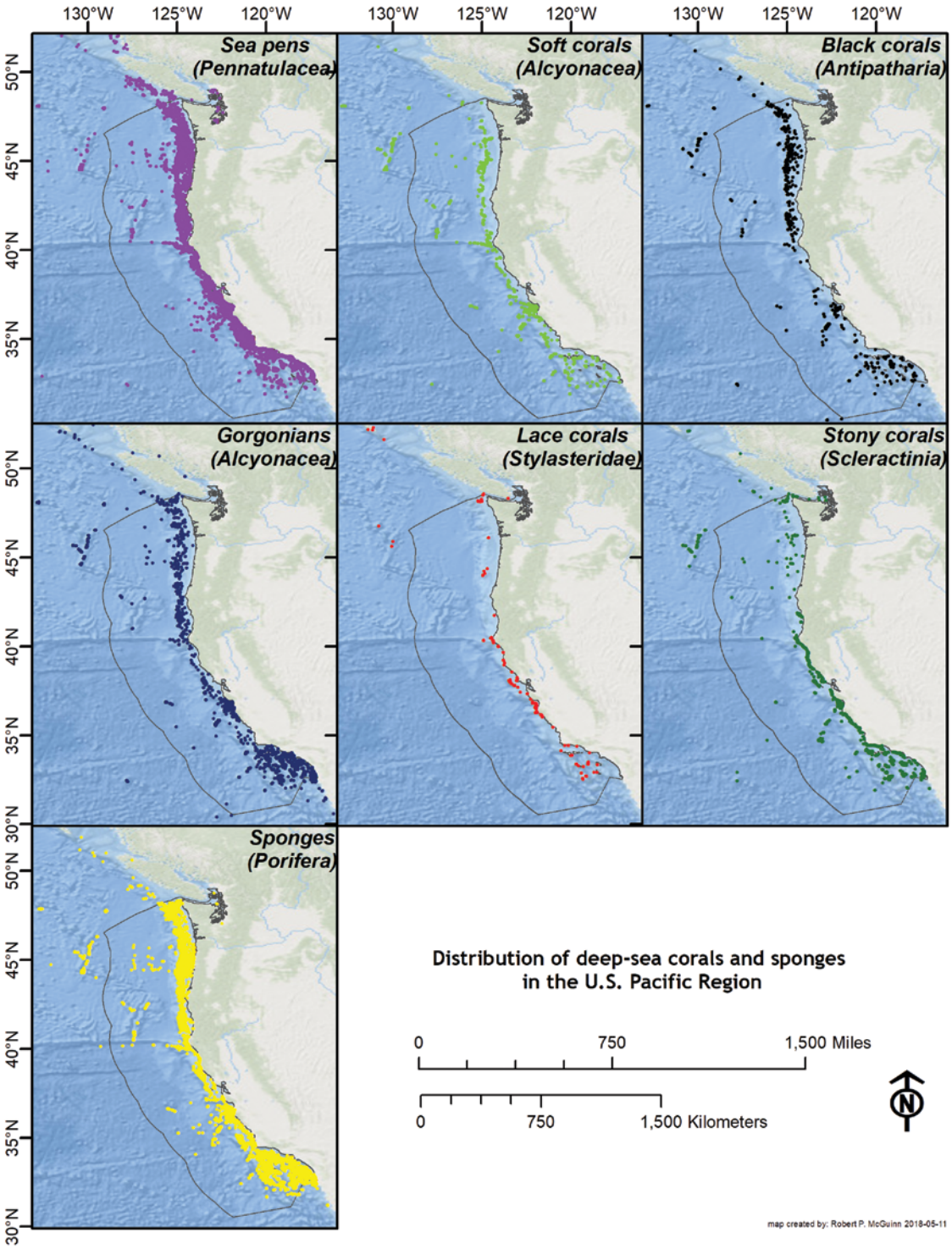
Appendix 2: Maps of Deep-Sea Coral and Sponge Location by Region

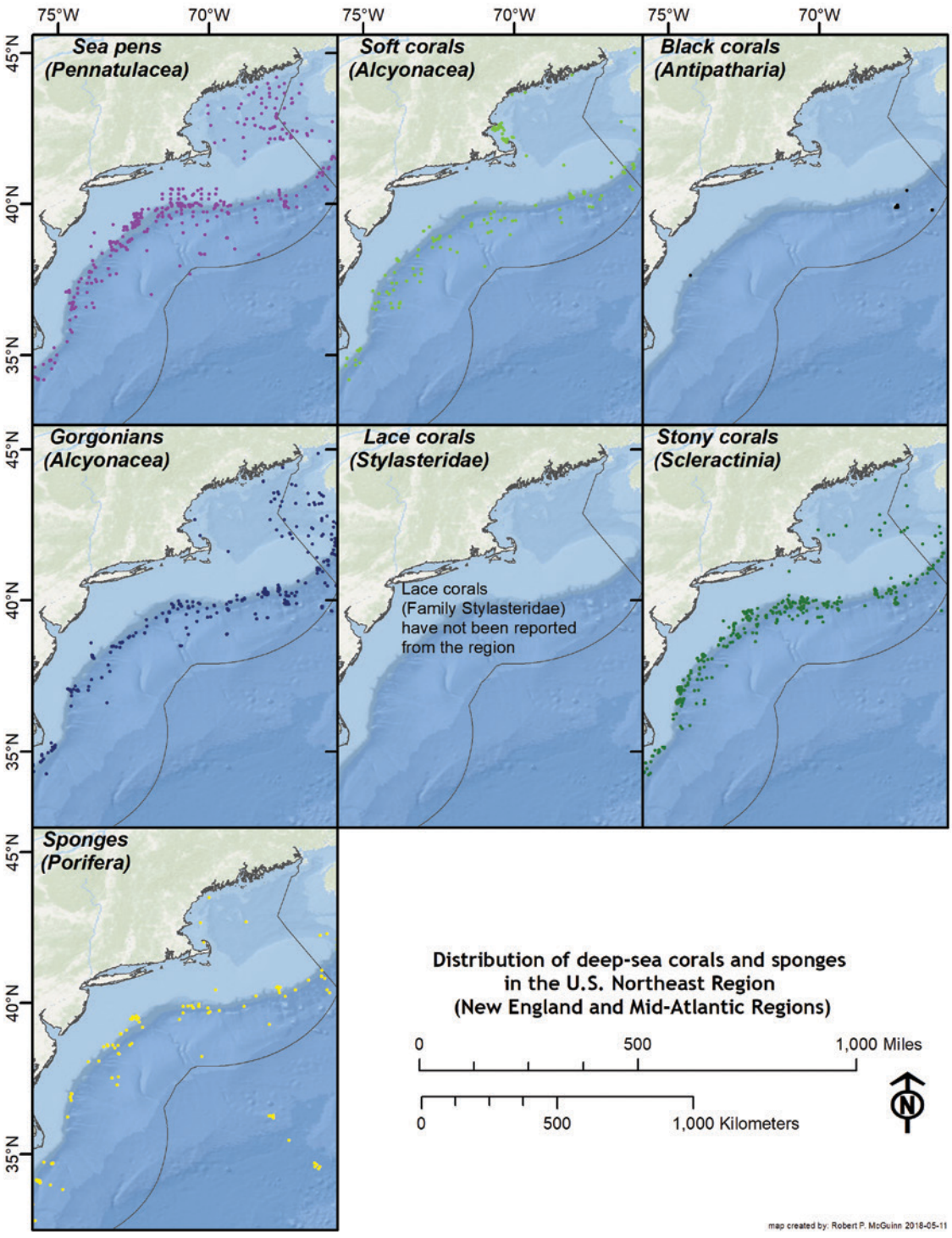
Records of deep-sea corals and sponges shown in this appendix can be downloaded from NOAA's Deep-Sea Coral Data Portal.

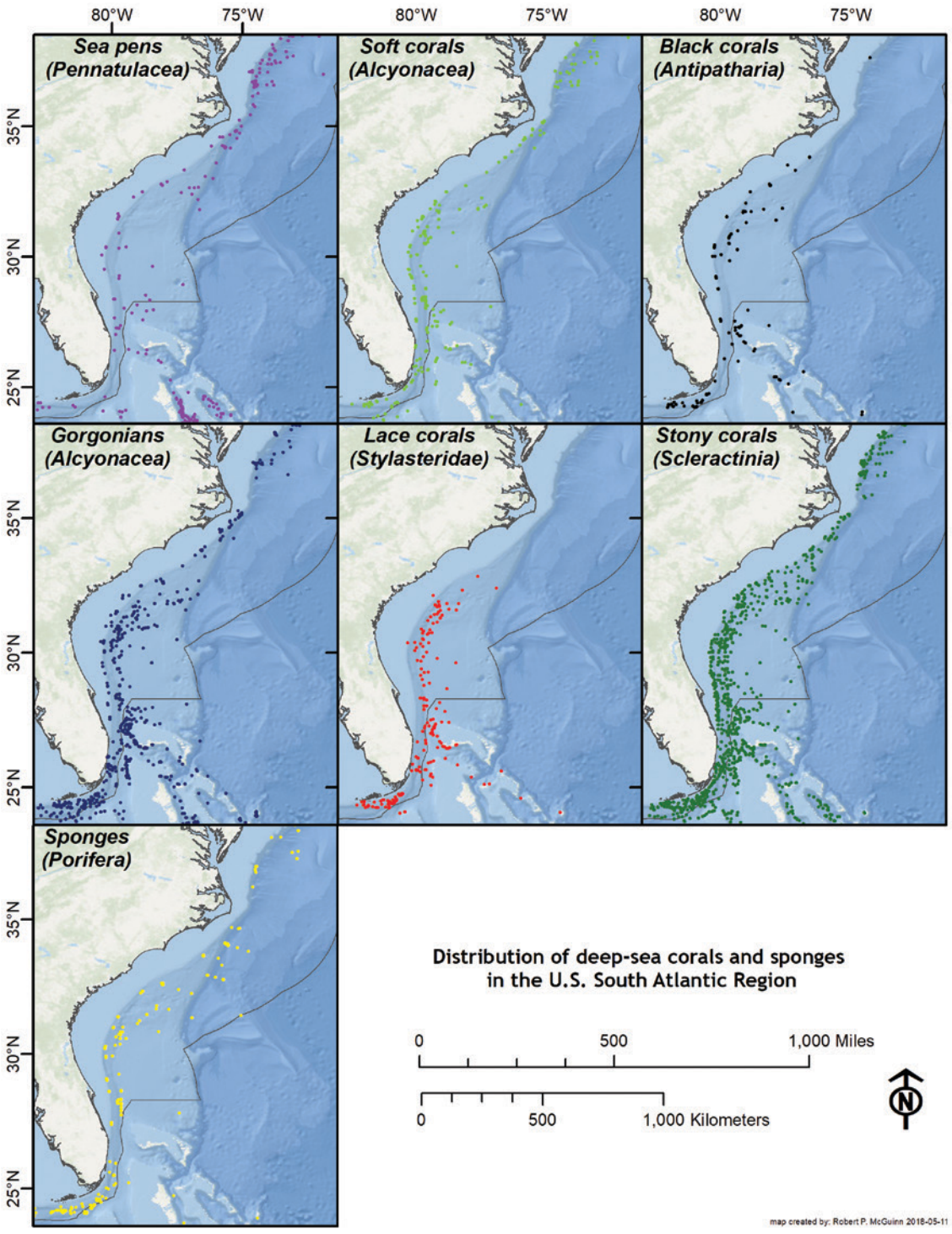


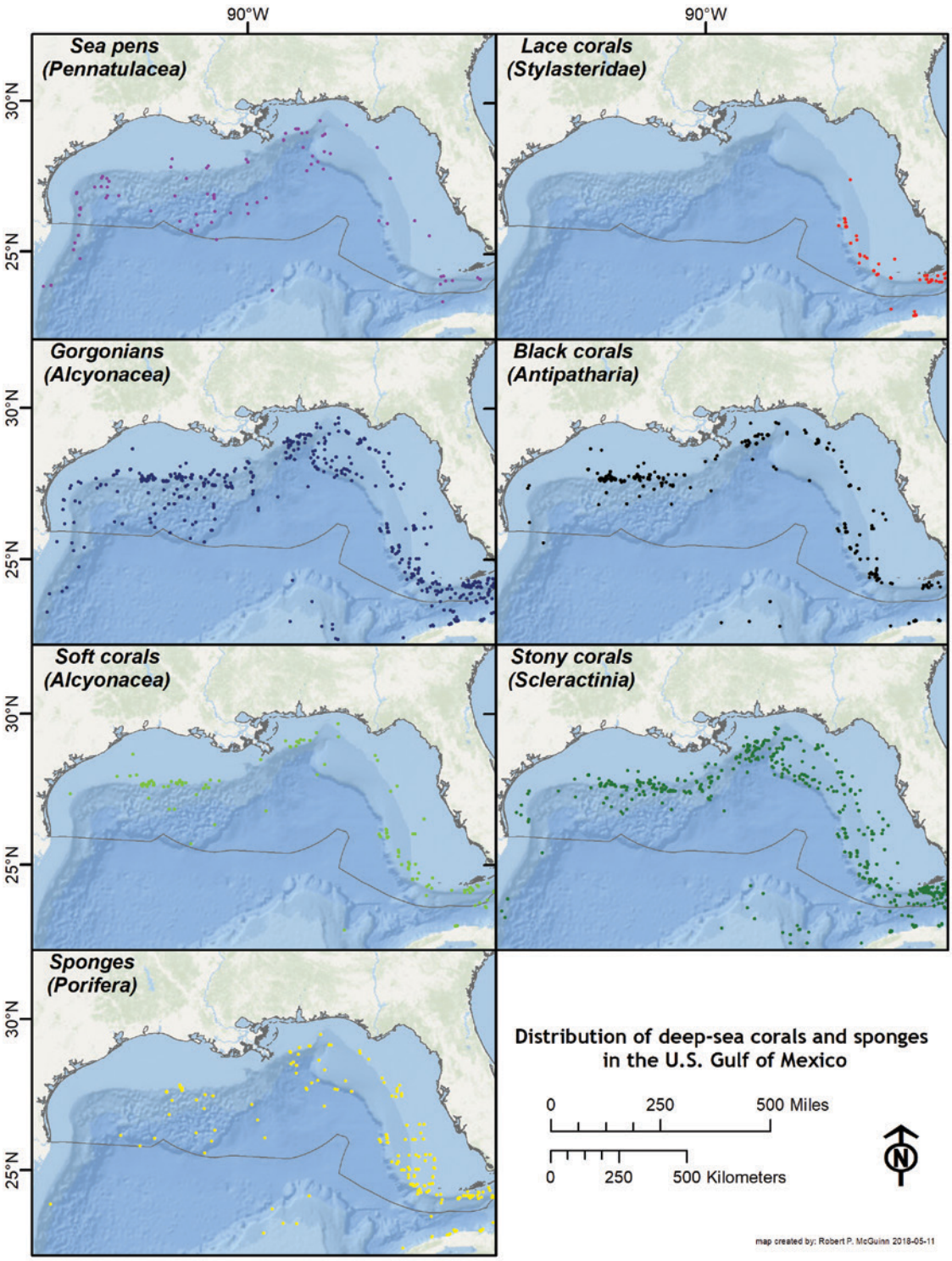
Note: Based on CAPSTONE surveys in 2016 and 2017, deep-sea corals and sponges are now known to occur in all U.S. Pacific Island jurisdictions. Data from areas outside the Hawaiian Archipelago are currently being analyzed.

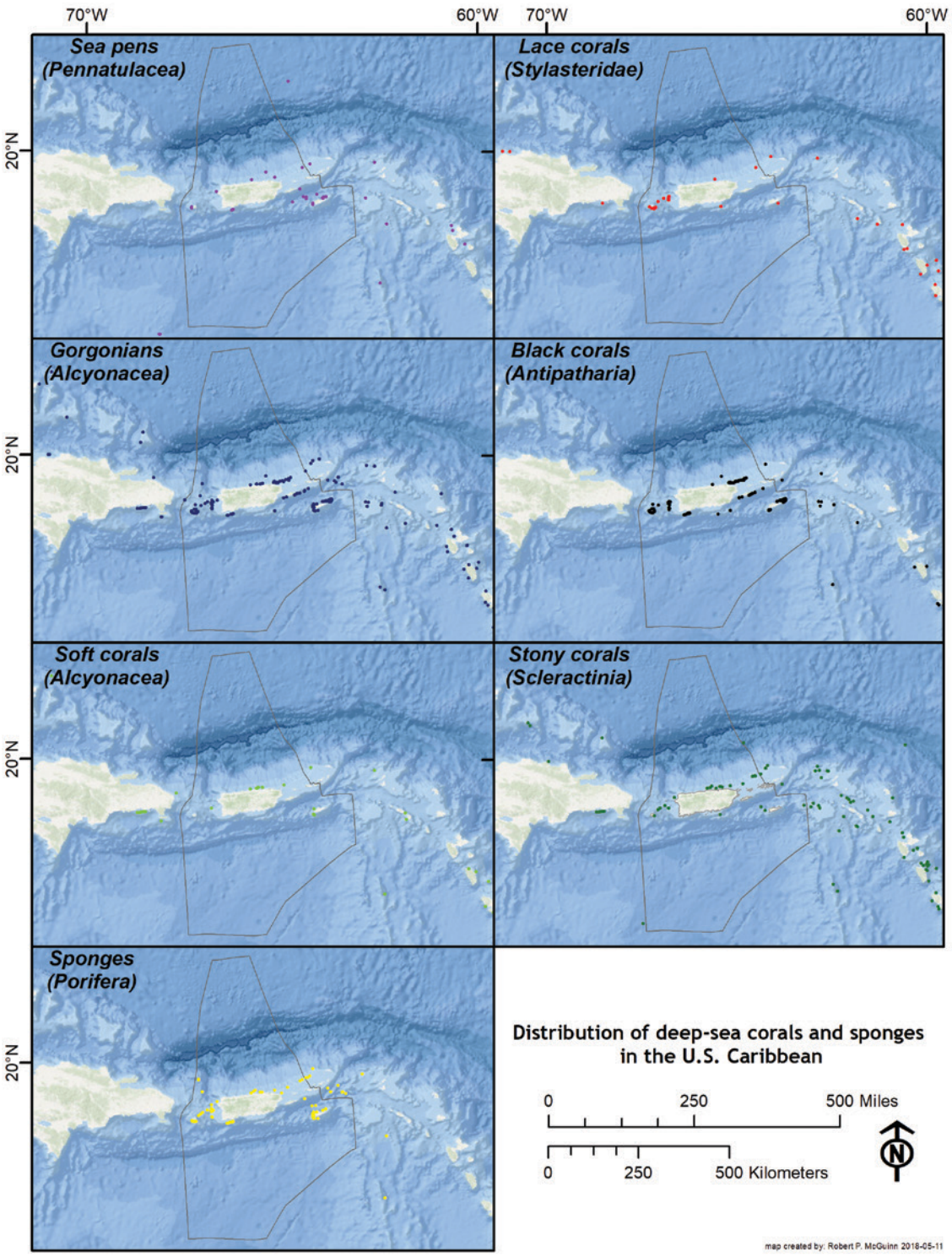



130°W
125°W
120°W
50°N
45°N
40°N
35°N
30°N
Sea pens (Pennatulacea)
Soft corals (Alcyonacea)
Black corals (Antipatharia)
Gorgonians (Alcyonacea)
Lace corals (Stylasteridae)
Stony corals (Scleractinia)
Sponges (Porifera)
Distribution of deep-sea corals and sponges in the U.S. Pacific Region
0
750
1,500 Miles
0
750
1,500 Kilometers
N
map created by: Robert P. McGuinn 2018-05-11


75°W
70°W
45°N
40°N
35°N
Sea pens
(Pennatulacea)
Soft corals
(Alcyonacea)
Black corals
(Antipatharia)
Gorgonians
(Alcyonacea)
Lace corals
(Stylasteridae)
Lace corals
(Family Stylasteridae)
have not been reported
from the region
Stony corals
(Scleractinia)
Sponges
(Porifera)
Distribution of deep-sea corals and sponges
in the U.S. Northeast Region
(New England and Mid-Atlantic Regions)
0
500
1,000 Miles
0
500
1,000 Kilometers
N
map created by: Robert P. McGuinn 2018-05-11


80°W
75°W
35°N
30°N
25°N
Sea pens
(Pennatulacea)
Soft corals
(Alcyonacea)
Black corals
(Antipatharia)
Gorgonians
(Alcyonacea)
Lace corals
(Stylasteridae)
Stony corals
(Scleractinia)
Sponges
(Porifera)
Distribution of deep-sea corals and sponges
in the U.S. South Atlantic Region
0
500
1,000 Miles
0
500
1,000 Kilometers
N
map created by: Robert P. McGuinn 2018-05-11


90°W
90°W
Sea pens
(Pennatulacea)
Lace corals
(Stylasteridae)
Gorgonians
(Alcyonacea)
Black corals
(Antipatharia)
Soft corals
(Alcyonacea)
Stony corals
(Scleractinia)
Sponges
(Porifera)
30°N
25°N
Distribution of deep-sea corals and sponges
in the U.S. Gulf of Mexico
0
250
500 Miles
0
250
500 Kilometers
N
map created by: Robert P. McGuinn 2018-05-11


70°W
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Sea pens
(Pennatulacea)
Lace corals
(Stylasteridae)
Gorgonians
(Alcyonacea)
Black corals
(Antipatharia)
Soft corals
(Alcyonacea)
Stony corals
(Scleractinia)
Sponges
(Porifera)
Distribution of deep-sea corals and sponges
in the U.S. Caribbean
0
250
500 Miles
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250
500 Kilometers
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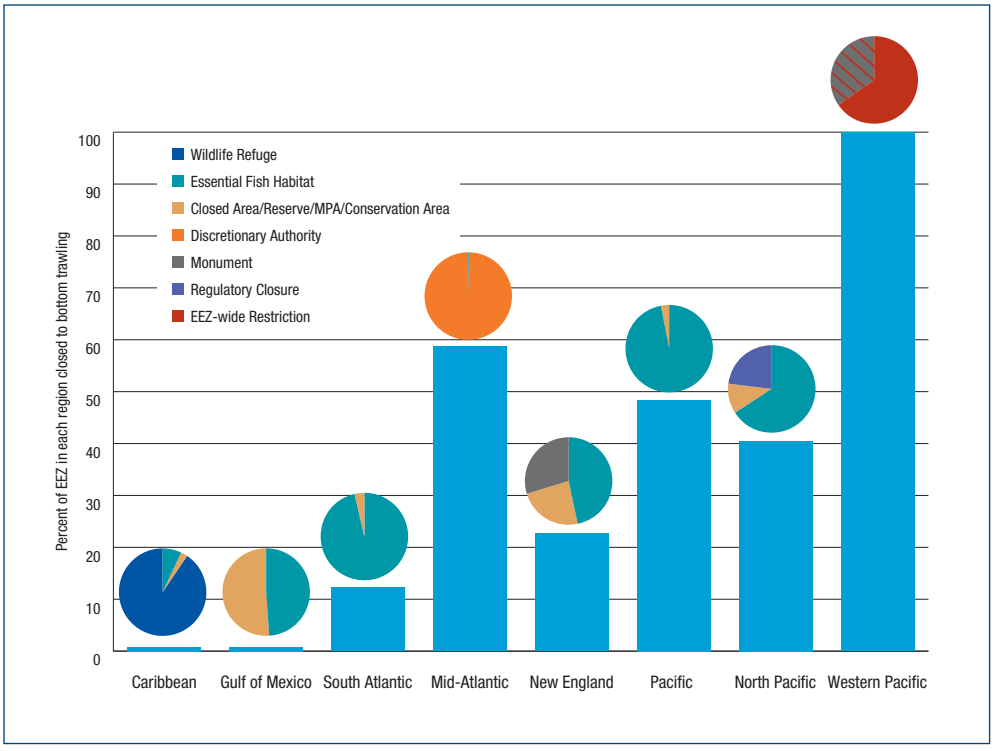
map created by: Robert P. McGuinn 2018-05-11

Appendix 3: Maps of Deep-Sea Coral and Sponge Protections and Areas with Potential for Fishing Gear Interaction

The Deep Sea Coral Research and Technology Program has compiled regional fishery management council actions, national marine sanctuary and marine national monument designations, Program-funded research results, and scientific literature relevant for deep-sea protections in each U.S. region. The maps in this section show current management areas in federal waters where bottom trawling is prohibited in each region. Bottom trawling has the potential to damage deep-sea corals. Highlighted locations are open to bottom-contact fishing and have evidence of substantial structure-forming deep-sea corals or potential fishing gear interactions with corals. Directed by the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to help reduce interactions between fishing gear and corals, the Program is committed to supporting studies that aid resource managers in developing and evaluating management options for vulnerable locations.

Every region of the United States, except the U.S. Caribbean, has now used data from the Program to inform protection of deep-sea coral resources. The chart below shows the percentage of each region closed to bottom trawling, the type of fishing that is usually most damaging to corals. It also shows the protection breakdown in each region by type, for example essential fish habitat (EFH). It is important to note that much of the closed areas shown in the following maps are too deep for normal bottom trawling operations, so have been closed as a precautionary measure to prevent expansion of these operations.

Data are available from the Program upon request and may be used by the councils to inform designation of zones to protect deep-sea corals from physical damage by fishing gear under the MSA deep-sea coral discretionary authority (Section 303(b)(2)(B)). The story map, "History of Deep-Sea Coral Protection in U.S. Waters," displays more information about spatial protections benefiting deep-sea corals. The *2016 Deep Sea Coral Research and Technology Program Report* to Congress contains further details on known deep-sea coral habitat areas that may be especially vulnerable to fishing activity.



Percentage of each region's seafloor within the U.S. exclusive economic zone (EEZ) that is closed to bottom trawling (blue bars). Pie charts indicate the relative amount of spatial protection in each region established through various types of authorization mechanisms. While national marine sanctuaries add protection in some capacities, they do not regulate fishing and are therefore not included in this chart. Note that although bottom trawling does not occur in the U.S. Caribbean, it is not explicitly prohibited. In the North Pacific, the Arctic commercial fishing closure is considered regulatory because it could be reversed by a change to the Arctic Fishery Management Plan. Western Pacific areas protected as marine national monuments are also protected as part of EEZ-wide trawl restrictions (indicated by the hatched section). MPA = Marine protected area.

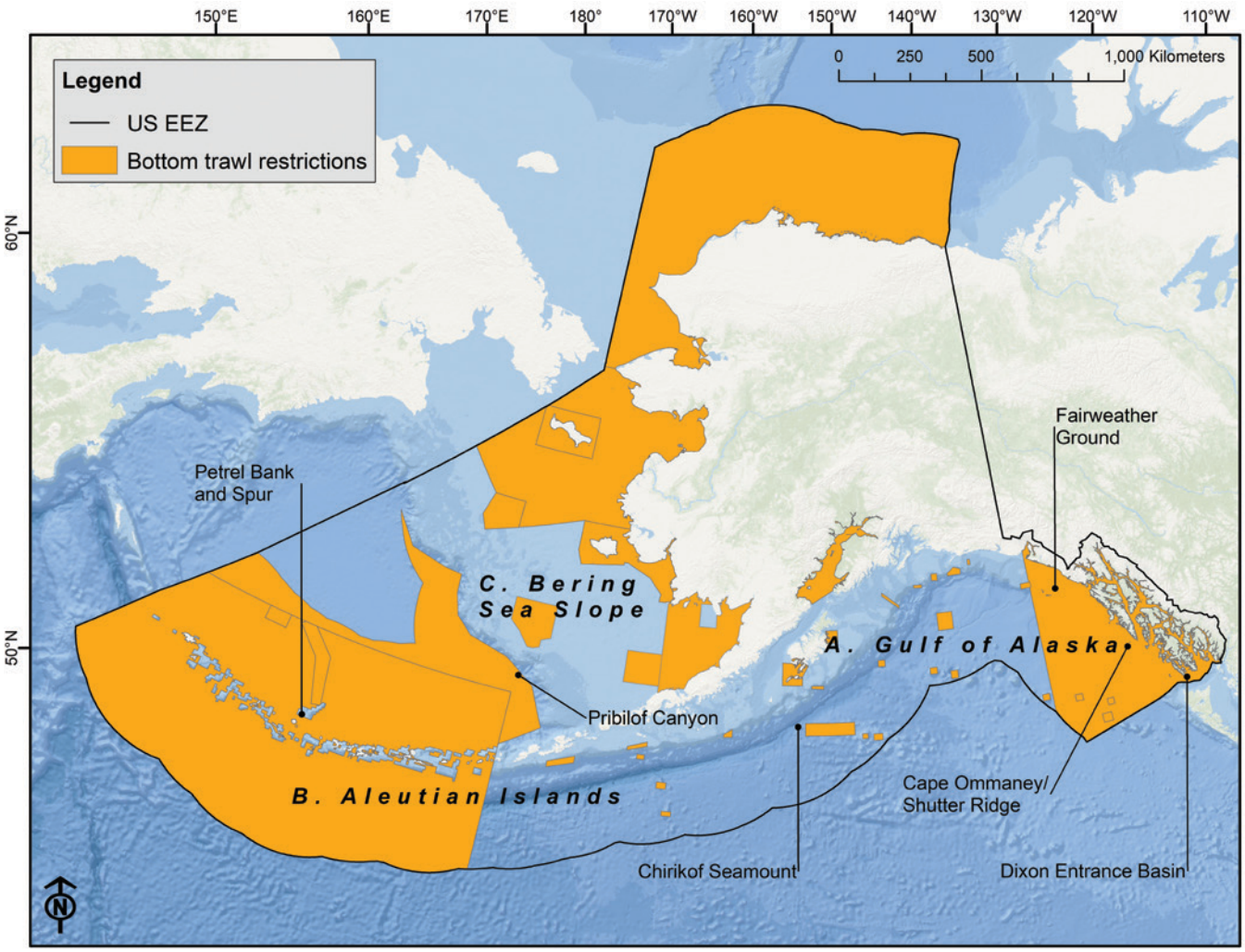
Alaska Region

The North Pacific Fishery Management Council has established extensive conservation areas around the region to protect coral habitats from fishing gear impacts. Coral communities that are still subject to fishing gear interactions include the following places.

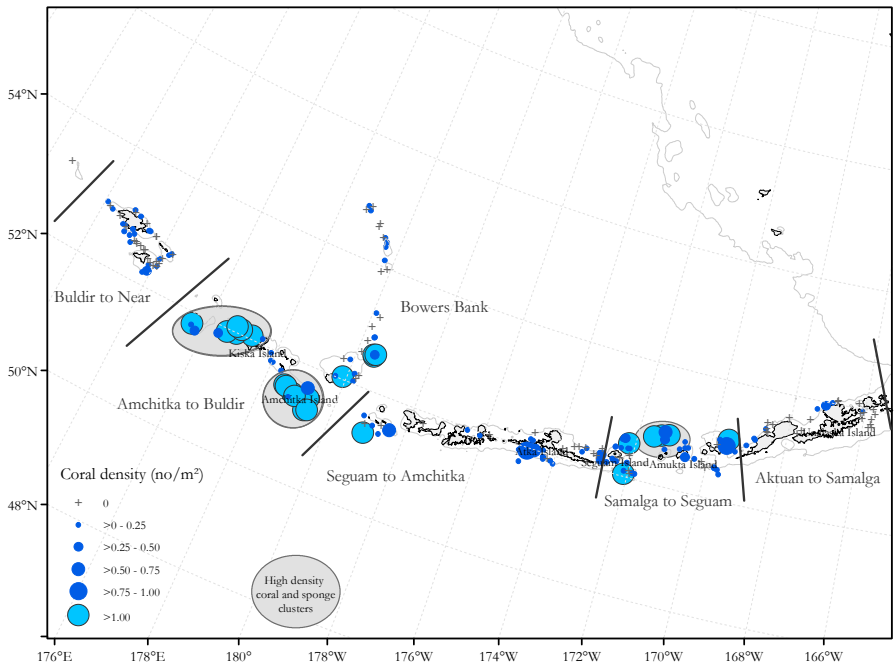
A. Gulf of Alaska: *Primnoa* coral habitats outside currently protected areas, including Chirikof Seamount, the Fairweather Ground, Cape Ommaney/Shutter Ridge, and Dixon Entrance basin. Most of these areas are closed to bottom trawling, but corals are vulnerable to other gear types operating in the region (e.g., longline gear).

B. Aleutian Islands, and Petrel Bank and Spur: The Aleutian Islands are home to some of the richest deep-sea coral habitats in the U.S. EEZ. The Aleutian Islands Habitat Conservation Area and Coral Habitat Protection Areas provide important protections, but surveys and habitat suitability modeling indicate that a number of high-density Aleutian Island "coral gardens" occur in areas that are currently open to bottom trawling. In addition, relatively small areas within the Aleutian Islands have high levels of coral bycatch in commercial fisheries as reported by the Alaska Groundfish Observer Program.

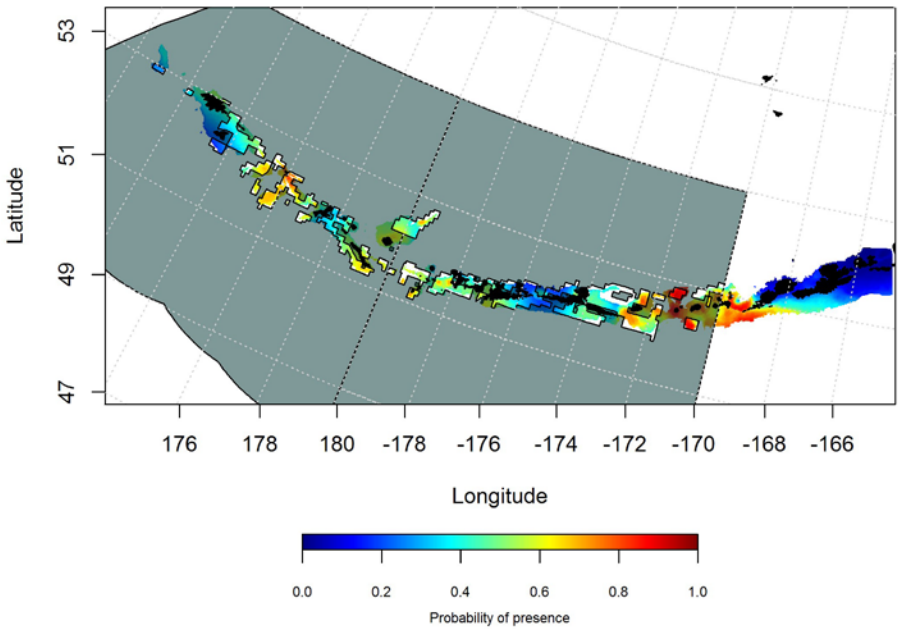
C. Bering Sea slope: Parts of the slope, including Pribilof Canyon, have been identified as coral habitat with potential for fishing gear interaction. Alaska Fisheries Science Center surveys and habitat suitability modeling indicate that slope coral densities are much lower than in the Aleutian Islands or Gulf of Alaska. About one-quarter of coral habitat predicted for the eastern Bering Sea slope occurs in Pribilof Canyon (about 10 percent of the total slope area).



Deep-sea coral and sponge protections and potential for bottom-trawl fishing gear interactions in the U.S. North Pacific region's exclusive economic zone (EEZ). See text above for descriptions of areas highlighted in the map.



Areas of high-density deep-sea coral communities in the Aleutian Islands identified by the Deep Sea Coral Research and Technology Program during 2012 and 2014 camera surveys (Goddard et al. 2017).



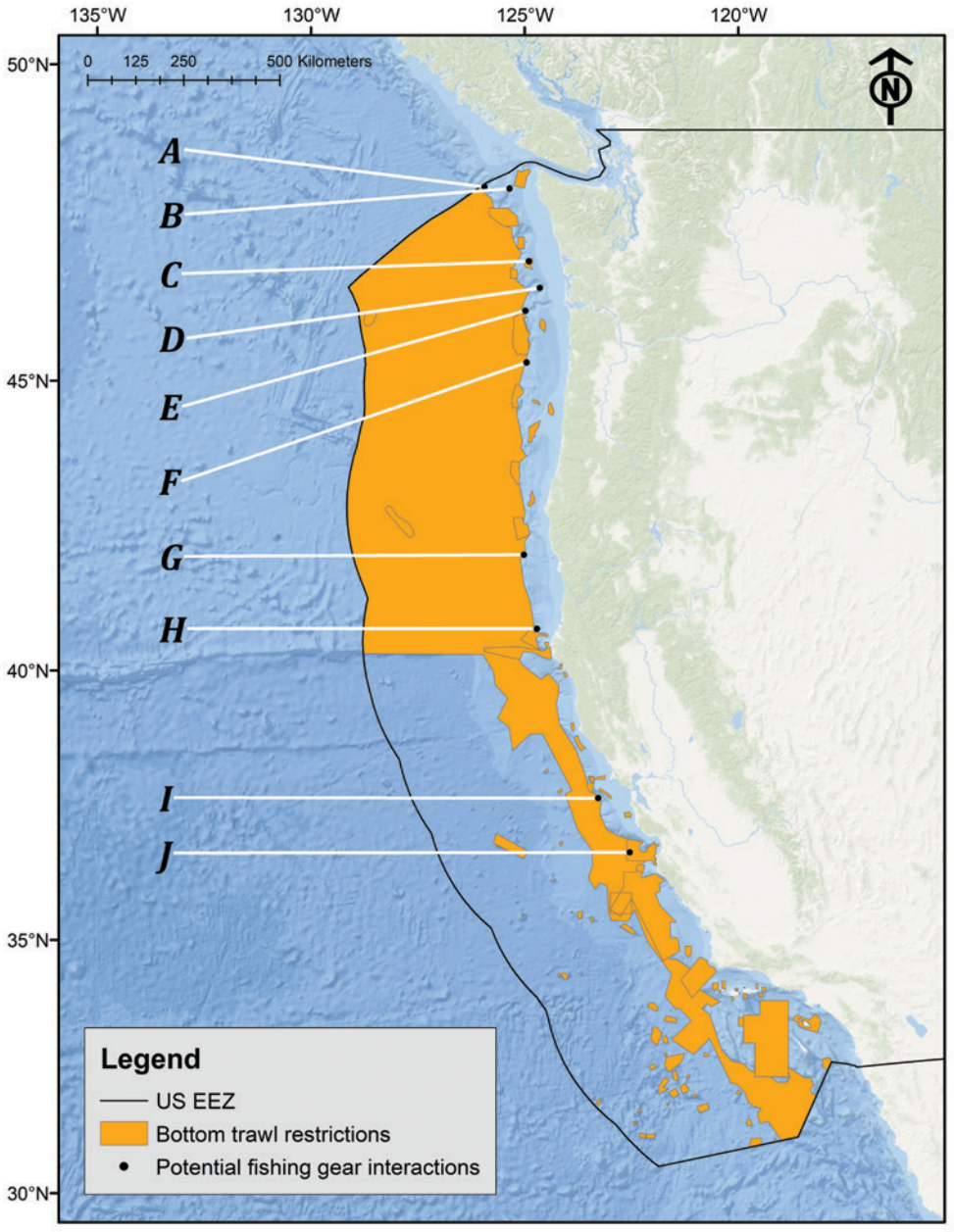
Deep-sea coral models predict areas with a high probability of coral and sponge habitats around the Aleutian Islands. The distribution of probability of presence for coral in the Aleutian Islands is shown above, with the areas closed to mobile fishing gear shaded in grey. (Credit: Chris Rooper, NOAA). Under current fishery management measures, approximately 50 percent of high probability coral habitat in waters shallower than 500 meters (1,640 feet) is not protected from bottom trawling.

West Coast Region

Although more than 40 percent of the West Coast EEZ was protected from bottom trawling in 2006, additional areas of documented deep-sea coral presence remain open to bottom trawling and other bottom-contact fishing activities. The spatially discrete areas listed below, based on observed coral bycatch and documented presence of coral aggregations, include areas considered by the Pacific Fishery Management Council for additional habitat protection.

A. High coral bycatch area bordering Nitinat Canyon.
B. Deep-sea coral areas in the Olympic Coast National Marine Sanctuary in Quinault Canyon adjacent to and east of the current Olympic Biogenic 2 EFH Conservation Area (proposed for closure by the Council in April 2018).
C. High coral bycatch areas surrounding the existing Grays Canyon EFH Conservation Area (proposed for closure by the Council in April 2018).
D. High coral bycatch areas in Wilapa Canyon (proposed for closure by the Council in April 2018).
E. Deep-sea coral areas in parts of Astoria Canyon outside the Astoria Canyon EFH Conservation Area (portions proposed for closure by the Council in April 2018).
F. High coral bycatch areas off Central Oregon (portions proposed for closure by the Council in April 2018).
G. High coral bycatch areas off the Oregon/California border (portions proposed for closure by the Council in April 2018).
H. High coral bycatch areas in Eel River Canyon outside of the Eel River Canyon EFH Conservation Area.
I. Rittenburg and Cochrane Banks and Escarpment within Greater the Farallones National Marine Sanctuary (proposed for closure by the Council in April 2018).
J. Certain areas of Monterey Bay National Marine Sanctuary, including the Ascension and Año Nuevo Canyon Complex (portions proposed for closure by the Council in April 2018).

"High coral bycatch areas" are areas with standardized coral bycatch (weight/km) in the top 1 percent of all coral bycatch coast-wide reported from commercial trawl fisheries, based on data from the West Coast Groundfish Observer Program.

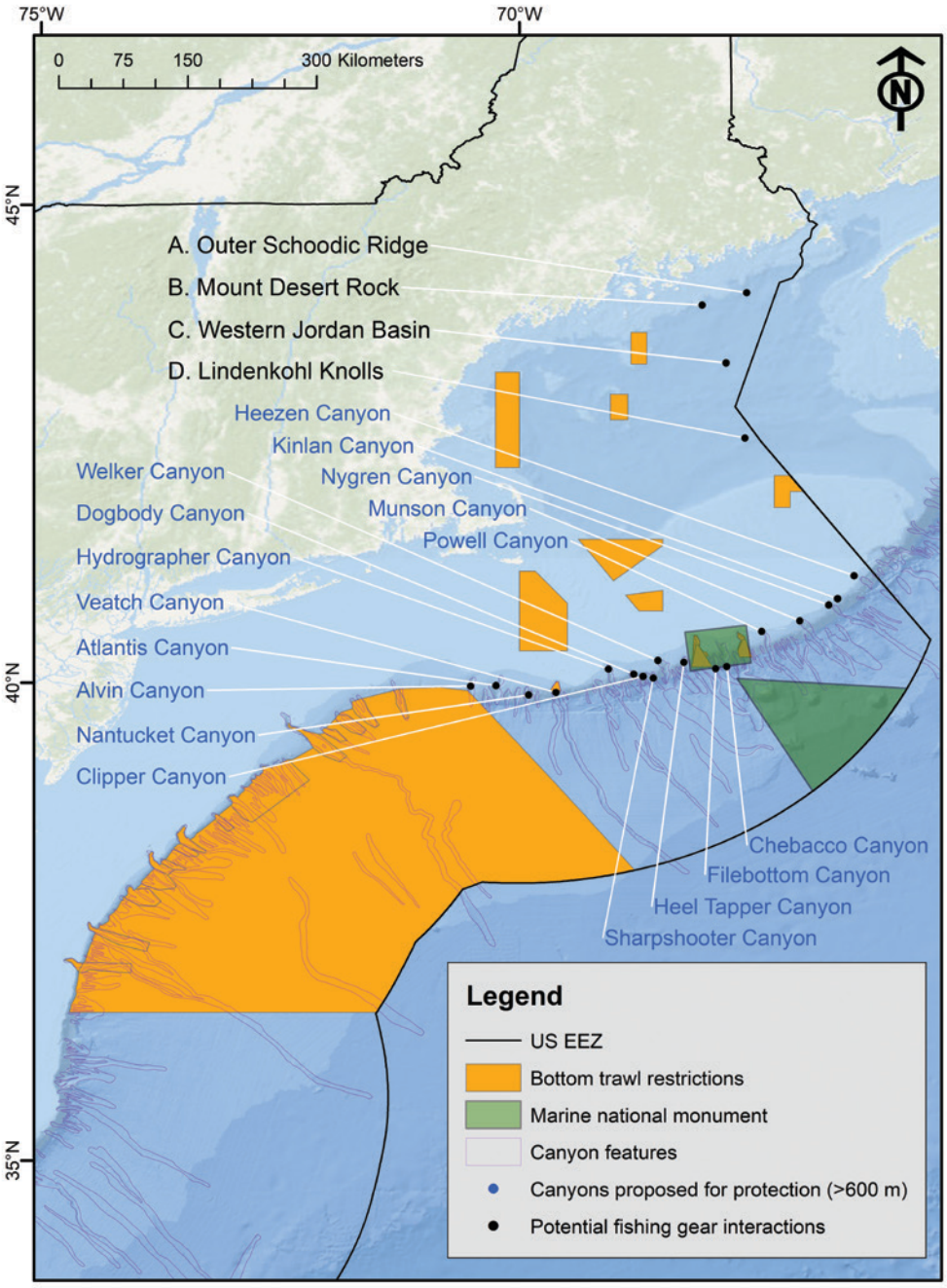


Deep-sea coral and sponge protections and potential for bottom-trawl fishing gear interactions in the U.S. Pacific region's exclusive economic zone (EEZ).

New England and Mid-Atlantic Regions

Since 2015, both the Mid-Atlantic and New England Fishery Management Councils have proposed management measures to protect deep-sea coral habitat, particularly on canyons and deep slopes. In 2017, NOAA approved protections for canyons and slopes proposed by the Mid-Atlantic Council that extend from approximately 450 meters depth to the edge of the EEZ. The Northeast Canyons and Seamounts Marine National Monument protects four seamounts and several canyons from most bottom-contact fishing gear impacts. A number of additional areas containing deep-sea coral communities have been proposed for protection by the New England Council (currently under review by NOAA), including canyons and slopes deeper than 600 meters and four areas of high-density coral gardens in the Gulf of Maine.

A. Outer Schoodic Ridge.
B. Mount Desert Rock.
C. Western Jordan Basin.
D. Lindenkohl Knolls.

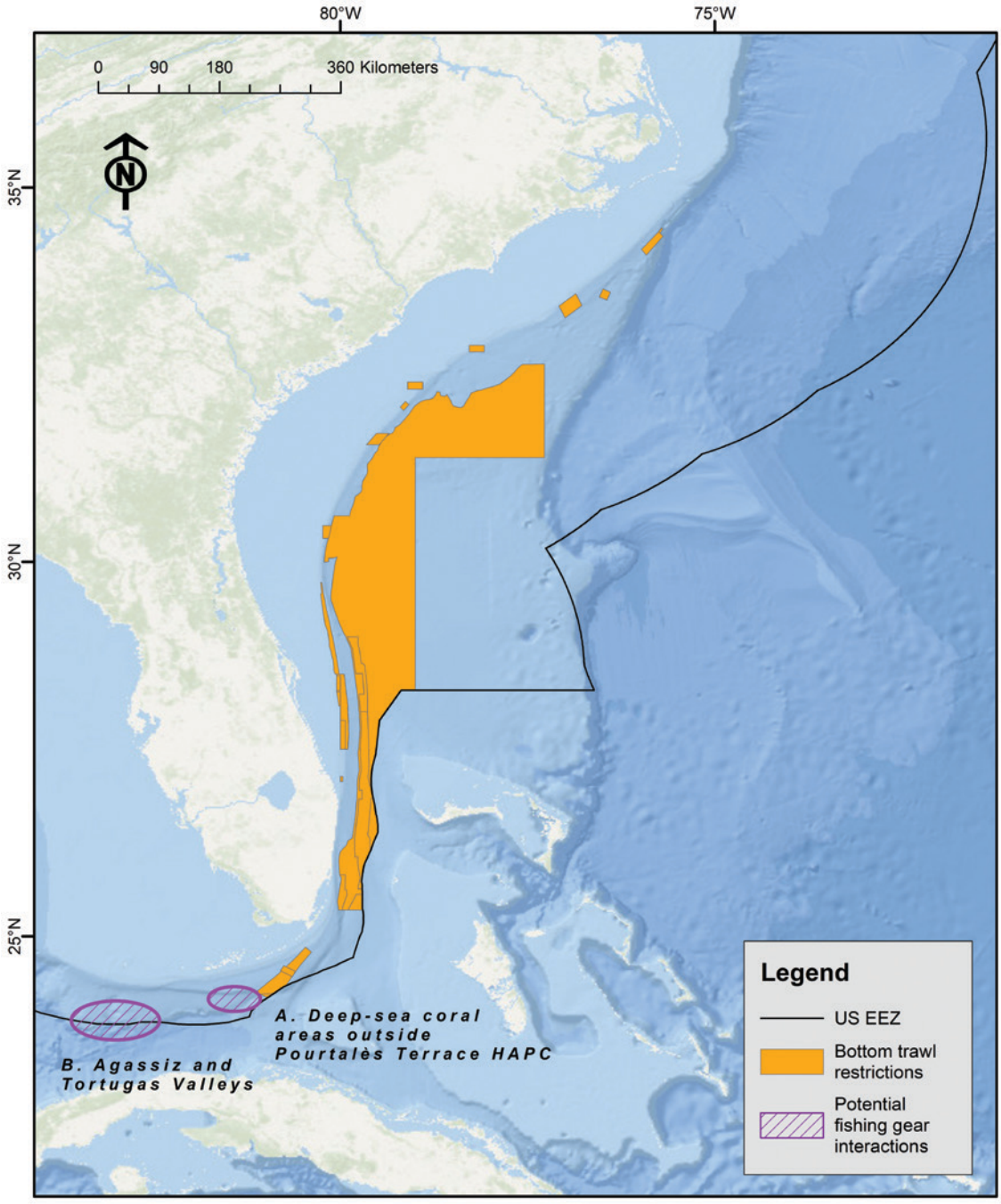


Deep-sea coral and sponge protections and potential for bottom-trawl fishing gear interactions in the U.S. New England and Mid-Atlantic regions' exclusive economic zone (EEZ). Note that canyon features are outlined in pink, and green monument designations are semi-transparent to show overlapping bottom trawl restrictions. The New England Fishery Management Council proposed protecting its EEZ deeper than 600 meters from bottom trawling in January 2018.

South Atlantic Region

The South Atlantic Fishery Management Council has closed large areas of its region to bottom fishing to protect deep-sea coral habitats, including five coral habitat areas of particular concern (CHAPCs) and the Oculina Bank HAPC. In 2015, regulations to implement Amendment 8 to the Coral Fishery Management Plan became effective, expanding the boundaries of two CHAPCs and the Oculina Bank HAPC to incorporate additional coral habitats identified by the Program and partners. Coral aggregations outside of the protected areas include the following.

A. Deep-sea coral areas outside the Pourtalès Terrace CHAPC.
B. Agassiz and Tortugas Valleys.

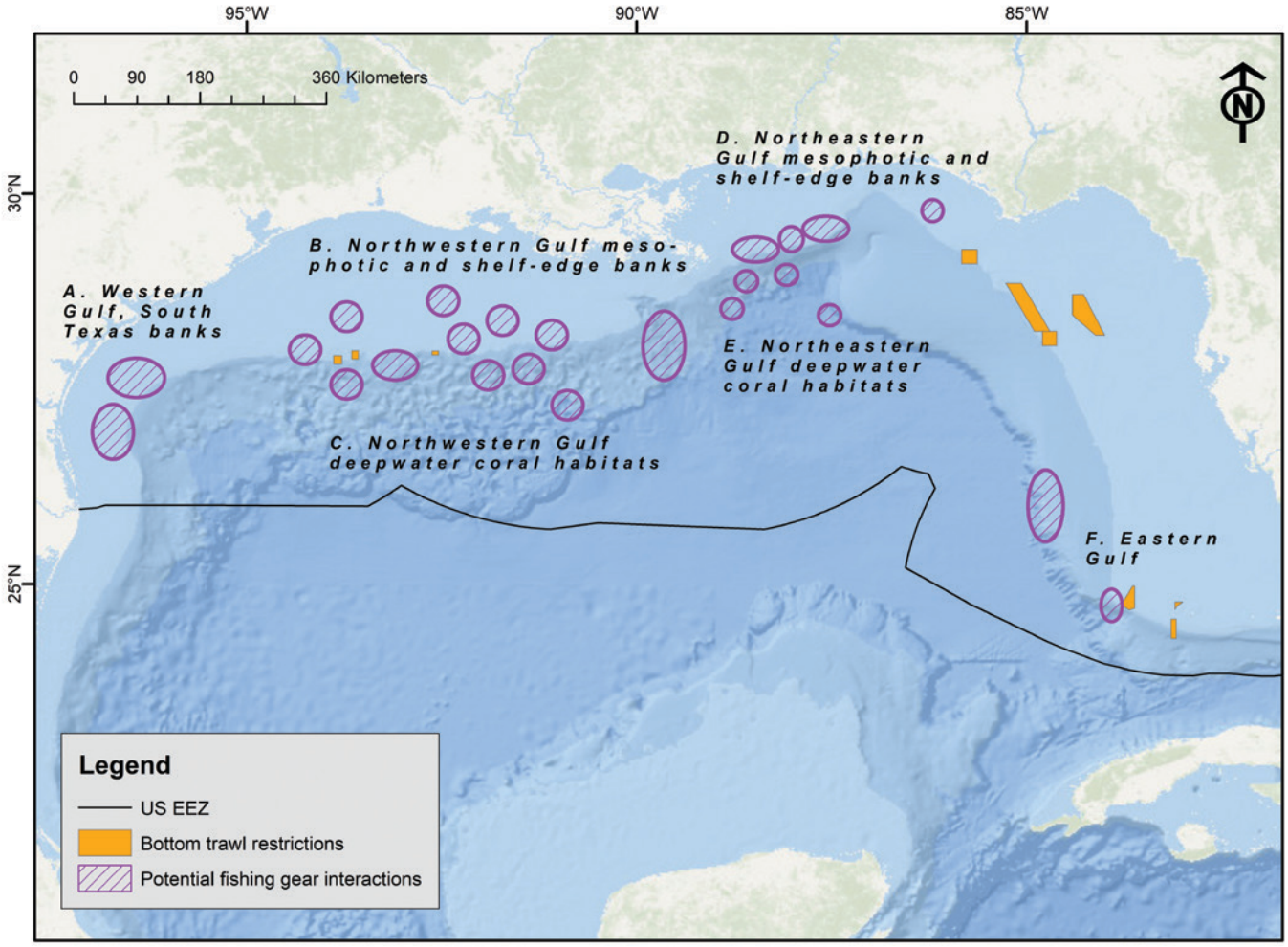


Deep-sea coral and sponge protections and potential for bottom-trawl fishing gear interactions in the U.S. South Atlantic region's exclusive economic zone (EEZ).

Gulf of Mexico Region

In the Gulf of Mexico, a number of deep-sea coral aggregations have been documented in habitats open to bottom fishing, as listed below. In 2018, the Gulf of Mexico Fishery Management Council is considering protecting a set of proposed sites as habitat areas of particular concern within many of these habitats.

A. Western Gulf South Texas Banks.
B. Northwestern Gulf mesophotic and shelf-edge banks.
C. Northwestern Gulf deepwater coral habitats.
D. Northeastern Gulf mesophotic and shelf-edge banks.
E. Northeastern Gulf deepwater coral habitats.
F. Eastern Gulf off southwest Florida.

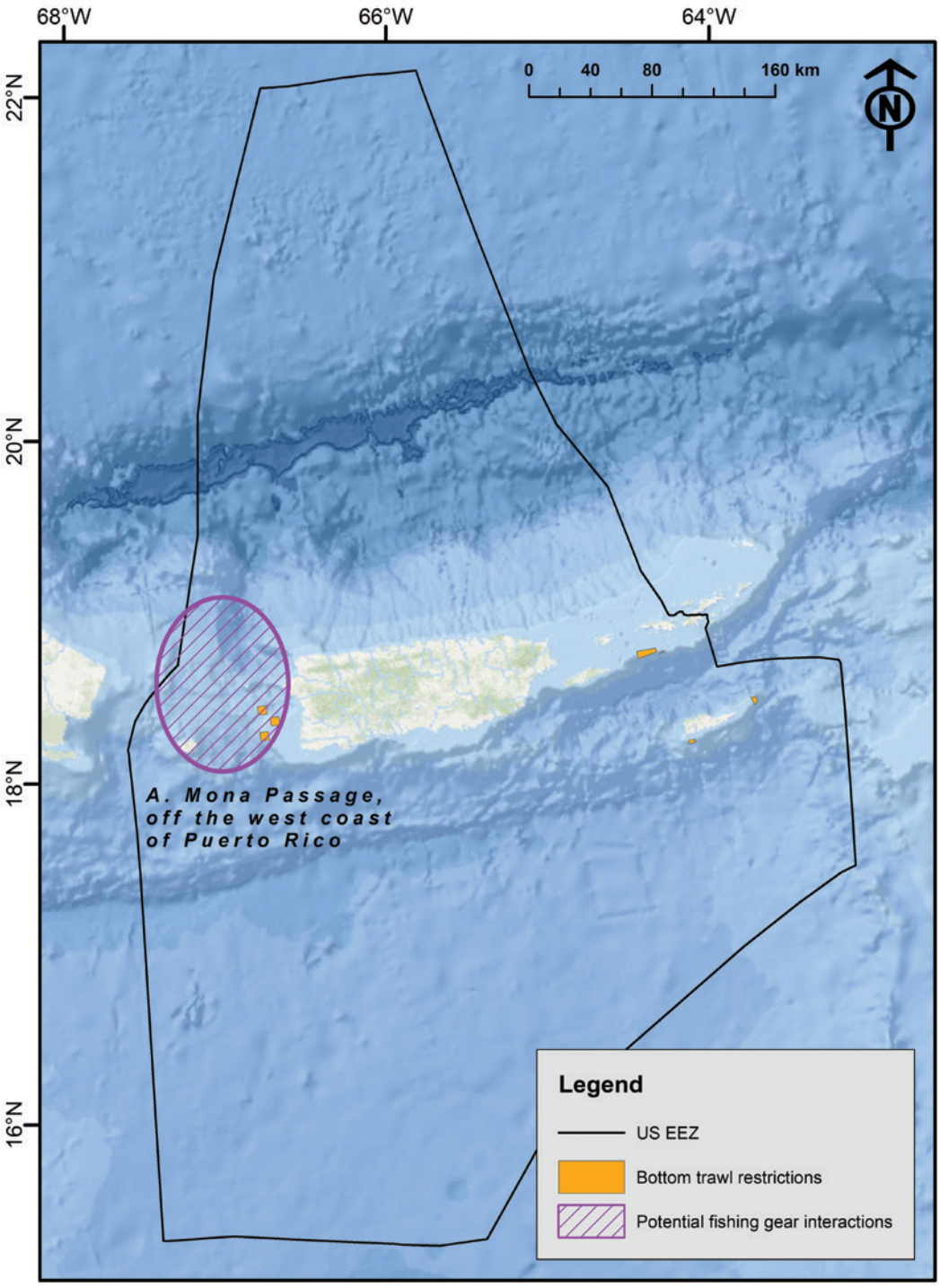


Deep-sea coral and sponge protections and potential for bottom-trawl fishing gear interactions in the U.S. Gulf of Mexico region's exclusive economic zone (EEZ).

U.S. Caribbean

Research on deep-sea habitats in the U.S. Caribbean to date is limited, and specific locations of deep-sea corals and their amount of contact with fishing gear are not well known. However, a major area of deep-sea coral aggregations open to bottom fishing includes the following.

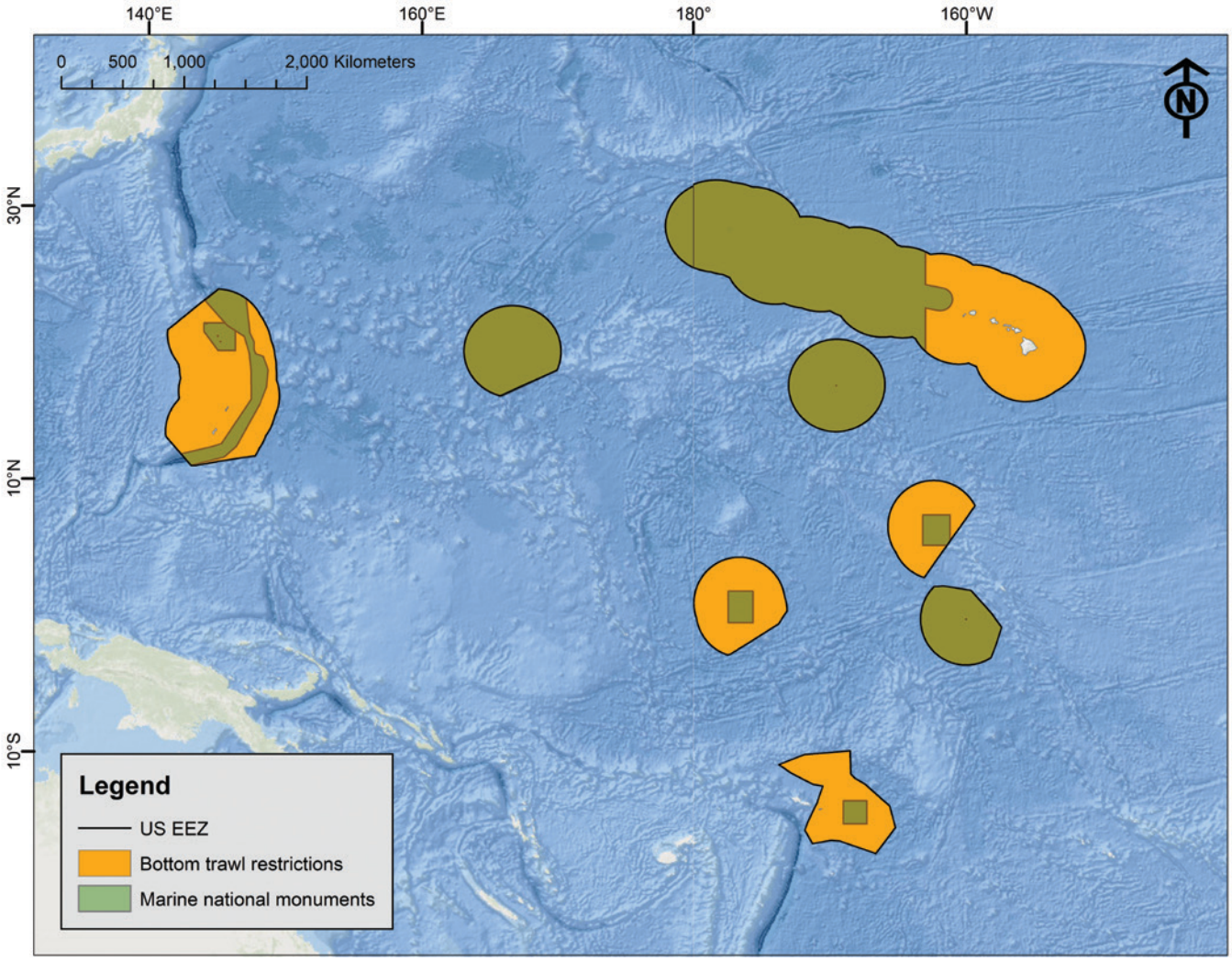
A. Mona Passage, off the west coast of Puerto Rico, where deep-sea corals have been documented.



Deep-sea coral and sponge protections and potential for bottom-trawl fishing gear interactions in the U.S. Caribbean region's exclusive economic zone (EEZ).

Pacific Islands

Bottom trawls, bottom longlines, and bottom gillnets have been prohibited throughout the U.S. Pacific Islands EEZ since 1983. Thus, there is little potential for bottom gear to interact with deep-sea corals in this region. A number of marine national monuments have recently been established or expanded in the Pacific Islands, and recent surveys have documented important deep-sea coral communities in these monuments.



Deep-sea coral and sponge protections in the U.S. Western Pacific region's exclusive economic zone (EEZ). Bottom trawling is prohibited in the entire Western Pacific EEZ. Note that green monument designations are semi-transparent to show overlapping bottom trawl restrictions.

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National Oceanic and Atmospheric Administration
RDML Tim Gallaudet, Ph.D., USN Ret., Acting NOAA Administrator

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