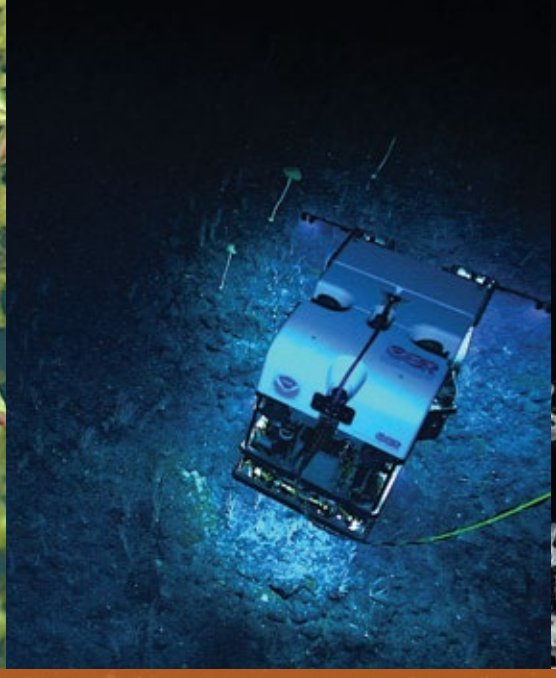


Deep Sea Coral Research and Technology Program
2016 Report to Congress

NOAA FISHERIES

About This Report

The National Oceanic and Atmospheric Administration's (NOAA's) **Deep Sea Coral Research and Technology Program** (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 biennial report to Congress and the public summarizes 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, Fisheries Regional Offices, National Centers for Coastal Ocean Science, and National Centers for Environmental Information. These programs and offices support exploration, research, 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 2014 and 2015 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 by details of these activities available at https://deepseacoraldata.noaa.gov/. The report also briefly describes progress during this period in MSA-related management actions that contribute to protecting deep-sea coral areas.

A subset of deep-sea coral research activities funded and carried out by NOAA programs and offices other than the Deep Sea Coral Research and Technology Program are briefly acknowledged in the report but not specifically discussed as they are outside the scope of this report.

Deep Sea Coral Research and Technology Program
National Marine Fisheries Service

2016. All photos from NOAA, except as noted.

COVER PHOTOS: Top photos are from NOAA Ship Okeanos Explorer's Hohonu Moana *expedition in 2015. Left: Squat lobster on undescribed genus of bamboo coral (family Isididae, discovered in 2007 in the Papahānaumokuākea Marine National Monument). Middle: NOAA's* Deep Discoverer *remotely operated vehicle surveys seafloor in Northwestern Hawaiian Islands. Right: Brittle stars entwined in a gorgonian coral, on a ridge that had been completely unexplored. Bottom: Red bubblegum coral (*Paragorgia sp.*) and pale* Lophelia pertusa *corals provide habitat at 300 meters (nearly 1,000 feet) deep in Southern California's Channel Islands National Marine Sanctuary.*

Contents

Starfish and abandoned fishing net with Primnoa coral at Outer Schoodic Ridges, Gulf of Maine

Coral colony at East Salmon Bank, more than 2,100 meters (6,890 feet) deep in the Papahānaumokuākea Marine National Monument, as observed on the 2015 Hohonu Moana *expedition.*

Executive Summary

In every U.S. region, near and far from the shoreline, deep-sea corals grow slowly in the darkness and sustain an array of marine life. These complex habitats are areas of high biodiversity and activity for commercial fish and other marine species. In 2014 and 2015, six of the eight U.S. Regional Fishery Management Councils worked to improve the management of deep-sea coral habitats. To inform these Council actions, NOAA's Deep Sea Coral Research and Technology Program supports essential science and provides distinctive information to guide management of these unique ecosystems. With an investment averaging only $2.48 million per year and through its extensive partnerships, this Program is creating the foundation to understand deep-sea coral distribution, biology and ecology.

The Program completed fieldwork in two regions in this 2-year period. The Northeast Fieldwork Initiative visually surveyed 31 submarine canyons between Maine and Virginia and discovered coral gardens just 25 miles off the coast of Maine. Secondly, the Alaska Fieldwork Initiative systematically took images of the seafloor at more than 200 stations throughout the 1,200-mile Aleutian Islands chain, confirming widespread corals and commercially important fish using the coral areas. These initiatives tell us about many deep-sea coral communities that no humans had seen before. The involved scientists shared their findings and enabled the respective Councils to act on the newest data.

The Program is a central partner for new research in the Pacific Islands region that began in 2015 and will continue until 2017. This research is also discovering deep-sea coral communities, and likely new species, in places never before surveyed. These observations support the region's national marine sanctuaries and extensive new marine national monuments, many of which are remote and rarely studied.

The Program's Deep-Sea Coral Data Portal (https://deepseacoraldata.noaa.gov), launched in 2015, includes a library, photo gallery, and searchable map displaying the distribution of more than 300,000 deep-sea corals and sponges. Maintained by the Program, the portal presents the most comprehensive collection of deep-sea coral and sponge information for U.S. waters.

None of these accomplishments would be possible without the extensive contributions from our collaborators within and outside of NOAA. The elements needed to make this program such a success—from ship time, predictive habitat suitability models, underwater survey tools, lab analyses, to the data management processes—are a result of multiple partners pooling resources together for a shared mission. This cooperation exemplifies NOAA's commitment to building partnerships internally and externally to deliver high-quality research in a cost-effective manner.

Our collaborations are translating rapidly into better management and conservation, and 2015 saw the development of the first proposed deep-sea coral zone under the Regional Fishery Management Councils' discretionary authority to protect corals from fishing gear impacts. The Mid-Atlantic Fishery Management Council has proposed the designation of the Frank R. Lautenberg Deep-Sea Coral Protection Area in honor of the late senator from New Jersey who advocated for deep-sea coral conservation. Encompassing more than 38,000 square miles, this area would be about the size of Virginia. Much of the area is based on the results of various studies conducted by NOAA and communicated to the Council through frequent engagements. The Program will continue to support the Councils as they develop habitat management measures for deep-sea coral areas around the nation.

We are only just starting to understand the basics of where and how deep-sea corals grow. Further studies will help us better understand how they contribute to resilient ecosystems and sustainable fisheries. In the coming years, the Program plans to explore the Pacific Islands' deep-sea coral communities further, investigate priority areas in the Southeast, and support continuing research in other regions of the United States.

A deep-sea red crab clings to bubblegum coral in a northeastern canyon.

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-foot depth) to more than 10,000 feet down. 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.

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.

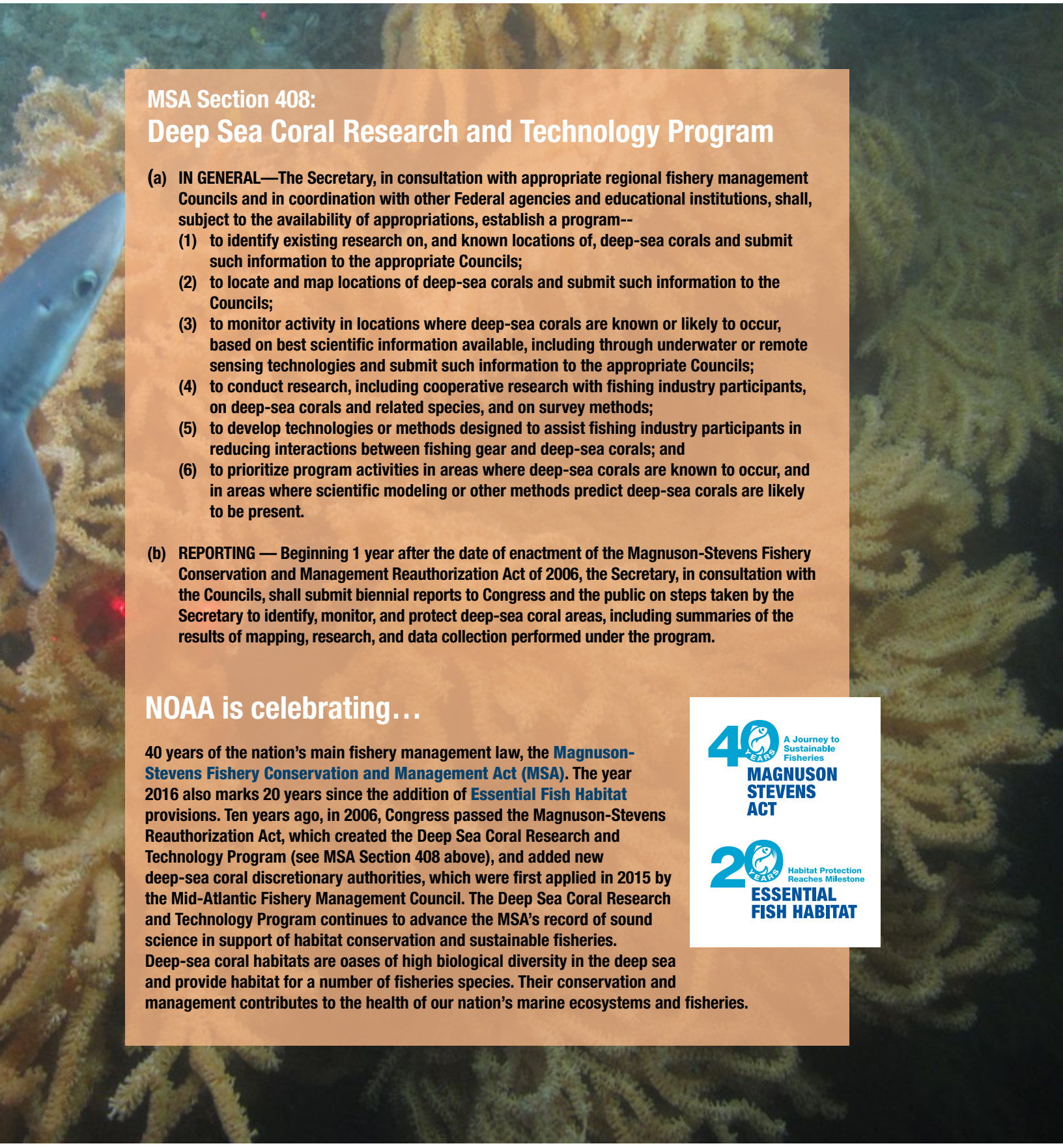
Lace corals, like these off California, are actually hydroids and only distantly related to other corals.

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

A few deep-sea coral species form reefs that, over millennia, can grow more than 100 meters (300 feet) tall. Many other coral species are shaped like bushes or trees and can form assemblages similar to groves or forests on the seafloor.

Nationwide, these complex structures provide habitat for many fish and invertebrate species, including certain commercially important ones such as grouper, snapper, sea bass, rockfish, shrimp, and crab. Moreover, organisms that live in deep-sea coral habitats produce chemicals having great potential for biomedical uses, and some deep-sea coral species have commercial value as jewelry and art objects.

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 carbon dioxide—can adversely affect corals' ability to grow or maintain their structures.



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.

NOAA is celebrating…

40 years of the nation's main fishery management law, the **Magnuson-Stevens Fishery Conservation and Management Act (MSA)**. The year 2016 also marks 20 years since the addition of **Essential Fish Habitat** provisions. Ten years ago, in 2006, Congress passed the Magnuson-Stevens Reauthorization Act, which created the Deep Sea Coral Research and Technology Program (see MSA Section 408 above), and added new deep-sea coral discretionary authorities, which were first applied in 2015 by the Mid-Atlantic Fishery Management Council. The Deep Sea Coral Research and Technology Program continues to advance the MSA's record of sound science in support of habitat conservation and sustainable fisheries.
Deep-sea coral habitats are oases of high biological diversity in the deep sea and provide habitat for a number of fisheries species. Their conservation and management contributes to the health of our nation's marine ecosystems and fisheries.

40 YEARS A Journey to Sustainable Fisheries
MAGNUSON STEVENS ACT

20 YEARS Habitat Protection Reaches Milestone
ESSENTIAL FISH HABITAT

Northeast Research Connects with Habitat Conservation

The Deep Sea Coral Research and Technology Program sponsored a Northeast Fieldwork Initiative from 2013 to 2015 with the primary objective to locate and characterize deep-sea coral communities in the region, which extends from offshore of Maine to Virginia. NOAA scientists, in collaboration with university researchers and other partners, implemented the initiative. Leveraging expertise and funding with other partners within and outside of NOAA and employing a wide range of research tools, the initiative advanced the science of deep-sea corals in the region's submarine canyons, seamounts, and coral gardens.

Northeast Fieldwork Initiative

BY THE NUMBERS

$2,379,000 contribution from the Program, over 3 years (2013-2015)

9 cruises completed

300,000 images collected

470 hours of video recorded

147 camera tows

31 canyons visually surveyed

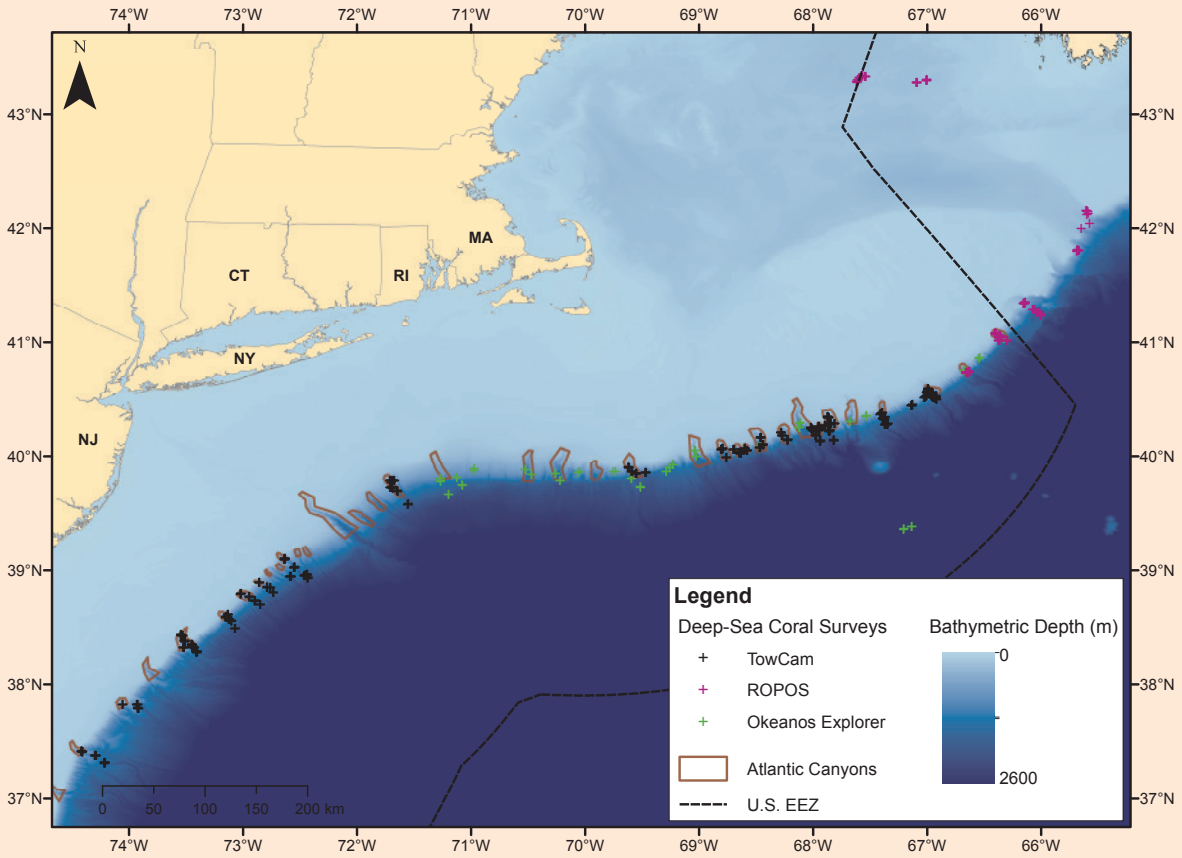
3 presentations to the Mid-Atlantic Fishery Management Council and its advisory bodies

3,271 meters (10,732 feet), deepest observation during the initiative

Canyons and Seamounts

Under the initiative, teams of scientists conducted surveys throughout the Northeast region using either a towed

Large bubblegum coral colonies in Heezen Canyon.

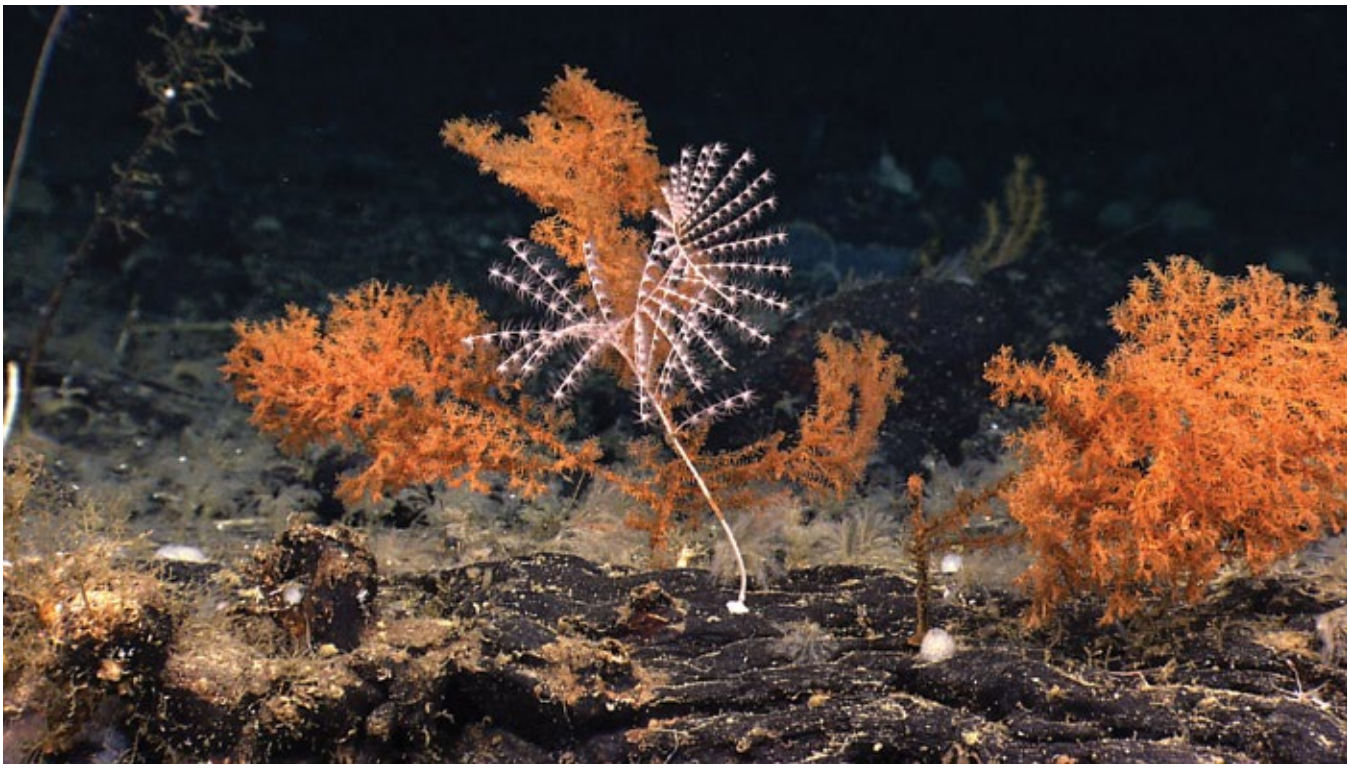


From canyons and other sites (shown as black crosses) surveyed by NOAA and partners in 2012–2015 using a towed camera system, more than 168,000 images were gathered. Also shown are sites sites surveyed by ROVs in the 2014 Remotely Operated Platform for Ocean Science (ROPOS) cruise and the 2013 *Okeanos Explorer* cruise.

camera system or a remotely operated vehicle (ROV) deployed from NOAA ships. Each summer, several major and minor canyons and inter-canyon areas were investigated. Many of these canyons had never been surveyed previously; for other canyons, only limited, historical data were available. Canyons were prioritized and selected for survey in consultation with the New England and Mid-Atlantic Fishery Management Councils, along with input from other state and local partners. Given the management interest in locating deep-sea coral habitats, it was extremely important to target surveys at those areas most likely to support coral growth. Using high-quality multibeam sonar maps and results of a regional habitat suitability model to guide their sampling, scientists collected videos and photos from almost all the major canyons, several minor canyons, and one previously unexplored seamount in the region.

Overall 24 canyons were investigated using a towed camera.[1] The 86 camera tows resulted in more than 168,000 images revealing steep canyon walls, sedimented slopes, and isolated boulders. Stony corals, black corals, most gorgonian and soft corals, and the majority of sponges observed were on

[1] Investigations included three research cruises during the 2013–2015 initiative, and a cruise in 2012 to validate the habitat suitability model to prepare for the initiative.



High diversity of corals, including black corals and several species of gorgonian corals, all living together to form a community.

hard substrates, whereas sea pens and red crabs were common on soft sediments. Canyon morphology, the degree of sedimentation, depth, and currents appear to play a role in the biodiversity of corals, sponges, and fishes observed in each canyon. Scientists observed corals in every canyon; however, abundance and diversity of corals varied dramatically. For example, only a few colonies of widely dispersed corals were observed in Washington Canyon (off Virginia) whereas a "coral forest" of bubblegum corals was observed in Heezen Canyon (off Maine).

Several large species of gorgonian corals were distributed throughout the canyon system. The sea fan, *Paramuricea* sp., was commonly observed in Munson, Powell, Gilbert, and Veatch canyons. Overall, stony corals were not especially abundant or diverse. A solitary, small cup coral was the most often observed stony coral, usually seen on canyon walls and in dense aggregations along ledges or overhangs. Other highlights from these cruises included the first observations of black corals in some of the northern canyons (e.g., Gilbert Canyon), discovery of a biodiversity hotspot in the relatively shallow (300–500 meters, or 980–1,640 feet) Wilmington Canyon, and observations of corals in minor canyons. Each canyon appears to have its own biological and geological signature.

Scientists are currently analyzing nearly 170,000 images from the towed camera to describe and quantify the corals, sponges, fishes, and other invertebrates observed at these locations. Additionally, locations of corals and sponges will be added to NOAA's Deep-Sea Coral and Sponge Database and available for download on the Deep-Sea Coral Data Portal. Scientists will summarize each of the 86 camera tows and publish site characterization reports.

In 2013, the Program partnered with the Office of Ocean Exploration and Research and others to conduct the Northeast U.S. Canyons Expedition in 2013 aboard NOAA ship *Okeanos Explorer*. During 31 ROV dives, scientists surveyed eight major canyons, three minor canyons, areas on the continental slope, and Mytilus seamount. They observed at least 58 taxa of deep-sea corals representing 20 families.[2] At least 24 species had never been documented in previous faunal lists for this region; geographic range extensions are likely for several additional species after all images are reviewed. Results also show that the fish and crustacean species observed in and around coral habitat are correlated with coral species richness. It is possible that corals increase local diversity of associated species, since some species use corals as a hiding place, forage ground, or spawning habitat. For example, several species of squat lobsters and brittle stars are closely associated with deep-sea corals.

This expedition also had a major public outreach component. Interest in deep-sea corals grew as many tuned in to the expedition's website to see firsthand what these deep-sea habitats looked like. Traffic to the live video feeds, web pages, and social media hit all-time highs for *Okeanos Explorer* expeditions, and more than 660,000 views were recorded.

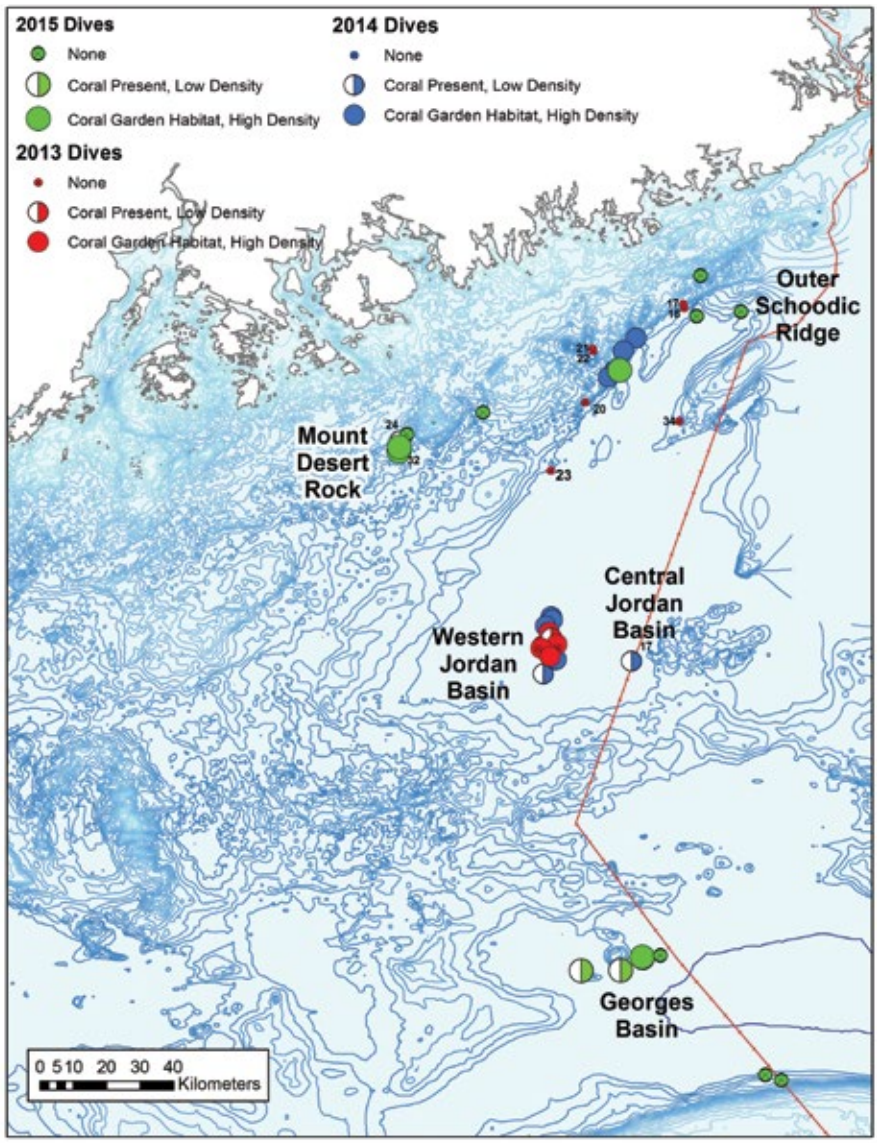
The discovery of new deep-sea communities and documentation of many rarely seen organisms represent only a glimpse of what these canyon habitats have to offer. The scientific

[2] Quattrini AM, Nizinski MS, Chaytor JD, Demopoulos AWJ, Roark EB, France SC, et al. (2015) Exploration of the Canyon-Incised Continental Margin of the Northeastern United States Reveals Dynamic Habitats and Diverse Communities. PLoS ONE 10(10): e0139904. doi:10.1371/journal. pone.0139904

Crew on the NOAA Ship Henry Bigelow *prepare for a dive with the Canadian ROPOS remotely operated vehicle.*

sampling method of using transects, ranging in length between 300 and 2,200 meters (984–7,218 feet), covers only a small portion of the diverse habitats in canyons that can be miles long and deep.

To further study coral habitats in the canyons, the Northeast Initiative established a successful partnership between Canada and the United States. In 2014, NOAA scientists, Canadian and U.S. academic partners, and Fisheries and Oceans Canada collaborated to characterize coral communities in the cross-boundary Gulf of Maine region—one of the most biologically productive ecosystems in the world. Using a Canadian ROV and a NOAA vessel, the project team collected videos, photos, and coral samples from Nygren and Heezen canyons in U.S. waters, and Corsair Canyon and the Northeast Channel Coral Conservation Area in Canada. Highlights of this mission included surveys in poorly known canyons, discovery of extraordinary deep-sea coral communities in Corsair Canyon, and collection of physical samples. These samples will be used for taxonomic identifications and inform ongoing research on coral population genetics, reproductive studies, and aging analyses.



Locations of deep-sea coral communities observed in the Gulf of Maine.

Coral Gardens in the Gulf of Maine

NOAA scientists partnered with researchers from the University of Connecticut to conduct 3 years of surveys, resulting in the discovery of spectacular "coral gardens" approximately 25 miles off the coast of Maine (see map). Using an ROV and a towed camera system, they found dense and extensive coral cover in western Jordan Basin, Outer Schoodic Ridge, and near Mount Desert Rock,

especially in areas of high vertical relief.[3] Based on preliminary analyses of images taken in 2013, these areas had some of the highest densities (8.6–15.7 colonies per square meter) of corals observed in the region. Colonies were so densely packed in some coral gardens in Outer Schoodic Ridge that it was challenging for scientists to obtain an accurate count. Central Jordan Basin and Georges Basin also contained coral communities, but those colonies were more patchy, less dense, and in lower relief environments than the aforementioned areas.

A few species of gorgonian corals dominate these Gulf of Maine sites. Corals on the steep vertical walls and cliffs of Outer Schoodic Ridge and Mount Desert Rock were primarily *Primnoa resedaeformis*, with lower abundances of *Paramuricea placomus*. Conversely, the major coral species found in western and central Jordan Basin and Georges Basin was *Paramuricea placomus*, with lower abundances of *Primnoa resedaeformis* and *Acanthogorgia cf. armata*.

A number of commercially important fish and shellfish species were observed at the coral sites, including Acadian redfish, haddock, pollock, cusk, monkfish, cod (both juveniles and adults), silver hake, spiny dogfish, and lobster. The fish were observed searching for and catching prey (e.g., shrimp, amphipods, krill, and other small fish) that were also found among the coral.

Within sites in Western and Central Jordan Basin, Outer Schoodic Ridge, and Georges Basin, coral communities exhibited evidence of damage, likely from recent fishing activities with bottom trawls or the setting and recovery of traps. In some steep areas, tracks left by fishing gear were denuded of corals and associated fauna. In other coral patches, large but still living colonies appeared

[3] Auster PJ, et al. (2014) Imaging Surveys of Select Areas in the Northern Gulf of Maine for Deep-sea Corals and Sponges during 2013-2014. Report to the New England Fishery Management Council - 1 December 2014.

Abundant Acadian redfish and Primnoa *corals were observed at Outer Schoodic Ridge in 2014.*

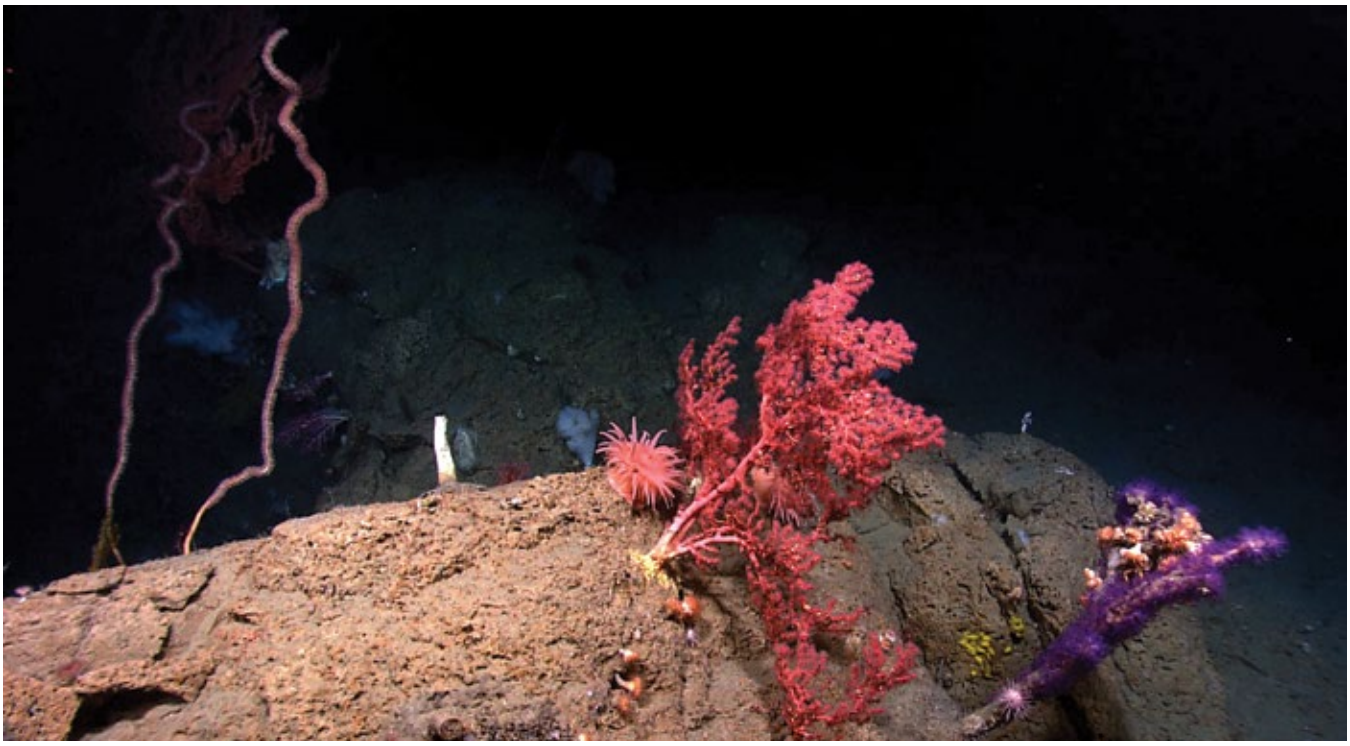
Control room for the Canadian ROPOS remotely operated vehicle.

damaged. The difference in coral sizes observed in some patches suggests previous impacts followed by recovery as evidenced by settlement and growth of young corals. In areas such as Georges Basin, *Paramuricea* and associated species were often small; virtually all colonies occurred in rocky refuges out of the reach of fishing gear.

A highlight among the findings from this research is that the high-density coral areas were discovered only 25 miles from the coast in relatively shallow waters (200–250 meters, or 656-820 feet). Coral habitat here encompasses an area much larger than previously thought. The proximity of these habitats to shore, their associations with commercially important fish and shellfish species, and the evidence of fishing gear impacts increase the likelihood that they function as key habitat for managed fish species.

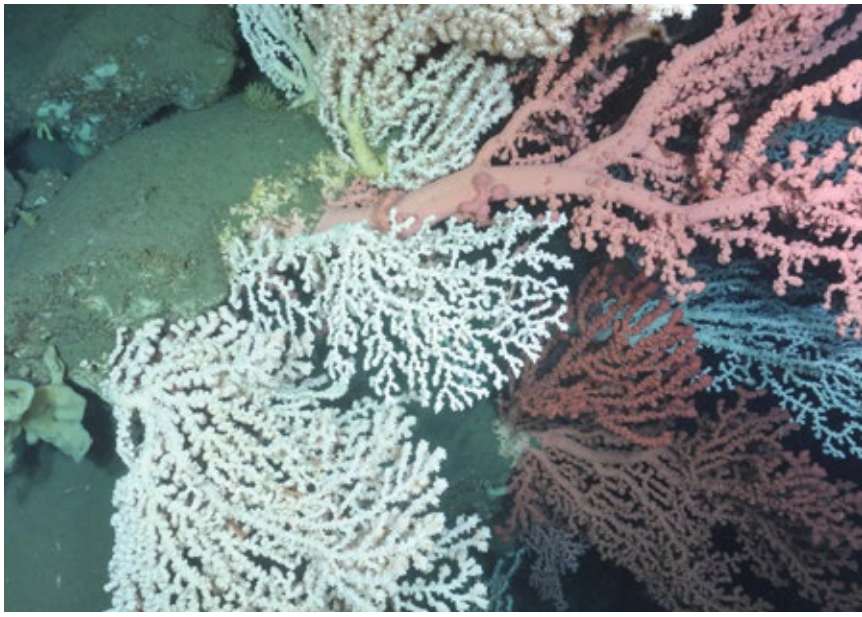
Detailed analyses of images to determine coral and sponge distributions in relation to geology, associated species, and coral size structure are ongoing. Specimens, primarily of the dominant corals *Primnoa* and *Paramuricea*, were collected during ROV dives in Outer Schoodic Ridge and Western and Central Jordan Basin, and these specimens will be incorporated into studies on taxonomy, reproduction, age and growth, and genetics.

The 2014 Gulf of Maine cruise in collaboration with Canadian partners, as described in the previous section, also surveyed Jordan Basin on both sides of the international boundary. Data collected during this mission extended the known distribution of deep-sea coral habitats in the western North Atlantic and expanded U.S. investigations to encompass the entire Gulf of Maine ecosystem. This project also opened lines of communication across borders to manage and protect marine resources. U.S. scientists gained valuable experience by working with Canadian colleagues who have conducted deep-sea coral research in the region for a longer period and who have enacted a variety of conservation initiatives to protect deep-sea coral habitats. These collaborations and data lay the foundation for future conservation efforts in U.S. waters and across the border.



Our Northeast Fieldwork Initiative has exponentially increased knowledge of deep-sea coral habitats in the submarine canyons and Gulf of Maine, and revealed that much remains to be explored. Deep-sea research requires expensive and specialized ships and survey equipment, and the Program benefited from assets and expertise from numerous partners, thus allowing the completion of nine major expeditions.

Details on these and other projects under the Northeast Fieldwork Initiative are available at NOAA's Deep-Sea Coral Data Portal: https://deepseacoraldata.noaa.gov/fieldwork-studies/ne-fieldwork-fy13-15.



Above, octocorals, cup corals, and anemones share a rock at 1,459 meters (4,800 feet) in Hendrickson Canyon. Bottom, coral colonies in Heezen Canyon.

Alaska Research Explores Ecologically Rich Deep-Sea Coral Habitats

Deep-sea corals have been observed throughout the Alaska region, ranging from a single species of small soft coral in the Arctic Ocean, to large communities in the Gulf of Alaska. In the Aleutian Islands, scientists found 137 coral and 150 sponge species, of which 85 or more may exist nowhere else in the world. Deep-sea coral abundance, size, and diversity in some communities in Alaska are among the highest on Earth.[4]

Previous information on the distribution of these corals came from decades of trawl and longline surveys for fisheries stock assessments, bycatch records from commercial fisheries, and limited underwater visual surveys primarily in 2002-2004 and 2010 targeting coral communities. In this reporting period, the Deep Sea Coral Research and Technology Program's Alaska Fieldwork Initiative concluded 3 years of extensive at-sea research and filled many knowledge gaps with undersea observations, coral habitat models, and a suite of studies on coral biology and ecology.

Alaska Fieldwork Initiative

BY THE NUMBERS

$2,608,811 support from the Deep Sea Coral Research and Technology Program, over 3 years (2012-2014)

11 projects

6 research cruises to visually locate and characterize coral habitats

5 research cruises to examine rockfish habitat use in the central Gulf of Alaska

216 camera transects in the Aleutian Islands; 68 percent observed corals and 82 percent observed sponges

250 camera transects in the eastern Bering Sea

21,910 in-situ measurements of height for corals and sponges

500,000 photos taken

853 records of coral locations from visual surveys added to NOAA's Deep-Sea Coral Database

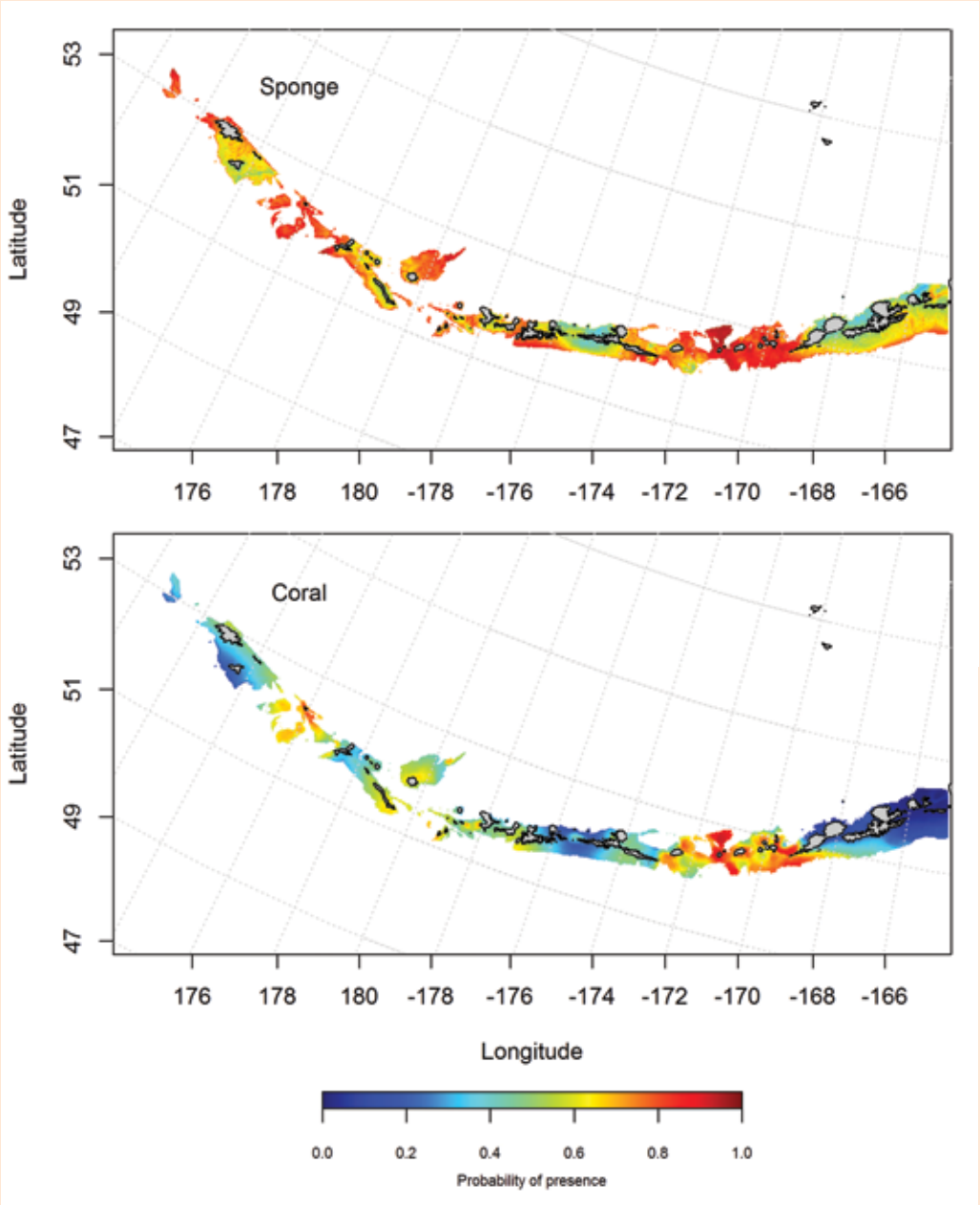
Aluetian Islands habitat models and surveys

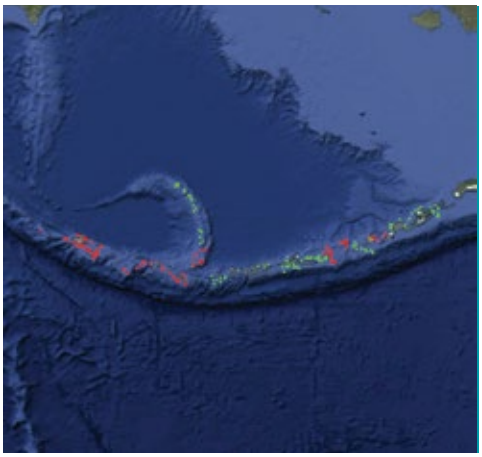
A key project in this three-year initiative was building new habitat models to predict the location, abundance, and diversity of deep-sea corals and sponges in three parts of Alaska: Aleutian Islands, eastern Bering Sea, and Gulf of Alaska. The Aleutian Islands are an active area of volcanic activity and much of the seafloor is comprised of exposed rocks and boulders. The model predicts corals to occur in various parts of the island chain, and sponges are expected to be ubiquitous (see figures).[5] Their distribution seems to be influenced by the currents, probably because the currents sweep the seafloor clear of sediment, creating surfaces for these animals to live on, and because the currents deliver more food particles to them. In the Gulf of Alaska, corals

[4] Stone R P (2014) The ecology of deep-sea coral and sponge habitats of the central Aleutian Islands of Alaska. NOAA Professional Paper NMFS 16.

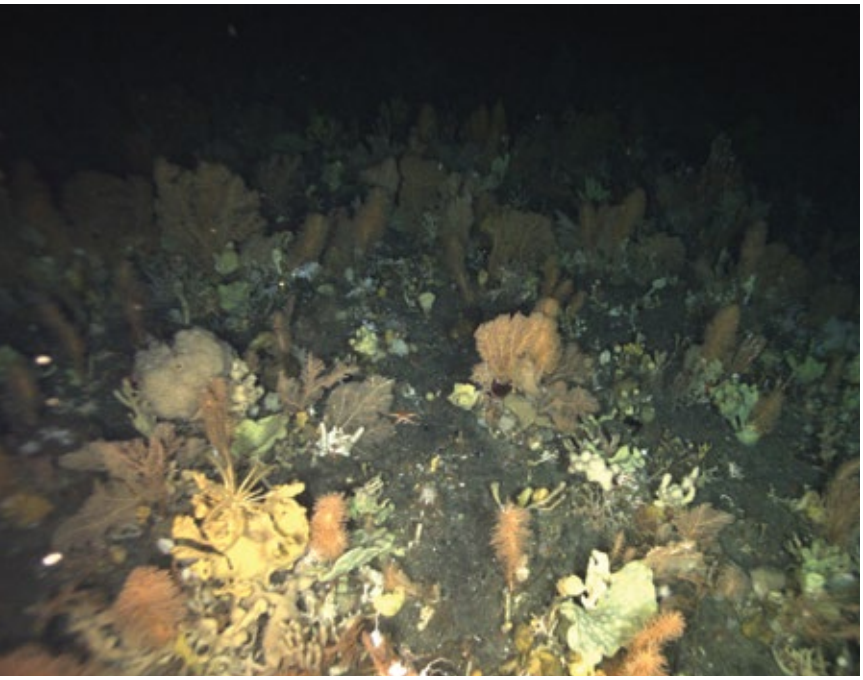
[5] Rooper CN, Zimmermann M, Prescott MM, Hermann AJ (2014) Predictive models of coral and sponge distribution, abundance and diversity in bottom trawl surveys of the Aleutian Islands, Alaska. Marine Ecology Progress Series 503:157-176.

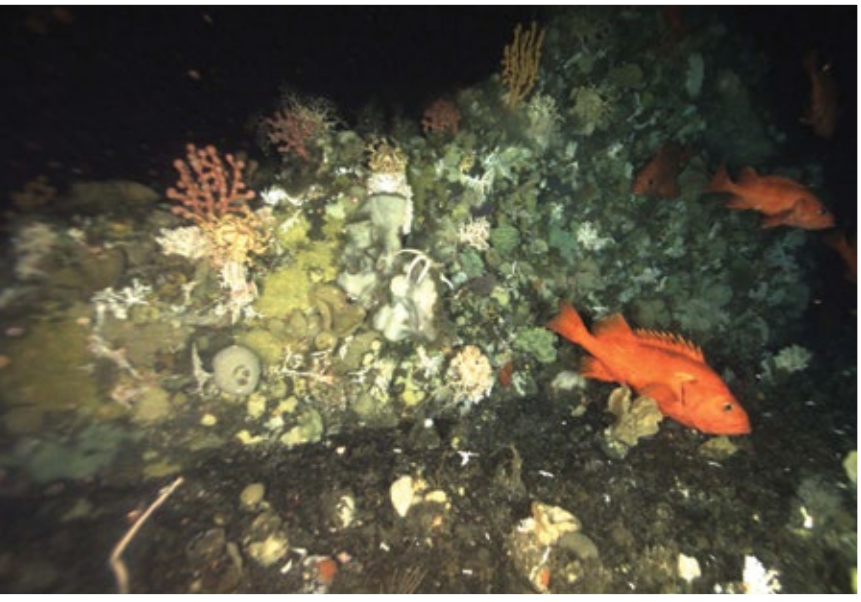
Habitat model predicting the probability of presence of sponges and corals in the Aleutian Islands.





Throughout the Aleutian Islands, 216 locations were visually surveyed. The 2012 survey locations are shown in green, and the 2014 ones in red.





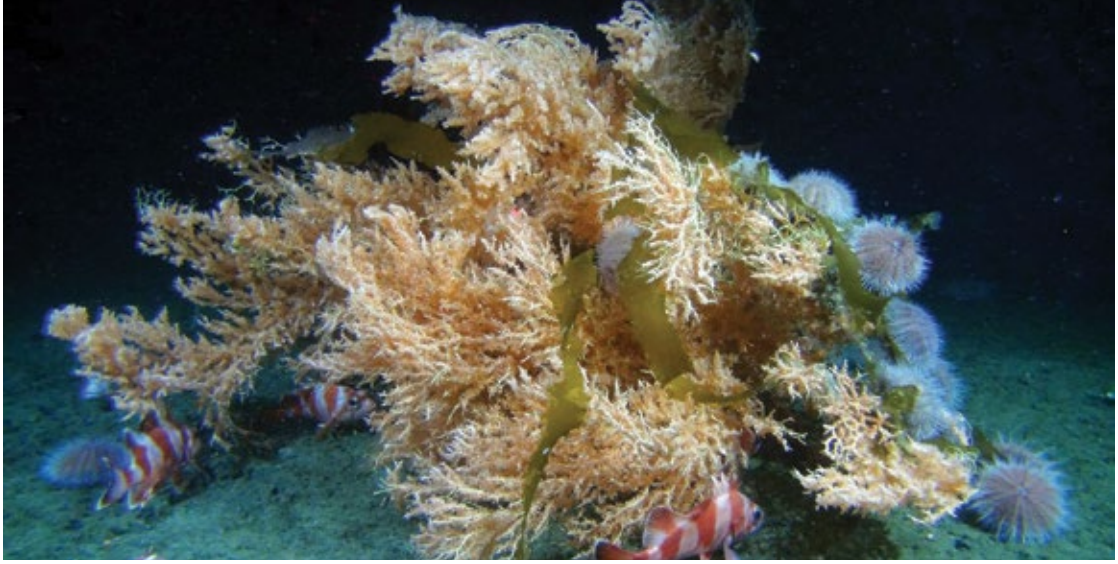
The deep-sea coral and sponge gardens in the Aleutian Islands are among the most dense and diverse deep-sea habitats in U.S. waters.

and sponges are expected to occur in a number of distinct hotspots where depth and currents are suitable.

Scientists deployed a camera system to survey the seafloor and verify the accuracy of the model. Among 216 randomly selected stations throughout the Aleutian Islands, about 68 percent had corals and 82 percent had sponges. Comparing the undersea observations with the model predictions, researchers found that the model performed well in predicting coral presence, and coral and sponge densities.

Most Aleutian corals and sponges measured between 10 and 60 centimeters (4–24 inches) tall, and the tallest coral exceeded 1 meter (3.3 feet). Their average density was 0.5 colonies per square meter for both corals and sponges, but in coral gardens the density can exceed 10 colonies per square meter. Many commercially important fish species were observed among coral and sponge communities in the Aleutian Islands. Atka mackerel and yellow Irish lord (a sculpin species) were both observed guarding egg nests in sponge beds. Various rockfishes were commonly observed using corals and sponges as habitat.

In response to a request from the North Pacific Fishery Management Council, the Program also supported a team of scientists to survey seafloor communities at 250 stations in and around the Bering Sea canyons to validate a separate coral and sponge habitat model. Corals were found at 32 of 250 randomly selected stations. Their densities were



Rockfish and sea urchins congregate around a large red tree coral (Primnoa pacifica) *in the Gulf of Alaska.*

generally highest in Pribilof Canyon, and corals were largest in the slope area to the northwest of Pribilof Canyon. For sponges, densities and heights were highest surrounding Pribilof Canyon, north of Bering Canyon, and in some locations in Zhemchug Canyon. Both corals and sponges were far less dense and diverse than in the Aleutian Islands.

Aside from efforts to develop and groundtruth habitat suitability models, scientists in this fieldwork initiative accomplished many other projects:

Red tree coral habitat areas in the Gulf of Alaska: Red tree corals (*Primnoa pacifica*) can grow exceptionally large, up to 5 meters (16 feet) tall and 7 meters (23 feet) wide,[6] and form dense thickets that provide rich habitat for fish and invertebrate species. Fisheries stock assessment surveys in previous years indicated presence of red tree coral in four sites in the Gulf of Alaska. Researchers in Alaska's 3-year initiative conducted ROV surveys at these sites to determine the presence and habitat preferences of red tree coral colonies and other coral species. They collected coral samples for age, growth, and genetic analyses, and deployed and retrieved settlement plates on the seafloor to study how coral populations grow and how often young corals enter the population. Large red tree coral colonies were found at three of the four sites studied, and the preliminary results have indicated that young corals are rare.

Commercially important fish species in coral and sponge ecosystems: Many fish species targeted by commercial fishing have been observed in coral and sponge ecosystems in Alaska, but whether and how corals and sponges support fisheries had not been fully studied. In this fieldwork initiative, scientists repeatedly observed six sites off of Kodiak—two with corals, two with boulders and no corals, and two more consisting of mostly flat sandy seafloor—to see if their rockfish populations differ. To date, the results show that the sites with large structures, either boulders or corals, host more rockfish than bare seafloor, and those fish have a higher fat content, indicating they are in better condition. Fish in sites with large structures also appear to be in better reproductive health and may produce more young fish. Ongoing analysis of the diet of the fish collected will help to illustrate the productivity of fish stocks within coral and sponge habitats.

"... sites with large structures, either boulders or corals, host more rockfish than bare seafloor ..."

[6] Waller RG, Stone RP, Johnstone J, Mondragon J (2014) Sexual Reproduction and Seasonality of the Alaskan Red Tree Coral, *Primnoa pacifica*. PLOS ONE 9(4): e90893. doi: 10.1371/journal.pone.0090893

Effects of longline fishing gear: Bottom longlines contact the seafloor and potentially can entangle organisms on the seafloor other than the intended groundfish. To understand whether and how longlines might disturb coral and sponge habitats, scientists attached measurement devices and an underwater camera to the longline to observe the gear's movement. The results indicated very little movement of the longline gear when it is left on the seafloor catching fish, but during gear retrieval there is more movement of the gear along the seafloor, with the potential to damage coral and sponge habitats. Further analysis of these data is currently underway.

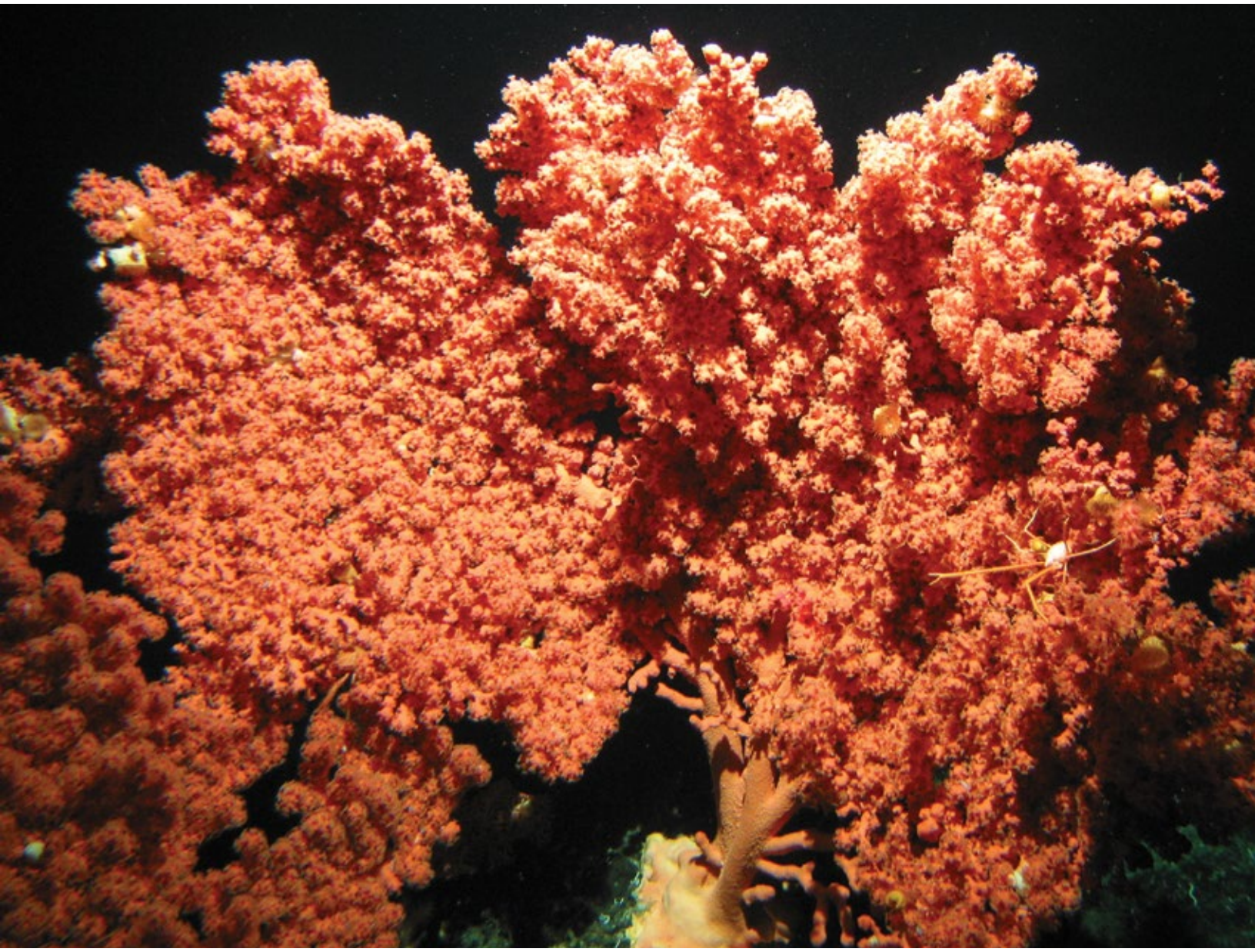
Understanding how oceanographic conditions and geology influence coral and sponge distributions: The Program supported annual monitoring efforts to measure oxygen, pH, and other oceanographic conditions during fisheries stock assessment surveys in the Aleutian Islands, Gulf of Alaska, and eastern Bering Sea slope. These datasets will enable fishery scientists and managers to understand existing conditions and detect evidence of climate change in deeper waters that may affect deep-sea corals. The datasets have already shown that there are naturally occurring differences in oceanographic conditions at very predictable locations, such as areas east of Samalga Pass in the Aleutian Islands as compared to areas to the west.

Most coral and sponge species require rocky bottoms to settle and grow. The Program helped to compile and map data on bathymetry, sediment, and substrate types in the Aleutian Islands and Gulf of Alaska between 50 and 1,500 meters (164–4,921 feet) deep. The data have been used in habitat models for Alaska, and both the oceanographic information and maps of substrate type will inform future efforts to study areas of high probability of coral and sponge communities.

Additional studies: The information and samples collected by the Program are being studied by NOAA's partners for taxonomic identifications, coral population connectivity, and compounds with biomedical applications.

The projects undertaken during the Alaska Fieldwork Initiative are already yielding results that can inform habitat and fisheries management in the Alaska region. The models of coral and sponge distribution are being used in evaluations of the effectiveness of existing closed areas and to address the effects of fishing on essential fish habitat. Red tree coral research can provide information to evaluate how removal by fishing may affect their populations and the ecosystem services they provide. Research on the role of coral habitat in rockfish productivity is relevant to a number of habitat-related issues currently under consideration by both the North Pacific and the Pacific Fishery Management Councils. By providing completely new data and understanding, the research projects in Alaska promise to move the management of coral and sponge habitat forward dramatically.

Details on the initiative can be found in NOAA's Deep-Sea Coral Data Portal at https://deepseacoraldata.noaa.gov/fieldwork-studies/ak-fieldwork-fy12-14.



Large bubblegum coral in Alaska.

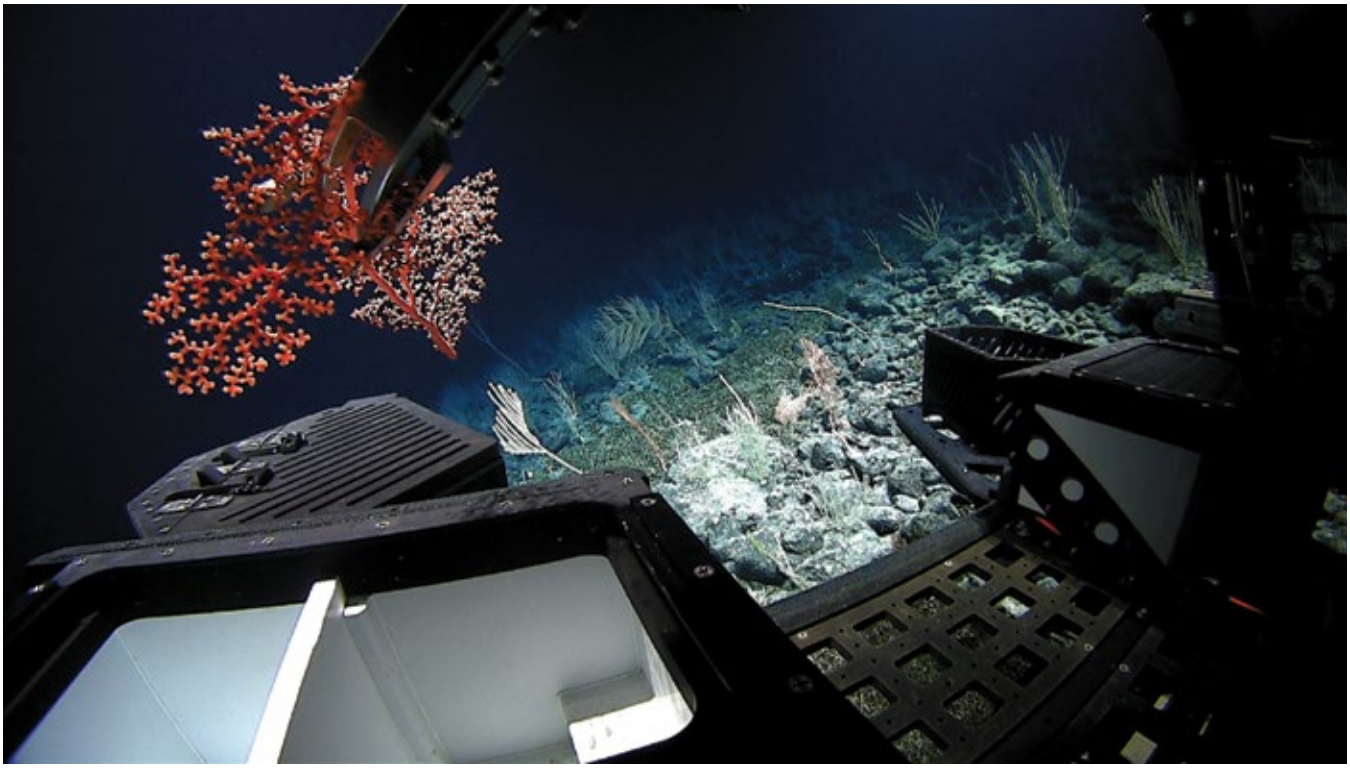
Pacific Islands Research Discovers Deep-Sea Coral Communities

The U.S. Pacific Islands Region encompasses more than 50 oceanic islands, including the Hawaiian Archipelago; the Commonwealth of the Northern Mariana Islands (CNMI); the territories of Guam and American Samoa; Rose Atoll; and the Pacific Remote Islands (Kingman Reef; Palmyra Atoll; Jarvis Island; Howland and Baker Islands; Johnston Atoll; and Wake Island). They include the nation's four Marine National Monuments, which feature some of the world's most pristine marine ecosystems.

Except for Hawaii, the region's deep-sea environment is virtually unexplored. To address this major knowledge gap, NOAA initiated CAPSTONE: the Campaign to Address Pacific monument Science, Technology, and Ocean Needs.

Over a three-year period, the Deep Sea Coral Research and Technology Program is participating in CAPSTONE to create foundational science for deepwater habitats in U.S. waters of the central and western Pacific. The campaign, led by the Office of Ocean Exploration and Research, is providing reliable and authoritative science to support decision-making by discovering and describing deep-sea habitats for the first time.

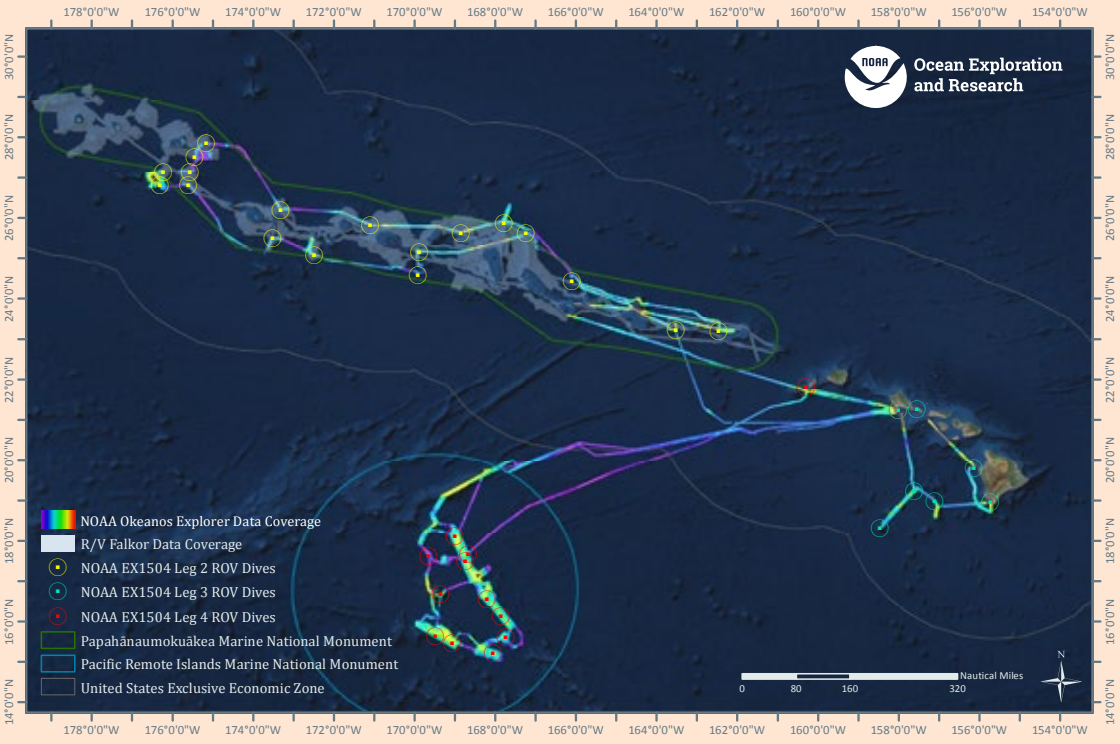
The first year (2015) of this campaign began with a 65-day expedition aboard NOAA Ship *Okeanos Explorer* to survey the Hawaiian Archipelago and Johnston Atoll. The expedition *Hohonu Moana*, meaning "deep ocean" in the Hawaiian language, mapped 79,333 square kilometers (30,631 square miles) of seafloor and conducted 37 remotely



A specimen of precious coral being collected during the Hohonu Moana *expedition, including the first scientific sample collections with the* Okeanos Explorer's *ROV.*

2015 Hohonu Moana: Exploring Deep Waters off Hawai'i

Bathymetry and ROV dive locations from four NOAA Ship *Okeanos Explorer* cruises



Map created by NOAA OER. Background data layer sources: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

operated vehicle (ROV) dives ranging from 323 to 4,829 meters (1,060–15,843 feet) deep. It discovered six previously unknown high-density deep coral communities. Seventy biological samples were collected during the cruise on the premise that they represent undescribed species or new records for the region. Although analysis is continuing, a definite result will be a substantial number of new records for the Central Pacific from this first year of collections. The ROV also collected rock samples so that scientists can learn about the origin and age of seamounts and other geologic features in the region.

The expedition also retrieved instruments that had been deployed to the seafloor in and near precious coral areas in Hawaii in previous years to record the temperature, direction, speed, and particle load of currents. Analysis of these records will help scientists determine the environmental factors that support coral growth. These instruments were in various states of disrepair after their long resident times on the seafloor, but scientists hope to retrieve current and temperature readings from at least a few of the instruments in 2016.

In addition, the expedition examined host corals marked in 2007 when they were in the early stages of being colonized by gold coral (*Kulamanamana haumeaae*), a species that can live for thousands of years. Scientists on the expedition imaged them with lasers to obtain data on their rates of growth since being marked. This analysis is ongoing.

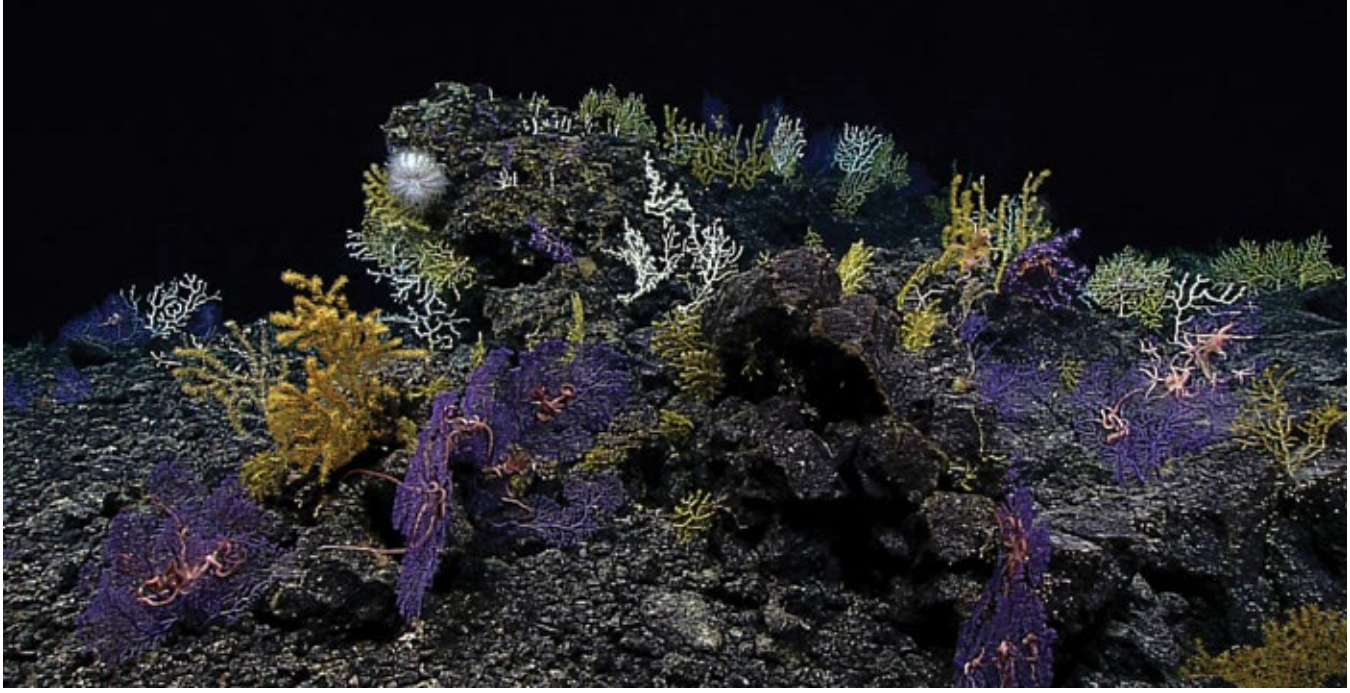
The expedition also surveyed areas that were covered by lava flows at different times in history and examined how coral communities differ in these places.

Primnoa *coral with a commensal crinoid (sea lily, left) and ophiuroid (brittlestar) observed on Kanehunamoku Seamount.*

This will tell us how corals colonize a fresh lava field and the rate at which the populations recover after being destroyed by lava or other disturbances. Scientists conducted an ROV dive on the western branch of the 1868 lava flow in order to compare findings with surveys conducted in 2011. Data are currently being analyzed to determine species richness, diversity, abundance, maximum size of species, and size class frequency of pink coral (Coralliidae). In addition, scientists are examining the seafloor terrain characteristics—such as substrate hardness, slope and curvature—along the survey track to determine whether there was an association between high coral abundance and specific characteristics of the seafloor terrain. Rock samples are being analyzed to confirm the age of the substrate as originating from the 1868 lava flow.

Parallel to the CAPSTONE *Hohonu Moana* expedition, scientists are working on several other projects under a 3-year fieldwork initiative sponsored by the Deep Sea Coral Research and Technology Program. Actions completed include the following:

- **Documented the locations and characteristics of deep-sea corals and sponges** by reviewing seafloor images taken from previous research cruises. The video annotation process will continue through 2016.
- **Examined the population structure, and determined the species and colony densities in black coral beds off Maui**. Data previously collected in 2004, 2008 and 2010 were reviewed in order to select sites for new surveys and plan for upcoming fieldwork activities. New fieldwork activities are planned for summer 2016 to re-survey five areas that were studied between 2004 and 2010, and to survey several additional sites in order to measure species abundances across a wide bathymetric gradient.
- **Surveyed black corals at depths between 50 and 90 meters (164-295 feet) off American Samoa to determine their distribution and species.** A review of 60 scientific articles was conducted to determine what species have been reported from American Samoa. Based on this review, only two black corals are known from American Samoa, and these were only known to genus level (*Antipathes* and *Cirrhipathes*). In April 2015, scientists conducted four dives to a maximum depth of 91 meters (299 feet) using mixed-gas technical diving off Tutuila Island in American Samoa. During these dives, 18 black coral specimens were collected. These specimens are currently being processed using scanning electron microscopy in order to identify them taxonomically. Follow-up fieldwork is planned in American Samoa to survey 10 additional sites in this depth range in 2016.



High-density coral community on the ridge crest of Swordfish Seamount, south of Oahu, at approximately 1,000 meters (3,280 feet) deep.

- **Conducted multibeam mapping of the seafloor shallower than 500 meters (1,640 feet)** around American Samoa, the Pacific Remote Islands, and the Northwestern Hawaiian Islands. Multibeam mapping was conducted using the NOAA ship *Hi'ialakai* around the remote U.S. Pacific Islands of Howland, Baker, Jarvis, Palmyra and Kingman.
- **Developed a model intended to guide deep-sea coral surveys**. The hypothesis that high-density coral communities can be found predominantly on ridges was supported by underwater observations. However, not every ridge has dense coral communities. During the 2015 dives, coral communities were found where stable substrate, such as bedrock or large boulders, was present. They were absent from debris slopes and other unconsolidated sediments. Depth also appears to be important, as no high-density communities were observed below 2,700 meters (8,858 feet). Next year, additional dives will be conducted to examine the role of ridge orientation, which may be a factor as well.

During the next 2 years, the fieldwork initiative's scientists will continue to participate in CAPSTONE, which plans to extend ROV surveys to CNMI, Wake Island, American Samoa, and Pacific Remote Islands where almost nothing is known about the coral and sponge communities. The Pacific Islands fieldwork initiative will also continue the other studies.

Although several national marine sanctuaries and marine national monuments have been established to protect the region's unparalleled ecosystems, scientific knowledge is limited about the marine species and habitats that lie in the depths of these protected areas. The Program's comprehensive effort to study the deep-sea communities will help fill missing knowledge for the managers and users of these sites.

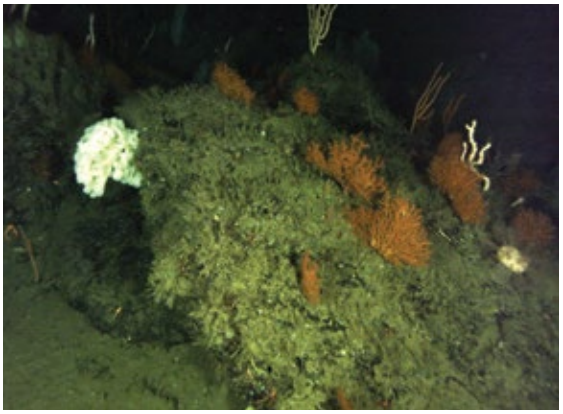
Additional details on the 10 projects under the 3-year Pacific Islands fieldwork initiative are available online: https://deepseacoraldata.noaa.gov/fieldwork-studies/pi-fieldwork-fy15-17.

Deep-Sea Coral Science Informs West Coast Fisheries and Sanctuary Management

Key accomplishments in deep-sea coral science in the West Coast region in this reporting period include visual surveys of corals and sponges off California, and a gathering of scientists across the nation to identify the relationship between valuable fish species and deep-sea corals and sponges.

Investigating areas of locally high coral bycatch

Damage from fishing gear is the major threat to deep-sea coral habitats off the West Coast, and coral bycatch in trawls is often the best measure we have on where such damage takes place. NOAA scientists and partners completed a research cruise in 2014 to visually survey an area off northern California where deep-sea corals had been caught during annual bottom trawl surveys for fisheries stock assessments and as bycatch in commercial fisheries. The seafloor in this area, about 50 kilometers (30 miles) off the coast between Crescent City and Mendocino, had never been explored with cameras before. Although trawl surveys indicated the presence of deep-sea corals in the general area, information was lacking on their specific locations, abundance, and associated species. The 2014 cruise, sponsored by the Deep Sea Coral Research and Technology Program, served to fill this information gap. Researchers completed 15 dives using a towed camera sled and an autonomous underwater vehicle, spending more than 42 hours underwater photographing organisms on undersea ridges at depths of 600 to 1,200 meters (1,969–2,625 feet). With perfect sea conditions and fair skies in an area notorious for foul weather, the researchers recorded more than 60,000 images of corals, sponges, fishes, and other marine life with paired digital cameras. Nearly 48,000 corals from at least 23 taxa were observed, including black corals, bamboo corals, and gorgonians—some of which may be hundreds if not thousands of years old. Densities of corals were among the highest that have been observed off the West Coast. Sponges occurred on most of the dives, with a total of 5,200 individuals representing 13 taxa. Relatively few fishes (mostly thornyheads) and little marine debris was observed. The ship's echosounder was used to map the seafloor and geologic features each night; water conductivity, temperature, dissolved oxygen, and depth were measured at each station. These data will help characterize seafloor habitat types associated with the corals and sponges.



Bright white lightbulb sponge (Hexactinella spp.), red sea fan (Plexauridae and Swiftia spp.*), white sea fan (*Paragorgia sp.*), and mushroom coral (*Heteropolypus ritteri*) at 743 meters (2,438 feet) deep near the Oregon-California border.*

Fishermen have long known that corals occur in this area off northern California, having retrieved parts of corals in their fishing nets along with the harvested fishes. Relatively high numbers of corals also have been recorded in bottom trawl surveys for groundfish stock assessment. From the exploration of these sites with cameras, we can now determine the extent of these coral colonies for the first

time. The highlight of the cruise was discovering forests of corals on rocky ridges adjacent to trawling grounds. With the elimination of large rollers on trawl nets, these areas of rough terrain likely have received less fishing pressure in recent years. Further analyses of the images and resultant data will improve our understanding of the influence of fishing on coral communities and will inform decisions to protect and conserve these sensitive habitats.

Exploring sanctuary waters

The Program provided partial support to a 2015 research cruise in the Channel Islands National Marine Sanctuary.[7] During the cruise, 212 square kilometers (82 square miles) of the sanctuary previously uncharacterized were mapped using high-resolution sonar. The map identified potential deep-sea coral habitats, which were then visually surveyed with a remotely operated vehicle. As a result, the coral *Lophelia pertusa* was observed for the first time on the north side of the sanctuary near San Miguel Island at 75-meter (246-foot) depth. An extensive "coral garden" with many rockfish was discovered at 60 to 80-meter (196 to 262-foot) depth, also on the north side of the sanctuary, near Santa Rosa Island. Gorgonian corals *Eugorgia rubens, Adelogorgia phyllosclera,* and *Leptogorgia chilensis* were documented in high abundance. Samples of eight sea fans and four stony corals were collected from 50 to 300 meter (164–984 foot) depth for species identification, age and growth studies, and lab experiments to test the effects of ocean acidification.

[7] Caldow C, Etnoyer PJ, Kracker L (2015) Cruise Report for 'Patterns in Deep-Sea Corals' Expedition: NOAA Ship *Bell M. Shimada* SH-15-03. NOAA Technical Memorandum NOS NCCOS 200. 15 pp. Silver Spring, MD.

Understanding associations of commercially-important fishes with deep-sea corals and sponges

Many managed fisheries species co-occur with deep-sea corals and sponges in complex rocky areas, but the degree to which these fishes rely on corals and sponges as habitat during any developmental life stage has been difficult to quantify. In response, the Deep Sea Coral Research and Technology Program sponsored a workshop in 2015 that brought together 13 academic and NOAA experts to articulate the role of deep-sea corals and sponges as habitat for valuable groundfish species in the West Coast and Alaska regions. The workshop participants concluded that, from Alaska to southern California, the degree to which these fishes associate with corals and sponges is highest in the north and decreases to the south. Density of corals and sponges also generally declines from north to south. In parts of Alaska, high levels of association between corals and juvenile rockfishes may indicate functional roles of corals as shelter and/or nursery grounds, but there is no significant evidence of this in California. Workshop participants noted that the West Coast region has experienced greater fishing pressure over a longer time period than Alaska, which has resulted in altered seafloor communities dominated by small rockfishes. The absence of large predators could be one factor to explain why the role of corals as shelter is not evident off the West Coast as compared to Alaska.

NOAA Ship Bell M. Shimada

More information on these and other studies funded by the Program on the West Coast can be found at https://deep-seacoraldata.noaa.gov/browse-other.

NOAA Gears Up for Southeast Regional Fieldwork Initiative

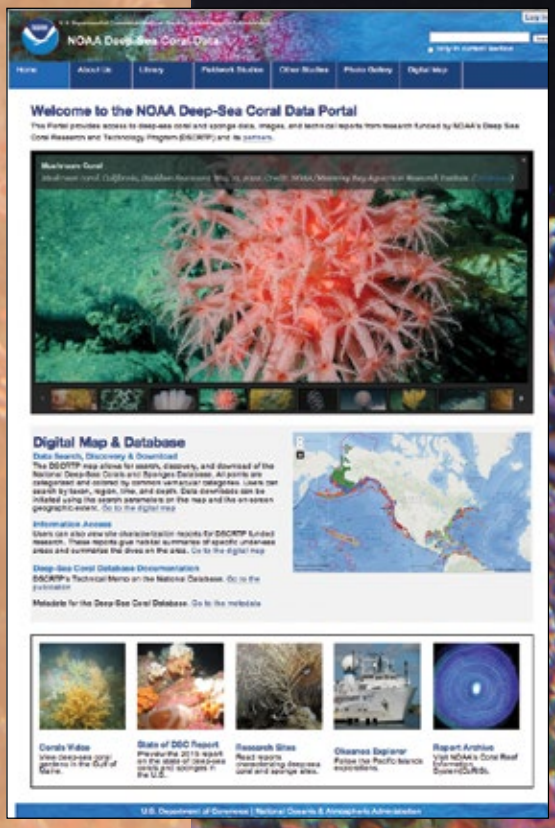
The Deep Sea Coral Research and Technology Program supported a research priority scoping workshop in November 2015 in Florida. The workshop generated recommendations for science priorities for a 4-year (2016–2019) deep-sea coral fieldwork initiative in the Southeast. The participants included representatives from the South Atlantic, Caribbean, and Gulf of Mexico Fishery Management Councils; collaborating federal agencies (Bureau of Ocean Energy Management (BOEM) and the U.S. Geological Survey (USGS)); academia; and three NOAA line offices. The workshop discussions led to many ideas for partnerships, identification of data gaps, articulation of management needs, and numerous suggested research activities. A workshop report is expected in 2016. NOAA is organizing a team to develop and implement a fieldwork plan for the 4-year initiative, which will likely include activities in the South Atlantic Bight, U.S. Caribbean, and Gulf of Mexico.

A squat lobster resides on an octorcoral in the Gulf of Mexico.

National Database for Deep-Sea Corals and Sponges Goes Online

https://deepseacoraldata.noaa.gov

The most comprehensive collection of deep-sea coral and sponge records and information for U.S. waters is available publicly in NOAA's Deep-Sea Coral Data Portal. The portal is designed to serve the data needs of Regional Fishery Management Councils, other ocean resource managers, and scientists. It includes a digital map displaying more than 300,000 records from the National Database for Deep-Sea Corals and Sponges. The new portal is maintained by NOAA's Deep Sea Coral Research and Technology Program.



In addition to showing the locations of corals and sponges, the fully searchable map also provides access to:

- Underwater photos of the organisms.
- Extensive associated data for download about the corals and sponges, including record provenance, details about where and how they were observed or collected, and, where available, ecologically important information, such as their density, size, and habitat.
- Reports that characterize the deep-sea coral and sponge habitats surveyed over the past decade by scientists from NOAA, other agencies, and universities.

The National Database for Deep-Sea Corals and Sponges is continually expanding, incorporating new records from recent fieldwork observations and historic archives. These records will be added quarterly to the Data Portal map, and additional software tools for data exploration and analysis are under development.

The Portal also offers information about all 60 studies funded by the Deep Sea Coral Program since 2009 and a growing library of NOAA publications on deep-sea corals and sponges.

NOAA and Partners Develop Management Actions to Protect Deep-Sea Coral Habitat

As the findings from Program-funded studies become available, and with the help of our partners' research, most regions in the United States are making progress in developing management actions for deep-sea coral habitats. Resource managers increasingly recognize that deep-sea corals are fragile and slow-growing organisms that serve an important role in unique and diverse deep-sea ecosystems.

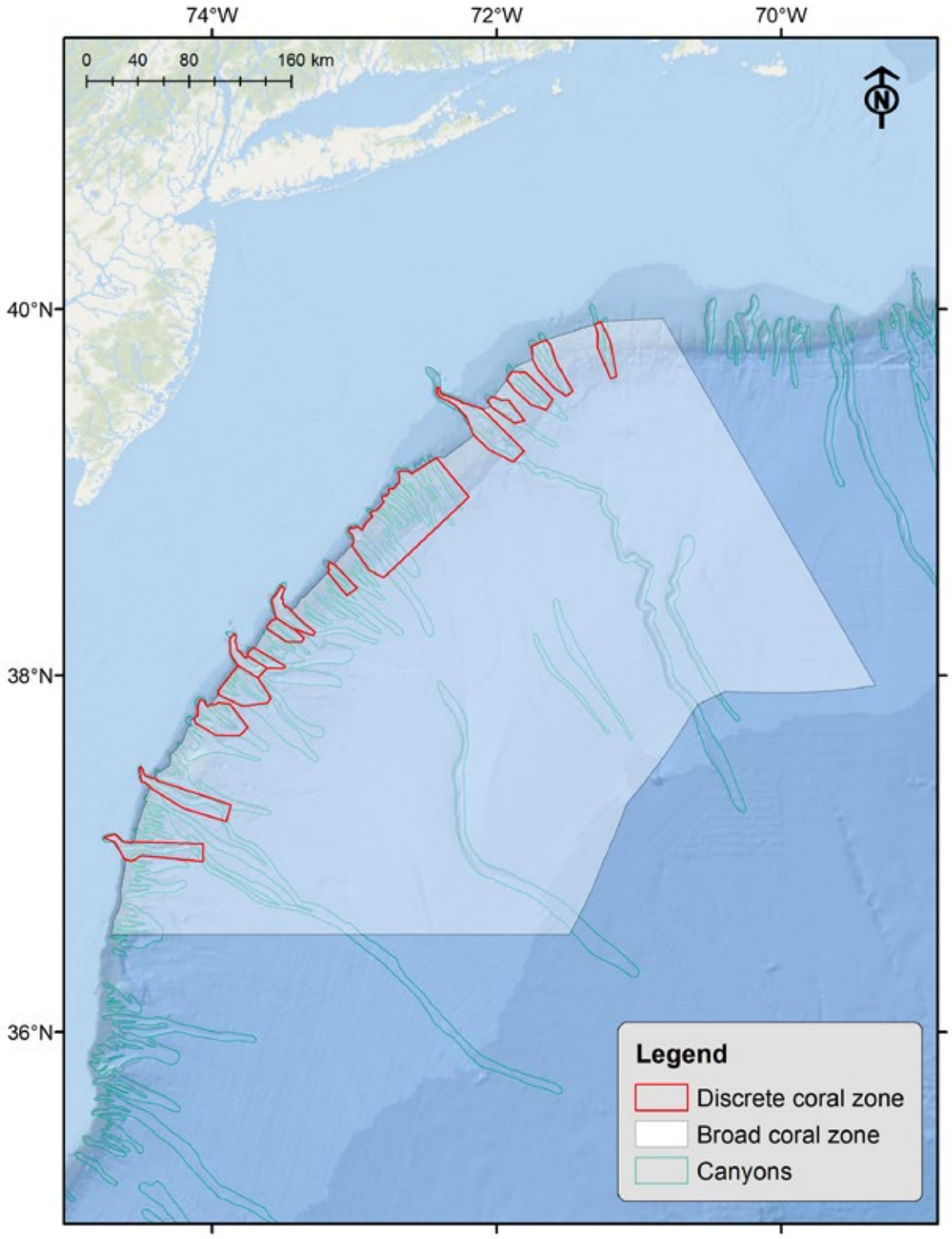
Mid-Atlantic

For the first time, protective zones for deep-sea corals have been proposed by a regional fishery management council under the MSA Section 303(b)(2)(B) discretionary authority. In June 2015, the Mid-Atlantic Fishery Management Council approved a suite of management measures to designate areas where deep-sea corals are protected from physical damage caused by fishing gear. These zones are named the Frank R. Lautenberg Deep-Sea Coral Protection Area in honor of the late senator from New Jersey who contributed tremendously to ocean—and deep-sea coral—conservation. This action was also the first time that predictive coral habitat models were used to help define major deep-sea coral protective measures.

The Council approved the designation of 15 discrete coral zones: areas in and around submarine canyons that have either confirmed occurrences of deep-sea corals or habitats suitable for corals as predicted by mathematical models. The Council also voted to establish a broad coral zone that extends from approximately the 450-meter (1,476-foot) depth contour to the Exclusive Economic Zone (EEZ) boundaries of the Council's management region, as a precautionary step to protect deeper habitats that generally have not yet been fished. The combined coral zones encompass an area larger than 38,000 square miles, or about the size of Virginia.

The Council submitted the deep-sea coral amendment to the Secretary of Commerce for review in early 2016. If approved, the use of all bottom fishing gear, including both mobile and stationary gear types, would be prohibited in the deep-sea coral zones. The red crab trap fishery would be exempted from these restrictions, at least for the first 2 years, and a provision would allow for vessel transit with stowed fishing gear. The amendment would also require the use of Vessel Monitoring Systems for all *Illex* squid vessels. The management measures approved by the Mid-Atlantic Council do not apply to gear used in the state-managed lobster fishery.

This deep-sea coral amendment follows approaches recommended in NOAA's Strategic Plan for Deep-Sea Coral and Sponge Ecosystems and is based on a growing body of scientific knowledge originating from the Program and its partners. Through multiple meetings and presentations, the scientists involved in the Program's Northeast Fieldwork Initiative (see above) provided the Mid-Atlantic Council and its advisory groups the latest observations of corals and the best predictions of likely coral locations. This engagement demonstrates our Program's proactive approach to present results in a timely manner and help resource managers make decisions.



Discrete and broad deep-sea coral protection zones (more than 38,000 square miles combined) in the Frank R. Lautenberg Deep Sea Coral Protection Area proposed by the Mid-Atlantic Fishery Management Council in 2015. Data source: MAFMC.

New England

A priority of the New England Fishery Management Council in 2016 is to develop an omnibus deep-sea coral amendment, which would establish coral management measures applicable to multiple fisheries. This effort will incorporate the new observations and model predictions of coral locations resulting from the Program's Northeast Fieldwork Initiative, as well as the Mid-Atlantic Council's approach described above. It builds upon a draft amendment from 2012, when NOAA had helped the New England Council compile a large body of existing deep-sea coral information. The draft amendment included options to designate discrete protection zones around canyons and seamounts, and in portions of the Gulf of Maine. It also included a broad zone that covers the region's deep waters off the continental shelf. During 2016, the Council will be updating the earlier proposals to reflect the most recent data on the distribution of deep-sea corals and their habitats.

In keeping with a Memorandum of Understanding signed by the chairs of the three Atlantic coast fishery management councils in 2013, management measures for New England will be developed in coordination with the Mid-Atlantic Council to make them as consistent as possible throughout the Greater Atlantic region.

South Atlantic

The largest distribution of deep-sea coral reef ecosystems in the United States occurs in this region. In 2010, NOAA implemented a South Atlantic Fishery Management Council action to prioritize sensitive reefs as deepwater Coral Habitat Areas of Particular Concern (CHAPCs), covering more than 60,000 square kilometers (23,000 square miles). In August 2015, NOAA implemented a further action to expand two of these CHAPCs (Stetson-Miami Terrace and Cape Lookout) as well as the Oculina Bank Habitat Area of Particular Concern (HAPC), protecting more than 850 square miles containing additional deep-sea coral habitat. The South Atlantic Council developed this management measure largely based on the Program's 2009–2011 fieldwork initiative, which documented the presence of deep-sea corals outside the existing protected habitats.

In all these protected areas, the use of bottom fishing gear and anchoring is prohibited. Fishing vessels are allowed to transit through the Oculina Bank HAPC with rock shrimp onboard when fishing gear is appropriately stowed, and royal red shrimp vessels are allowed to haul back fishing gear in an expanded shrimp access area adjacent to the Stetson-Miami Terrace CHAPC.

Gulf of Mexico

In June 2015 the Gulf of Mexico Fishery Management Council considered recommendations from its coral advisory bodies to evaluate 47 sites for HAPC designations and to protect them from fishing gear impacts. These sites are distributed throughout the Gulf of Mexico from Texas to Florida, and all have confirmed presence of multiple deep-sea coral taxa. The Council plans to seek further input from the fishing community on this proposal before officially starting a process to amend the Fishery Management Plan for Coral and Coral Reefs with new HAPC designations.

The Flower Garden Banks National Marine Sanctuary is evaluating proposed changes to its boundaries. These changes could expand the sanctuary to include Horseshoe Bank, McGrail Bank, Geyer Bank, Bright Bank, Sonnier Bank, Alderdice Bank, MacNeil Bank, Rankin Bank, and 28 Fathom Bank. All of these banks have confirmed presence of deep-sea corals. The current boundaries of the sanctuary, which encompass East and West Flower Garden Banks and Stetson Bank, would also be modified. The sanctuary is preparing an environmental impact statement to consider the effects of the expansion. If approved, the expansion would provide more long-term protection and research for these deep-sea coral habitats. The sanctuary has participated in the Fishery Management Council's HAPC process and is coordinating closely with the Council.

The Florida Keys National Marine Sanctuary is also beginning a process to consider boundary changes. The potential expansion could include more deep-sea coral areas at Pulley Ridge.

The Deepwater Horizon oil spill severely affected mesophotic and deep-sea coral communities in the Gulf of Mexico. The natural resource Trustees, led by NOAA, have been working together for more than 5 years to quantitatively assess the injuries. To date, injuries to these resources have been identified in at least three deep-sea coral communities[8] up to 13 miles from the wellhead and mesophotic coral communities on Pinnacles reefs.[9] The area containing mesophotic corals with observed injuries exceeds 4 square miles. Continued assessment and restoration planning for these critical Gulf resources is complicated by our limited understanding of key biological functions, limited experience with restoration at depth and with these species, and remote locations that limit accessibility. Consequently, actions to be taken under the Draft Programmatic Damage Assessment and Restoration Plan (DWH PDARP) will include phased implementation to allow for additional data collection, analyses, and synthesis to address critical uncertainties and adaptive decision-making. The injury assessment information collected thus far, and the extensive future restoration-focused research and monitoring activities supported by the DWH PDARP, are critical to advance understanding of deep-sea coral habitat function, including relationships to commercial and recreational fisheries in the Gulf. In addition, it will help support NOAA and its partners in the science-based identification, conservation, and management of important deep-sea habitats. The Deep Sea Coral Research and Technology Program's compilation of existing information and continuing research in the region provides valuable context for these efforts.

The Deepwater Horizon Oil Spill damaged deep-sea corals.

[8] Fisher CR, Hsing PY, Kaiser CL, Yoerger DR, Roberts HH, Shedd WW, Cordes EE, Shank TM, Berlet SP, Saunders MG, Larcom EA, Brooks JM (2014) Footprint of Deepwater Horizon blowout impact to deep-water coral communities. Proceedings of the National Academy of Sciences of the United States of America 111:11744-11749

[9] Etnoyer PJ, Wickes LN, Silva M, Dubick JD, Balthis L, Salgado E, MacDonald IR (2015) Decline in condition of gorgonian octocorals on mesophotic reefs in the northern Gulf of Mexico: before and after the Deepwater Horizon oil spill. Coral Reefs. doi:10.1007/s00338-015-1363-2

An anglerfish, Chaunacops coloratus*, found more than 3,000 feet deep in the Pacific Remote Islands Marine National Monument.*

Alaska and West Coast

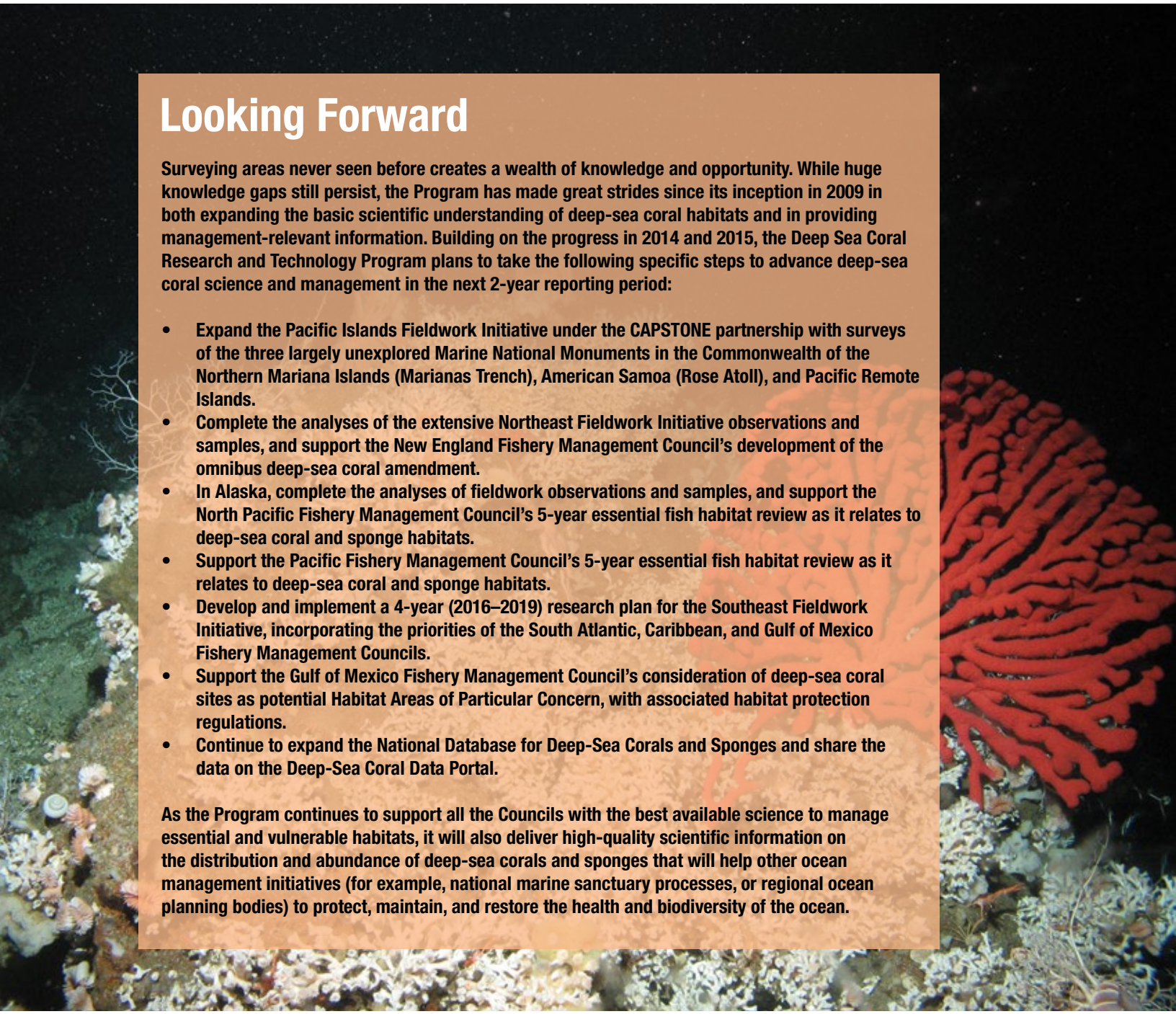
Both the Pacific and North Pacific Fishery Management Councils are conducting 5-year essential fish habitat (EFH) reviews for groundfish. To the extent that deep-sea coral communities serve as habitat for federally managed groundfish species, these reviews would present an opportunity to enhance management measures for coral areas, should the reviews find further measures necessary. The Program and other NOAA offices have generated a growing body of data on coral and sponge distributions and the fishes' associations with these habitats. These data are available to the Councils to inform habitat discussions. In addition to EFH measures, NOAA encourages the Councils to consider the use of deep-sea coral discretionary authority (MSA Sec. 303(b)(2)(B)) in cases where the 5-year reviews reveal significant deep-sea coral habitats that are vulnerable to fishing impacts.

In 2015, NOAA expanded two sanctuaries in north-central California: the Cordell Bank National Marine Sanctuary and the Greater Farallones National Marine Sanctuary. The former was expanded from 529 to 1,286 square miles, and the latter from 1,282 to 3,295 square miles. Deep-sea corals have been documented by our Program in both the original extent of the sanctuaries and in the expanded areas.[10] Sanctuary designations provide protection to deep-sea corals by prohibiting seafloor disturbance and discharge of material, and they offer programmatic support for research and education on coral habitats. In the Cordell Bank sanctuary's expanded area, future surveys will target Bodega Canyon and deep slope habitat. In the Greater Farallones' expanded area, the Point Arena Biogenic Areas I and II are targets for future surveys. Other priorities in the Great Farallones include continued surveys of Cochrane Bank for black corals and exploration west of the Farallon Escarpment for bamboo corals.

U.S. Pacific Islands

In September 2014, President Obama expanded the Pacific Remote Islands Marine National Monument under the authority of the Antiquities Act (Proclamation 9173). The expansion included the waters and submerged lands around Jarvis and Wake Islands and Johnston Atoll out to the seaward limit of the U.S. EEZ. This expansion provides additional protections to approximately 1,057,494 square kilometers (408,300 square miles) of ocean, including many underwater seamounts and ridges likely to include important deep-sea coral ecosystems. NOAA manages the Pacific Remote Islands Monument, and the Deep Sea Coral Research and Technology Program partnered with other NOAA programs to begin exploring some of the newly protected areas around Johnston Atoll in 2015.

[10] Fruh E, Clarke ME, Whitmire C (2011) A characterization of the deep-sea coral and sponge community in Bodega Canyon off the coast of California from a survey using and autonomous underwater vehicle. NOAA. Graiff K, Roberts D, Howard D, Etnoyer P, Cochrane G, Hyland J, Roletto J (2011) A characterization of deep-sea coral and sponge communities on the continental slope west of Cordell Bank, Northern California using a remotely operated vehicle. NOAA. Etnoyer P J, Cochrane G, Salgado E, Graiff K, Roletto J, Williams G, Reyna K, Hyland J (2014) Characterization of deep coral and sponge communities in the Gulf of the Farallones National Marine Sanctuary: Rittenburg Bank, Cochrane Bank and the Farallon Escarpment. NOAA Technical Memorandum NOS NCCOS 190.



Looking Forward

Surveying areas never seen before creates a wealth of knowledge and opportunity. While huge knowledge gaps still persist, the Program has made great strides since its inception in 2009 in both expanding the basic scientific understanding of deep-sea coral habitats and in providing management-relevant information. Building on the progress in 2014 and 2015, the Deep Sea Coral Research and Technology Program plans to take the following specific steps to advance deep-sea coral science and management in the next 2-year reporting period:

- **Expand the Pacific Islands Fieldwork Initiative under the CAPSTONE partnership with surveys of the three largely unexplored Marine National Monuments in the Commonwealth of the Northern Mariana Islands (Marianas Trench), American Samoa (Rose Atoll), and Pacific Remote Islands.**
- **Complete the analyses of the extensive Northeast Fieldwork Initiative observations and samples, and support the New England Fishery Management Council's development of the omnibus deep-sea coral amendment.**
- **In Alaska, complete the analyses of fieldwork observations and samples, and support the North Pacific Fishery Management Council's 5-year essential fish habitat review as it relates to deep-sea coral and sponge habitats.**
- **Support the Pacific Fishery Management Council's 5-year essential fish habitat review as it relates to deep-sea coral and sponge habitats.**
- **Develop and implement a 4-year (2016–2019) research plan for the Southeast Fieldwork Initiative, incorporating the priorities of the South Atlantic, Caribbean, and Gulf of Mexico Fishery Management Councils.**
- **Support the Gulf of Mexico Fishery Management Council's consideration of deep-sea coral sites as potential Habitat Areas of Particular Concern, with associated habitat protection regulations.**
- **Continue to expand the National Database for Deep-Sea Corals and Sponges and share the data on the Deep-Sea Coral Data Portal.**

As the Program continues to support all the Councils with the best available science to manage essential and vulnerable habitats, it will also deliver high-quality scientific information on the distribution and abundance of deep-sea corals and sponges that will help other ocean management initiatives (for example, national marine sanctuary processes, or regional ocean planning bodies) to protect, maintain, and restore the health and biodiversity of the ocean.

Appendix 1: Deep Sea Coral Research and Technology Program Investments

FY2014

Project	Fishery Management Council Region	Funding
Northeast Fieldwork Initiative, Year 2 of 3	New England; Mid-Atlantic	$800,000
Alaska Fieldwork Initiative, Year 3 of 3	North Pacific	$800,000
Bering Sea Groundtruthing Survey	North Pacific	$50,000
Exploring Off-Bottom Trawling and Other Approaches to Avoid Interactions With Structure-Forming Invertebrates During Pacific Ocean Perch Fishing on the Bering Sea Slope (cosponsored with the National Bycatch Reduction Engineering Program)	North Pacific	$50,000
Taxonomic and Genetic Identification of Deep-Sea Corals and Sponges in Bycatch and Field Surveys	Pacific; North Pacific	$77,000
Visual surveys of high-bycatch areas off Oregon and California	Pacific	$60,000
Incorporation of American Samoa and Line Islands Deepwater Cnidarian Records into the Deepwater Coral Program Database	Western Pacific	$51,935
International Deep-Sea Coral Symposium 2016	National	$10,000
National Database Development	National	$125,000
Deep-Sea Coral Data Management	National	$135,000
Program Coordination	National	$158,449
NMFS Management and Administration	National	$165,857
Total		**$2,483,241**

Details on the fieldwork initiatives are available online at https://deepseacoraldata.noaa.gov/browse-studies.

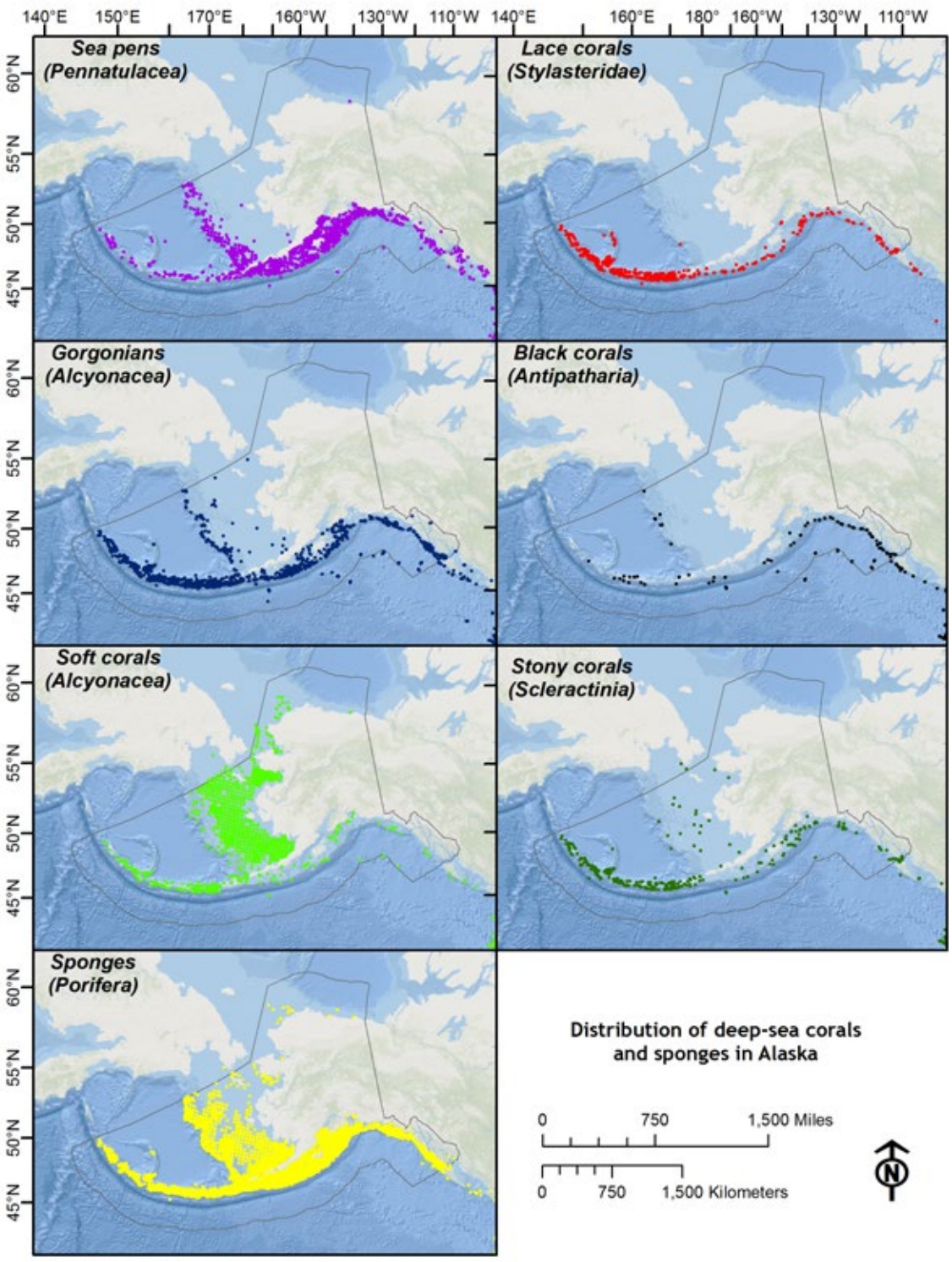
Details on other projects are available at https://deepseacoraldata.noaa.gov/browse-other.

FY2015

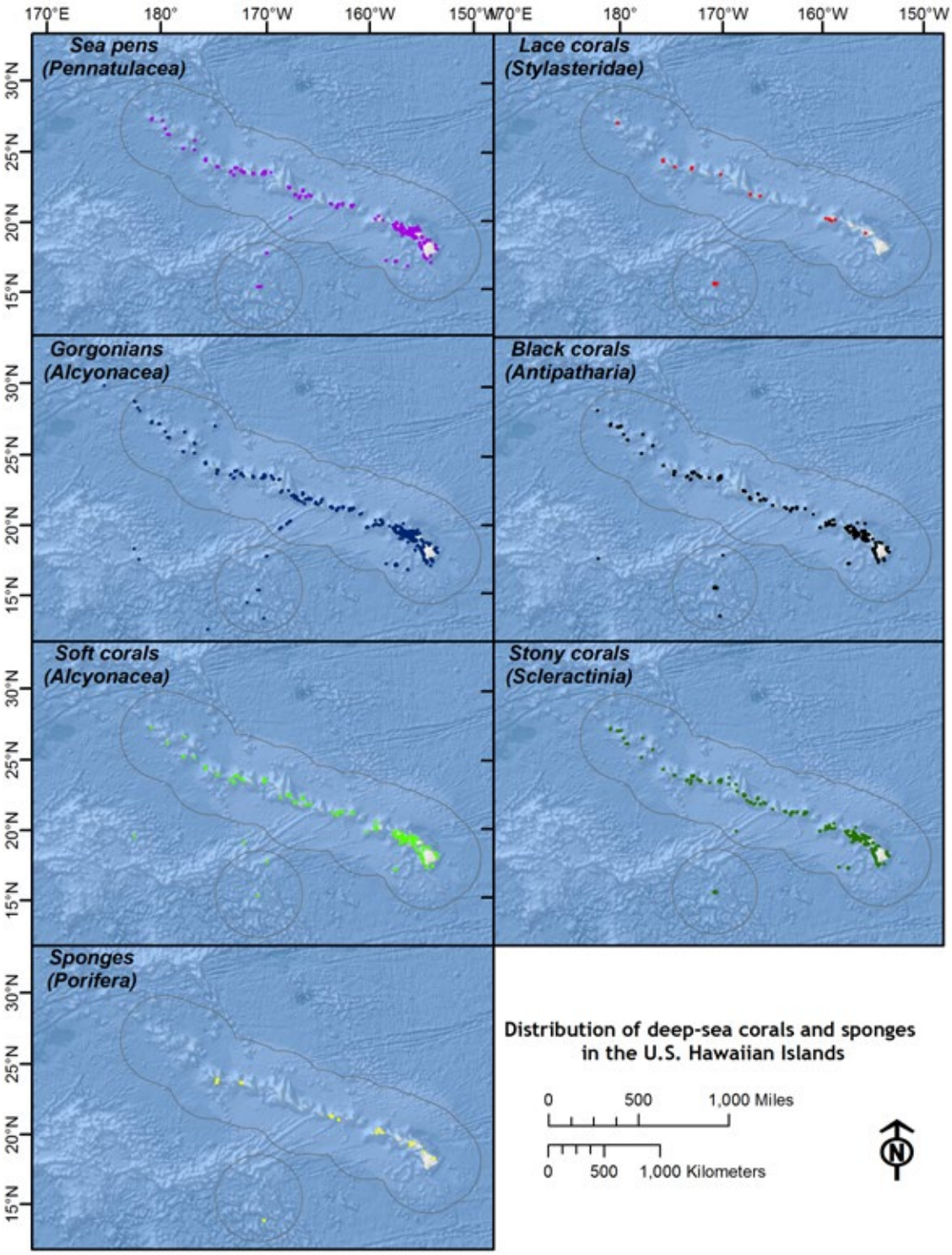
Project	Fishery Management Council Region	Funding
Pacific Islands Fieldwork Initiative, Year 1 of 3	Western Pacific	$825,000
Northeast Fieldwork Initiative, Year 3 of 3	New England; Mid-Atlantic	$779,000
Southeast Priorities Scoping Workshop	South Atlantic; Caribbean; Gulf of Mexico	$15,000
Mapping Commercial Bottom-Contact Fishing Intensity in the Gulf of Mexico in Relation to Deep Sea Coral Habitat Suitability	Gulf of Mexico	$30,000
Differences Between Mid and Outer Continental Shelf Mesophotic Communities	Gulf of Mexico	$13,000
Data-Mining Deep-Sea Coral Records from NCCOS ROV Video Missions in the U.S. Caribbean	Caribbean	$25,000
Taxonomic and Genetic Identification of Fisheries Bycatch of Deep-Sea Corals and Sponges	Pacific; North Pacific	$99,969
Role of Deep-Sea Corals and Sponges as Habitat for Managed Species	Pacific; North Pacific	$20,000
Do Deep-Sea Corals Have an Additive Effect on Fish Occurrence and Abundance When Controlling for Physical Habitat?	Pacific	$75,000
Characterizing the Habitat of Deep-Sea Coral and Sponges Assemblages and Associated Demersal Fishes in the Southern California Bight	Pacific	$55,000
National Database Development and Maintenance	National	$125,000
Deep-Sea Coral Data Management	National	$135,000
Program Coordination	National	$167,392
NMFS Management and Administration	National	$ 127,907
Total		**$2,492,268**

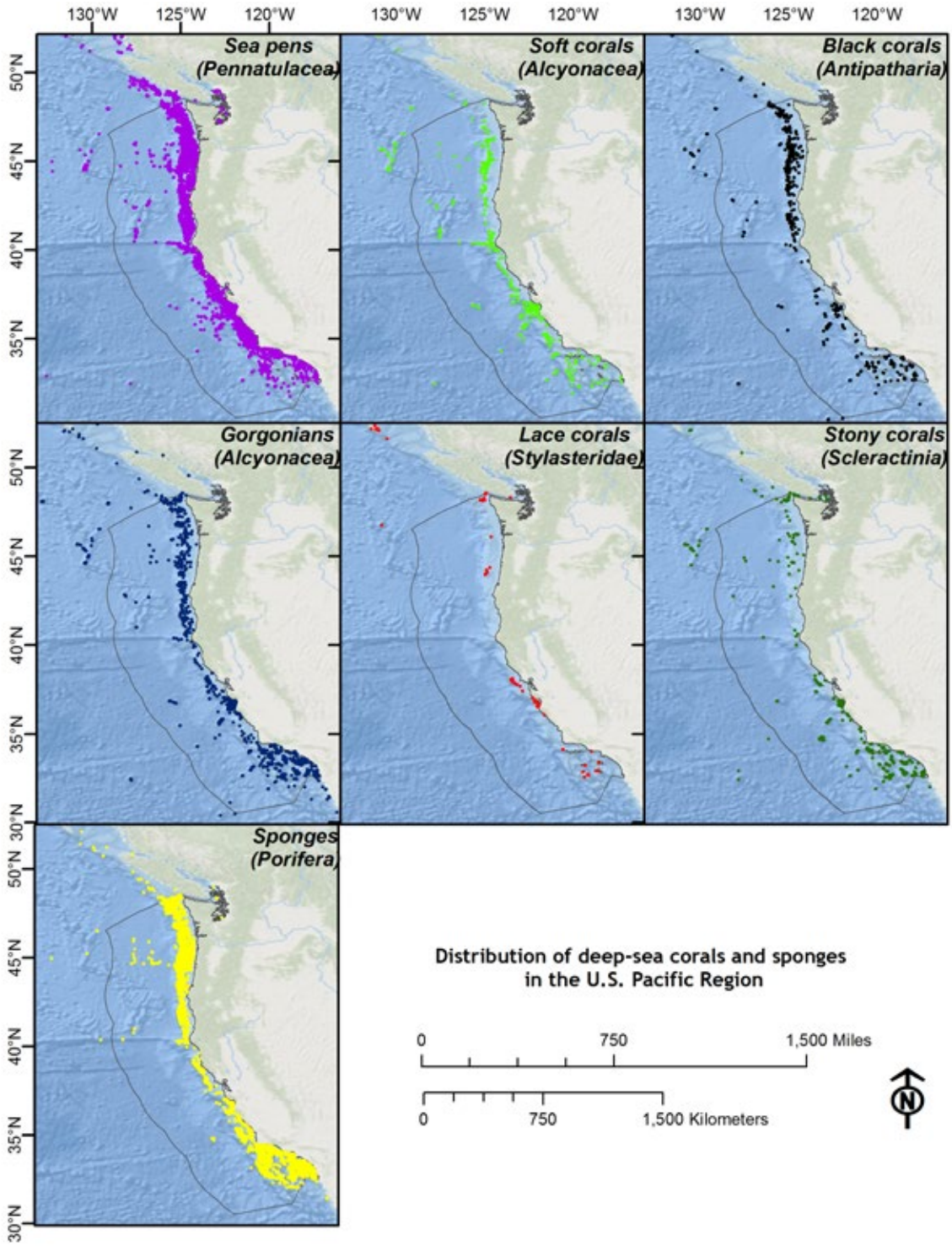
Appendix 2: Maps of Deep-Sea Corals and Sponges by Region

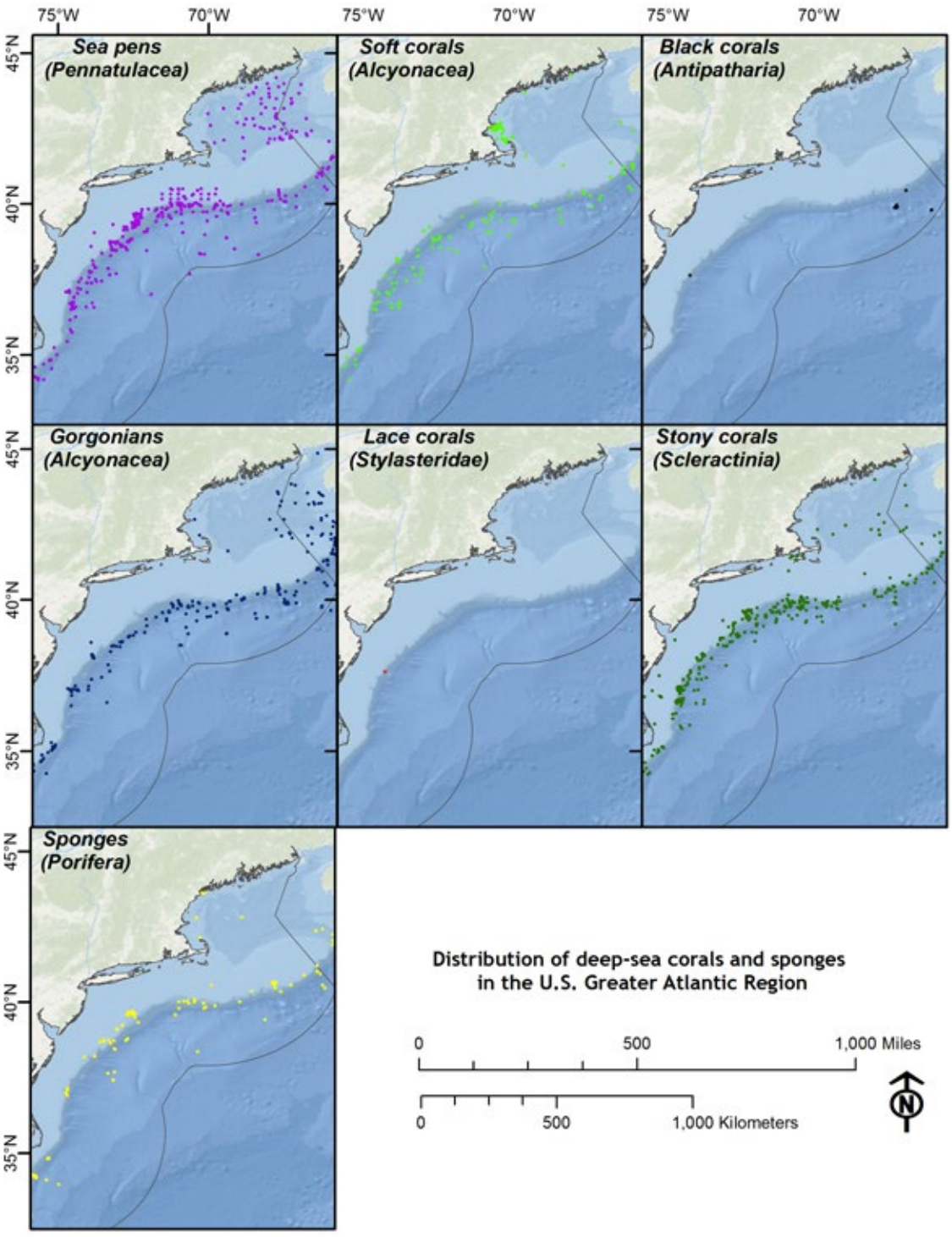
Records of deep-sea corals and sponges shown in this appendix can be downloaded from NOAA's Deep-Sea Coral Data Portal.

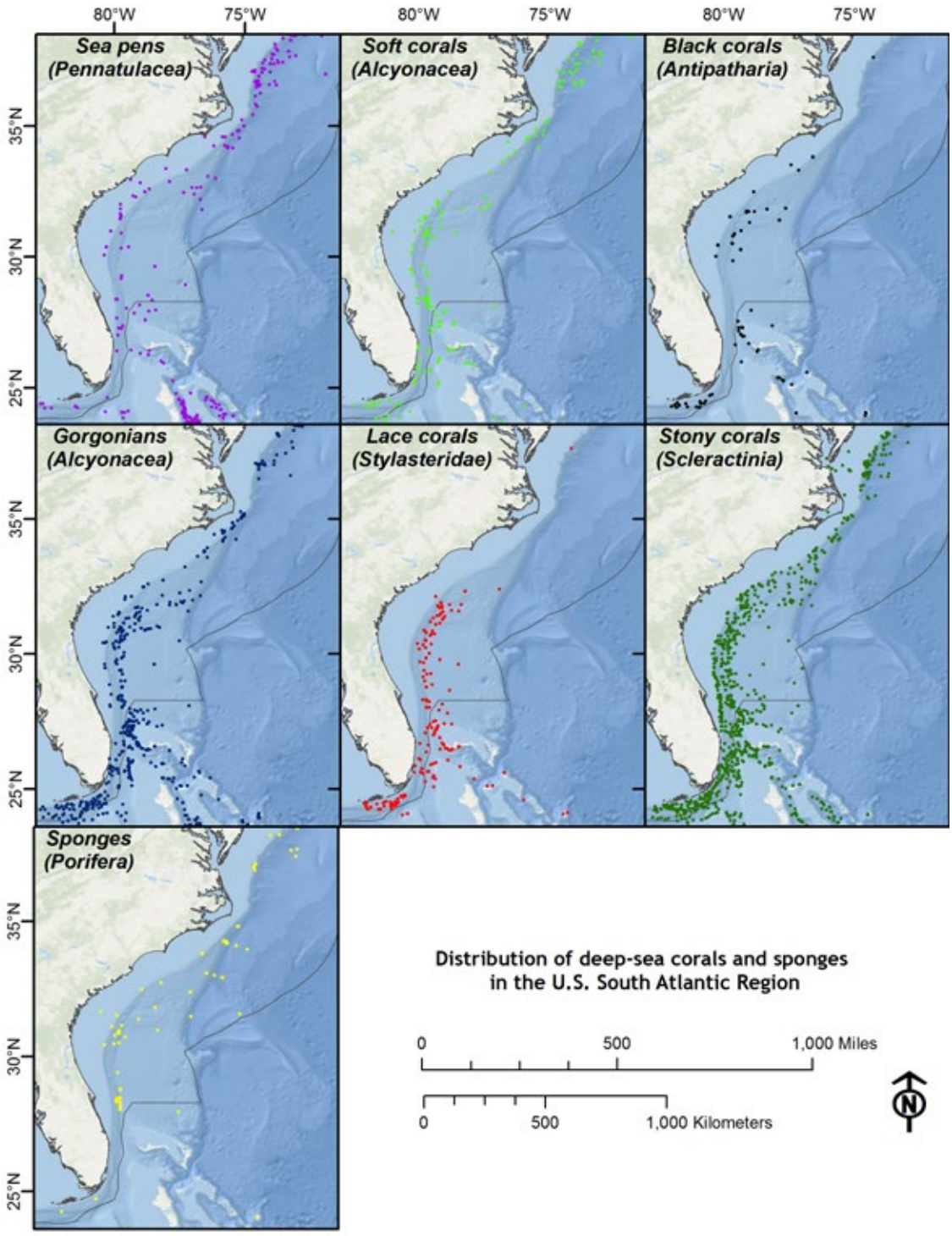


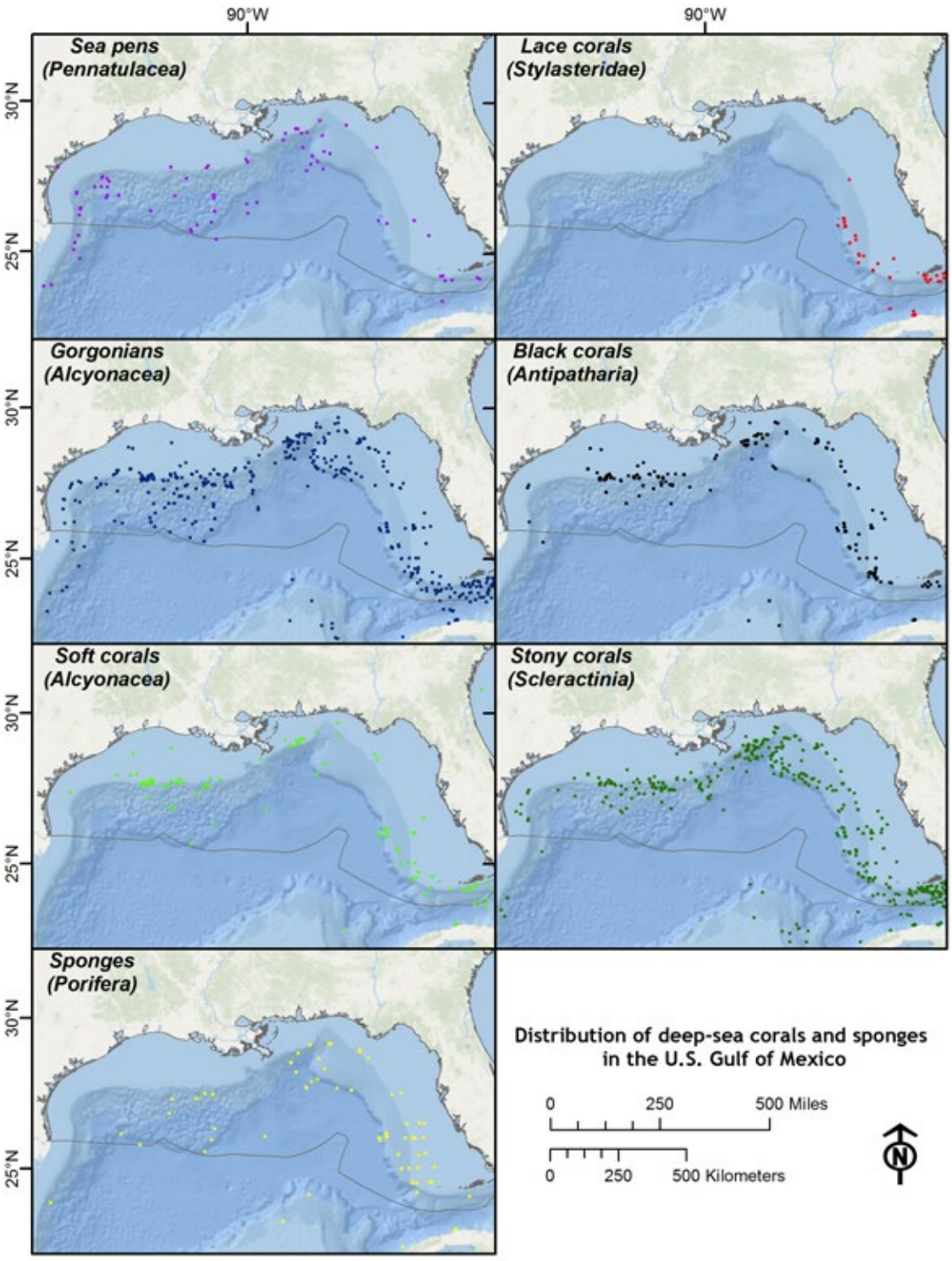
Note: Deep-sea corals are known or suspected to occur in all U.S. Pacific Island jurisdictions, but very little research has been conducted anywhere aside from the Hawaiian Archipelago. Deep-sea sponges also form important habitats in the region, but their distribution is even less well documented.

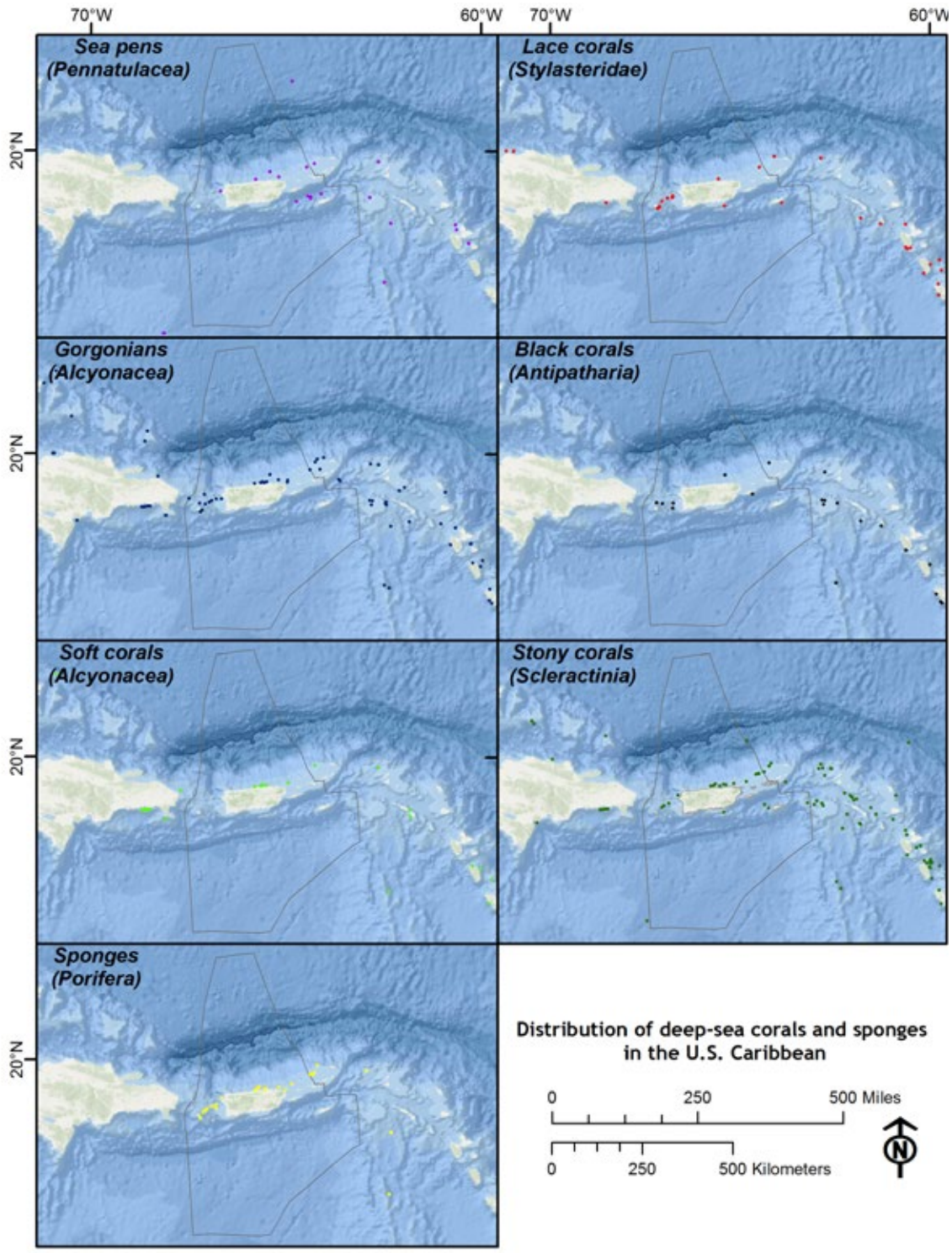


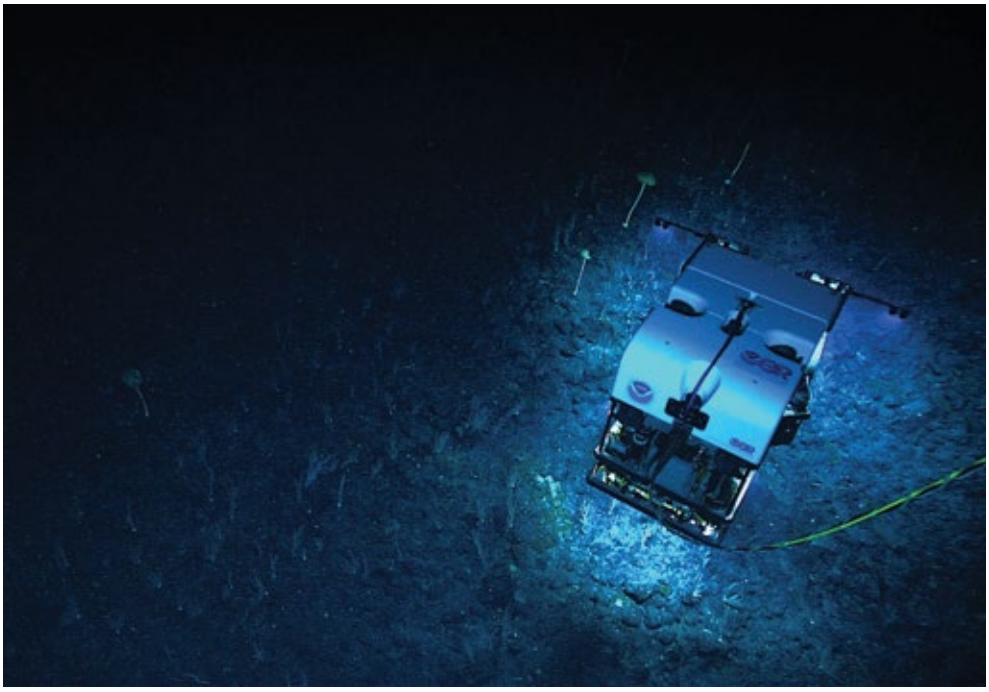

130°W
125°W
120°W
50°N
45°N
40°N
35°N
30°N
Sea pens (Pennatulacea)
Soft corals (Alcyonacea)
Black corals (Antipatharia)
Gorgonians (Alcyonacea)
Lace corals (Stylasteridae)
Stony corals (Scleractinia)
Sponges (Porifera)
Distribution of deep-sea corals and sponges in the U.S. Pacific Region
0
750
1,500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


75°W
70°W
45°N
40°N
35°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. Greater Atlantic Region
0
500
1,000 Miles
0
500
1,000 Kilometers
N


80°W
75°W
Sea pens
(Pennatulacea)
Soft corals
(Alcyonacea)
Black corals
(Antipatharia)
Gorgonians
(Alcyonacea)
Lace corals
(Stylasteridae)
Stony corals
(Scleractinia)
Sponges
(Porifera)
35°N
30°N
25°N
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


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


70°W
60°W
70°W
60°W
Sea pens
(Pennatulacea)
Lace corals
(Stylasteridae)
Gorgonians
(Alcyonacea)
Black corals
(Antipatharia)
Soft corals
(Alcyonacea)
Stony corals
(Scleractinia)
Sponges
(Porifera)
20°N
20°N
20°N
20°N
Distribution of deep-sea corals and sponges
in the U.S. Caribbean
0
250
500 Miles
0
250
500 Kilometers
N



Appendix 3: Deep-Sea Coral Areas with Potential for Interaction with Fishing Gear

The Deep Sea Coral Research and Technology Program, through a review of its funded research and other scientific literature, has identified locations with evidence of major aggregations of structure-forming deep-sea corals, and locations where fishing gear interactions with deep-sea corals have been documented or remain possible because the coral habitats are open to bottom fishing. Directed by the MSA to help reduce interactions between fishing gear and corals, the Program is committed to supporting studies that help resource managers to develop and evaluate management options for these locations, as listed below.

Data used for creating this list are available from our Program upon request and may be used by the Councils in analyzing whether and how to designate zones to protect deep-sea corals from physical damage by fishing gear under the MSA deep-sea coral discretionary authority (MSA section 303(b)(2)(B)). References are provided at the end of this appendix.

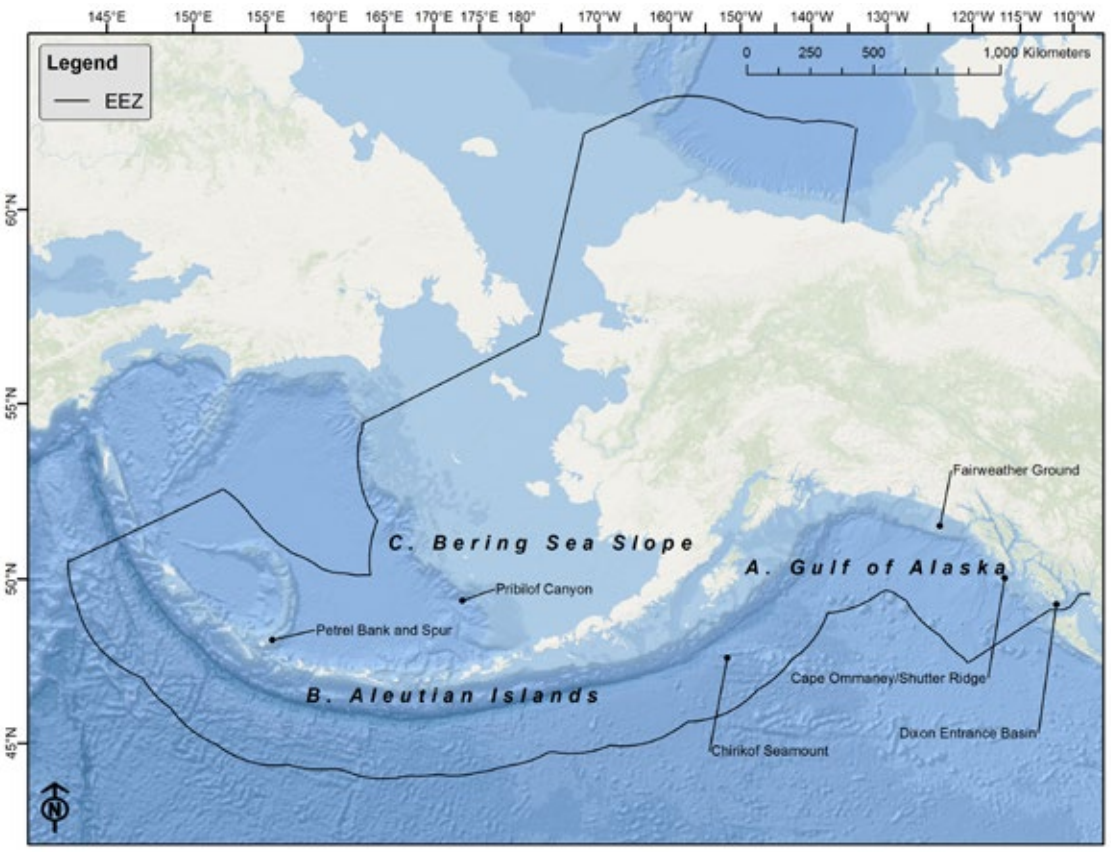
Alaska Region

The EEZ around Alaska includes four major regions: the Gulf of Alaska, Aleutian Islands, eastern Bering Sea, and the Arctic (Chukchi and Beaufort Seas). Corals known from the U.S. Arctic Ocean are mostly limited to one small species of soft coral, and the region is currently closed to fishing. The North Pacific Fishery Management Council has established extensive areas in each of the other three regions to protect coral habitats from fishing gear impacts. Coral aggregations outside of these areas could be considered for additional protection, including:

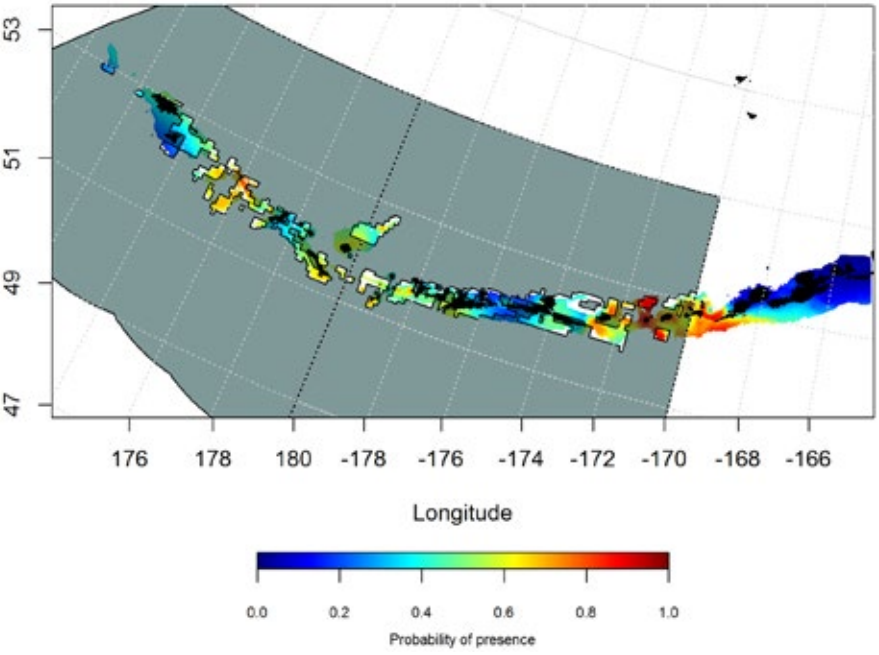
A. Gulf of Alaska: Primnoa coral habitats outside currently protected areas, including, but not limited to Chirikof, the Fairweather Ground, Cape Ommaney/Shutter Ridge, and Dixon Entrance basin. Most of these areas are closed to bottom-trawling, but corals are vulnerable to other gear types operating 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 extensive Aleutian Islands Habitat Conservation Area and smaller Coral Habitat Protection Areas provide important protection to much coral habitat. However, surveys conducted by the Deep Sea Coral Research and Technology Program and other newly analyzed information, along with predictive habitat modeling, suggest that certain areas, including many “coral garden” habitats, may currently remain open to bottom trawling. In addition, a number of 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. Parts of the Bering Sea slope, including Pribilof Canyon, were identified in previous editions of this report as coral areas with potential for fishing gear interaction. Since the last report, the Alaska Fishery Science Center has led predictive habitat modeling for corals in this area along with ground-truth surveys in partnership with the Deep Sea Coral Research and Technology Program. The results indicate that while corals do occur on the Eastern Bering Sea slope and canyons, their abundance and density are much less than in many areas of the Aleutian Islands and the Gulf of Alaska. About one quarter of the coral habitat predicted for the eastern Bering Sea slope occurs in Pribilof Canyon (about 10% of the total slope area). The predicted coral habitat also extends westward to the adjacent slope, indicating that this coral habitat concentration may not be unique to Pribilof Canyon. The North Pacific Council reviewed the new information in 2015 and concluded that further management action was not warranted at this time.



Under current fishery management measures, approximately 50 percent of the areas around the Aleutian Islands predicted by the model to have a high probability of coral and sponge habitats in waters shallower than 500 meters (1,640 feet) are protected from bottom trawling. The distribution of probability of presence for coral in the Aleutian Islands is shown below, with the areas closed to mobile fishing gear shaded in grey. (Credit: CN Rooper, NOAA)



West Coast Region

Although a significant extent of the West Coast EEZ is protected from bottom trawling (e.g., via essential fish habitat (EFH) protections and the Rockfish Conservation Areas), additional areas of documented deep-sea coral presence are open to bottom-contact fishing activities. The spatially discrete areas listed here, based on observed coral bycatch and documented presence of coral aggregations, could potentially be considered by the Council for additional protection.

A. High coral bycatch area bordering Nitinat Canyon

B. Deep-sea coral areas in the Olympic Coast National Marine Sanctuary adjacent to the current Olympic 2 EFH Conservation Area

C. Deep-sea coral areas in parts of Astoria Canyon outside of the Astoria Canyon EFH Conservation Area

D. High coral bycatch areas off Central Oregon

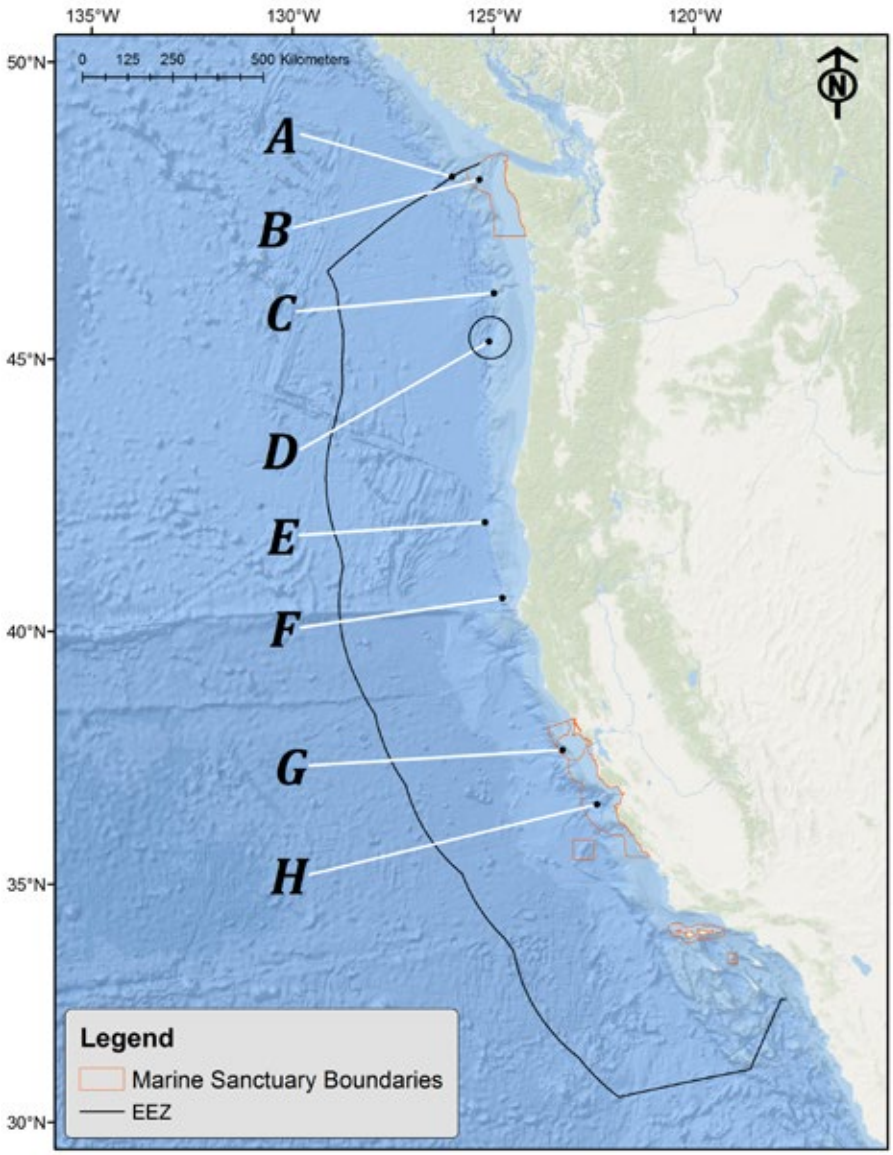
E. High coral bycatch areas off Oregon/California border

F. High coral bycatch areas in Eel River Canyon outside of the Eel River Canyon EFH Conservation Area

G. Rittenburg and Cochrane Banks and Escarpment within Gulf of the Farallones National Marine Sanctuary

H. Certain areas of Monterey Bay National Marine Sanctuary, including the Ascension and Año Nuevo Canyon Complex

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



Greater Atlantic Region

Four canyons (Norfolk, Lydonia, Oceanographer, and Veatch) have been closed to bottom trawling to protect the essential fish habitat of certain commercially fished species. These closures may have ancillary effects of protecting deep-sea corals that occur in these canyons.

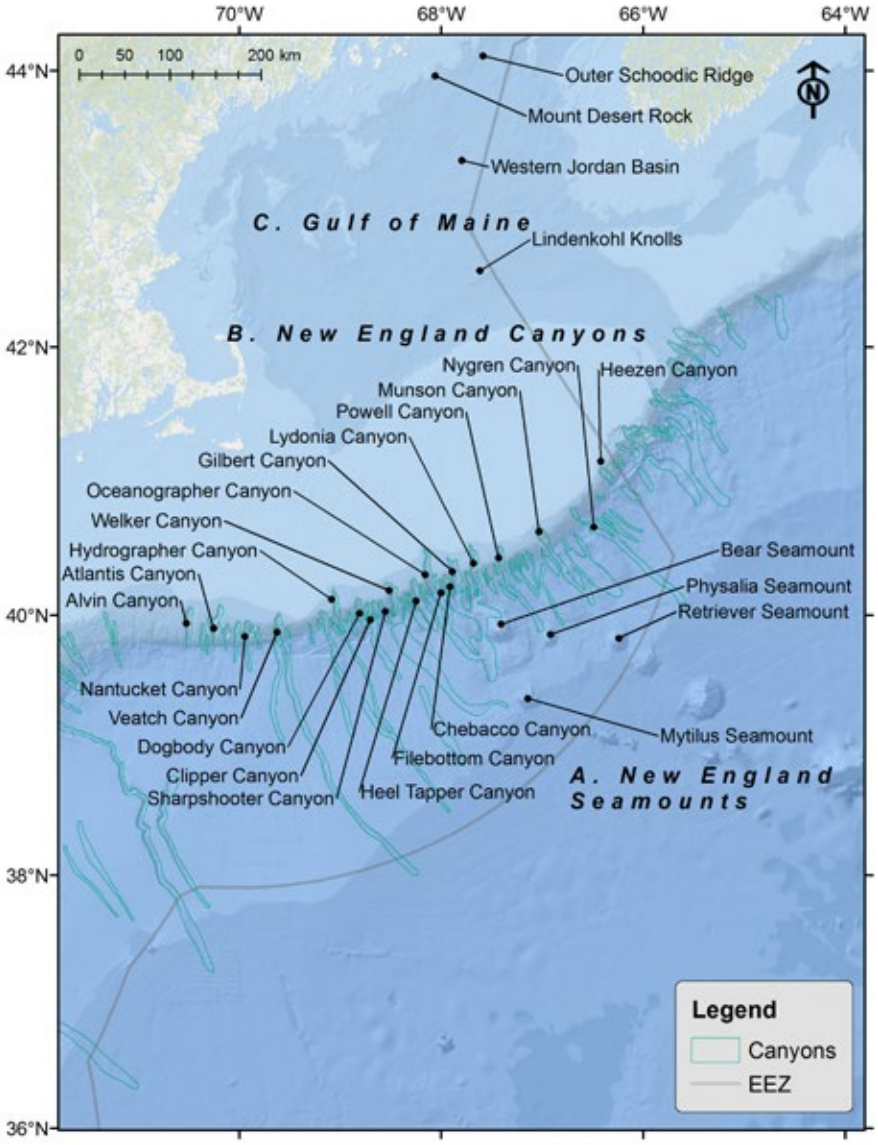
In 2015, the Mid-Atlantic Fishery Management Council proposed management measures to protect deep-sea coral habitats in 15 discrete areas in the portion of the outer continental shelf and slope that is within the Council's jurisdiction. These discrete areas are included in a much larger deep-sea coral zone (38,000 square miles) that extends from a landward extent of approximately 450 meters depth to the outer boundary of the U.S. EEZ. These measures were submitted to the Secretary of Commerce for review in early 2016.

In a related action, the New England Council is developing an omnibus amendment to protect deep-sea corals in submarine canyons and seamounts in the contiguous New England region. Areas being considered include:

A. Four New England seamounts within the U.S. EEZ: Bear, Retriever, Physalia, and Mytilus

B. A number of canyons on the outer continental shelf and slope, including Heezen, Nygren, Munson, Powell, Lydonia, Gilbert, Oceanographer, Welker, Hydrographer, Atlantis, and Alvin; also other minor canyons where corals have been documented in recent fieldwork

C. Four areas in the Gulf of Maine: Western Jordan Basin (114 Fathom Bump), Outer Schoodic Ridge, Mount Desert Rock, and Lindenkohl Knolls. Corals also occur in central Jordan Basin, but in lower density.

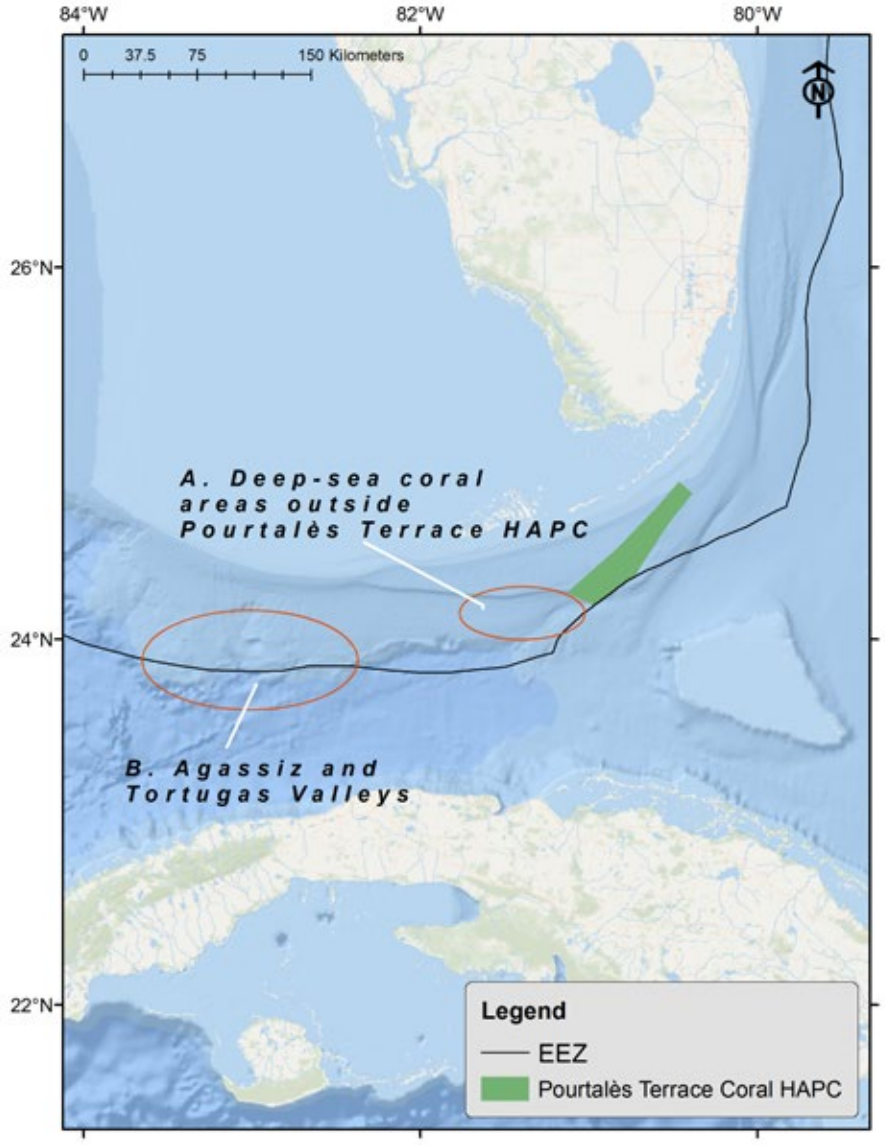


South Atlantic Council Region

Prior to this reporting period, the South Atlantic Fishery Management Council had closed large areas 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 CHAPS and the Oculina Bank HAPC to incorporate additional coral habitats identified by the Program and partners. Coral aggregations outside of the protected areas that could be considered for additional protection include:

A. Deep-sea coral areas outside the Pourtalès Terrace CHAPC

B. Agassiz and Tortugas Valleys

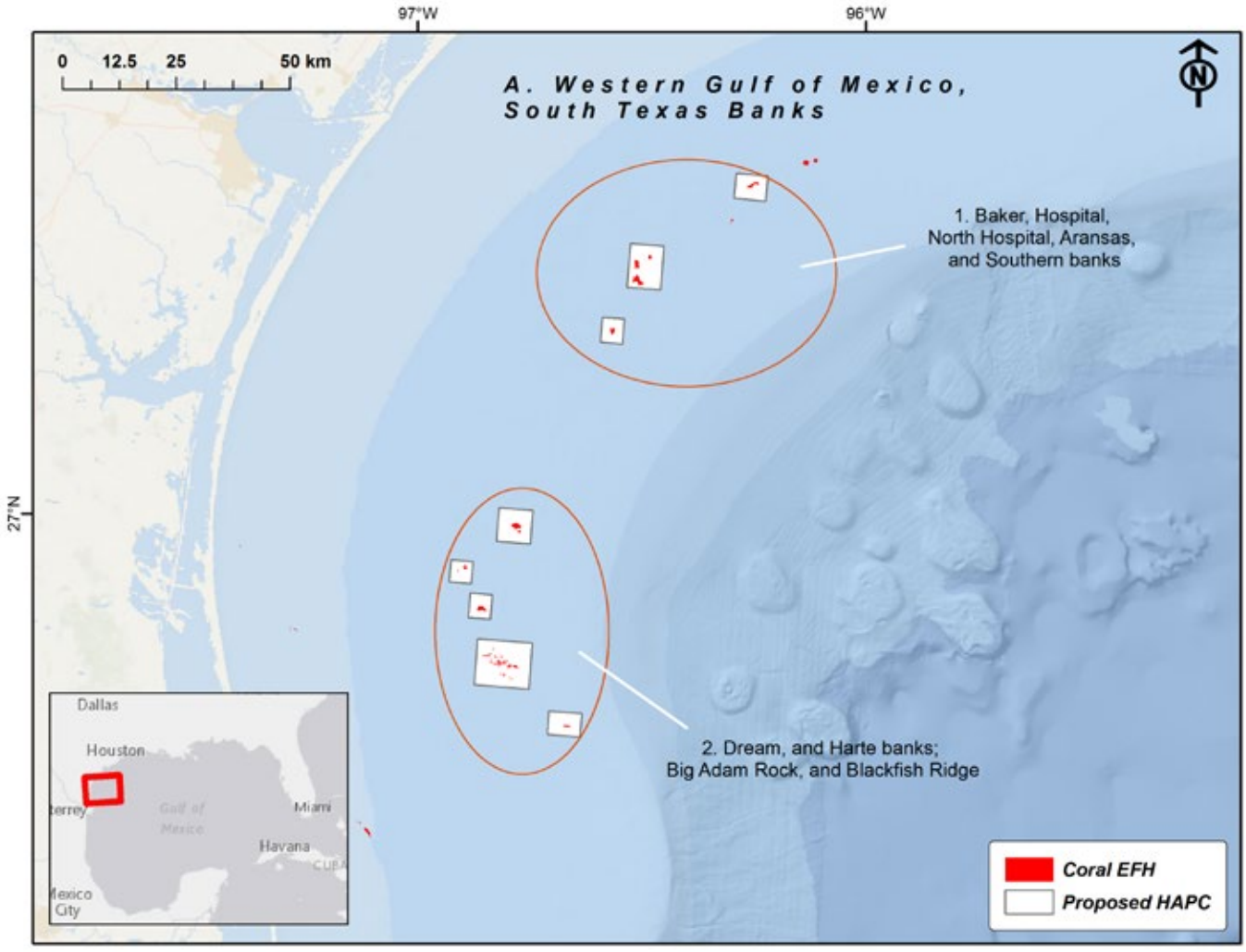


Gulf of Mexico Region

In the Gulf of Mexico, a number of deep-sea coral aggregations have been documented in areas open to bottom fishing, as listed below. The majority of these areas have been reviewed by the Gulf of Mexico Fishery Management Council's Joint Coral Scientific and Statistical Committee and Coral Advisory Panel. Many were the subject of surveys conducted by the Flower Garden Banks National Marine Sanctuary, the BOEM/USGS/NOAA Lophelia II Project, and BOEM's 4-year study "Deep-Water Reconnaissance of Potentially Sensitive Biological Features (PSBF's) Surrounding Shelf-Edge Topographic Banks in the Northern Gulf of Mexico."

A. Western Gulf of Mexico – South Texas Banks:

1. Baker, Hospital, North Hospital, Aransas, Southern Banks
2. Dream, and Harte banks; Big Adam Rock, and Blackfish Ridge



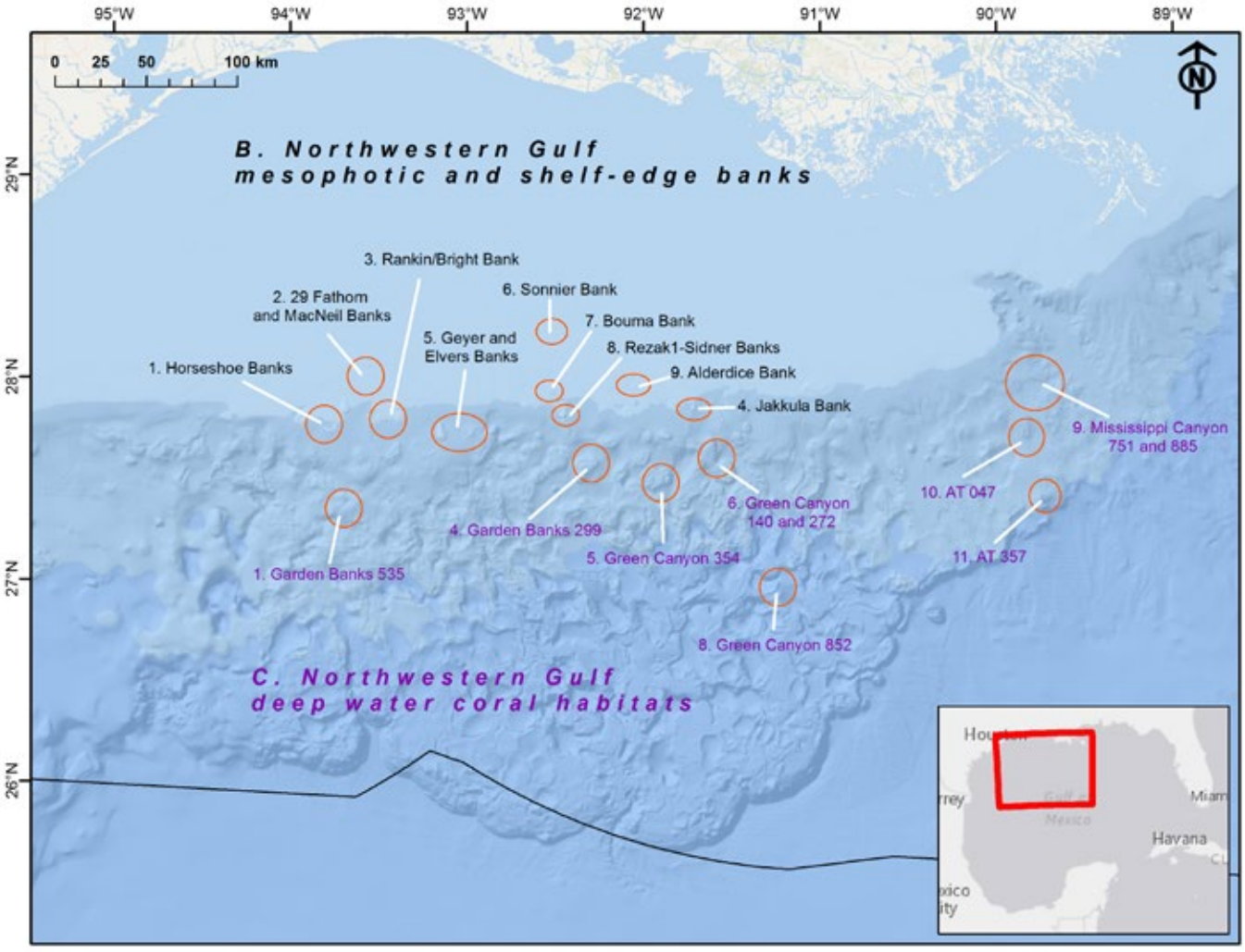
B. Northwestern Gulf mesophotic and shelf-edge banks:

1. Horseshoe Banks
2. 29 Fathom and MacNeil Banks
3. Rankin/Bright Bank
4. Jakkula Bank4*
5. Geyer and Elvers Banks
6. Sonnier Bank*
7. Bouma Bank*
8. Rezak*-Sidner Banks
9. Alderdice Bank*

C. Northwestern Gulf deepwater coral habitats:

1. Garden Banks 535
2. Garden Banks 235
3. Garden Banks 338
4. Garden Banks 299
5. Green Canyon 354
6. Green Canyon 140 and 272
7. Green Canyon 234
8. Green Canyon 852
9. Mississippi Canyon 751 and 885
10. AT047
11. AT357

* These areas are HAPCs but do not have regulations to prevent fishing gear from damaging coral habitat.

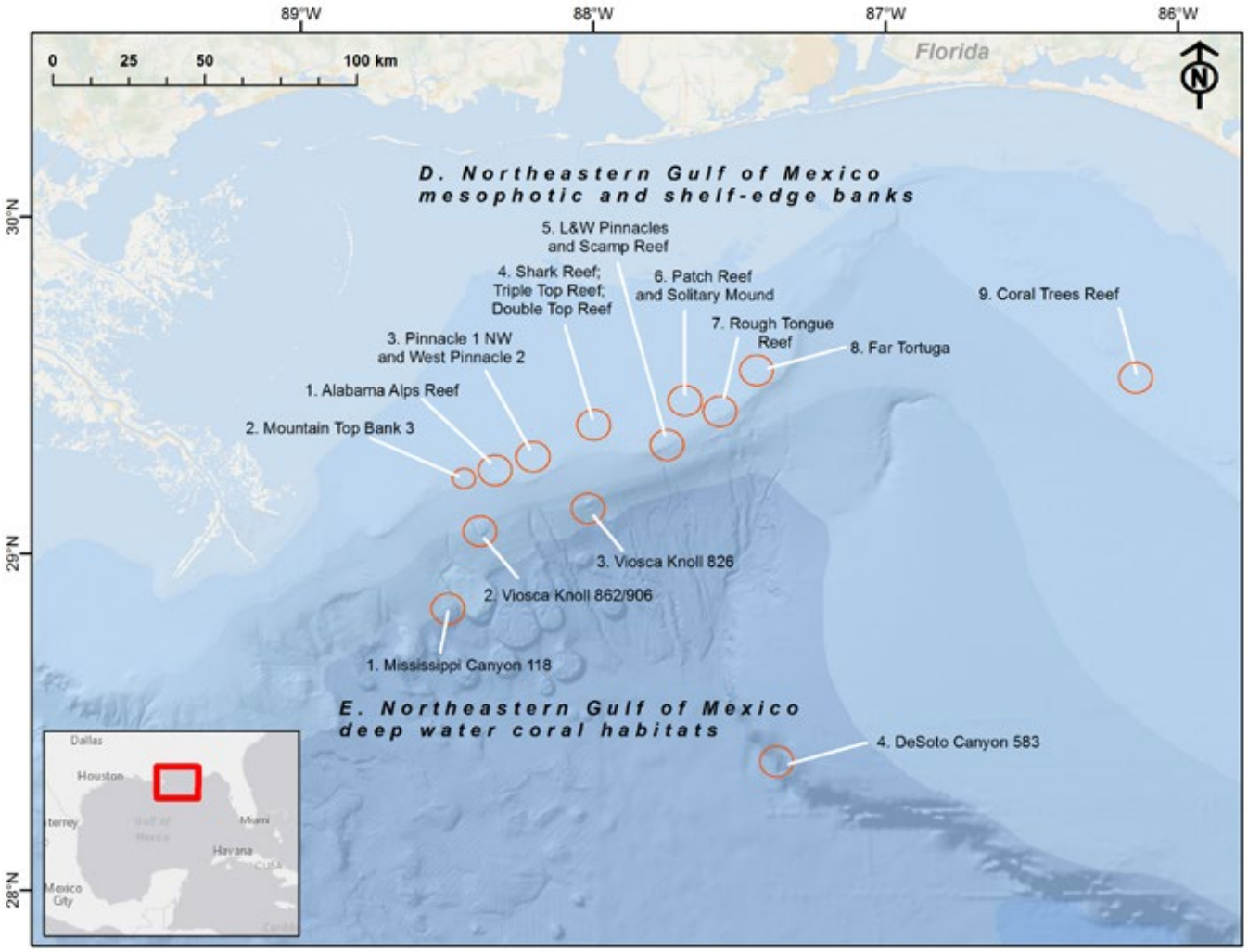


D. Northeastern Gulf of Mexico mesophotic and shelf-edge banks:

1. Alabama Alps Reef
2. Mountain Top Bank 3
3. Pinnacle 1 NW and West Pinnacle 2
4. Shark Reef; Triple Top Reef; Double Top Reef
5. L&W Pinnacles and Scamp Reef
6. Patch Reef and Solitary Mound
7. Rough Tongue Reef
8. Far Tortuga
9. Coral Trees Reef

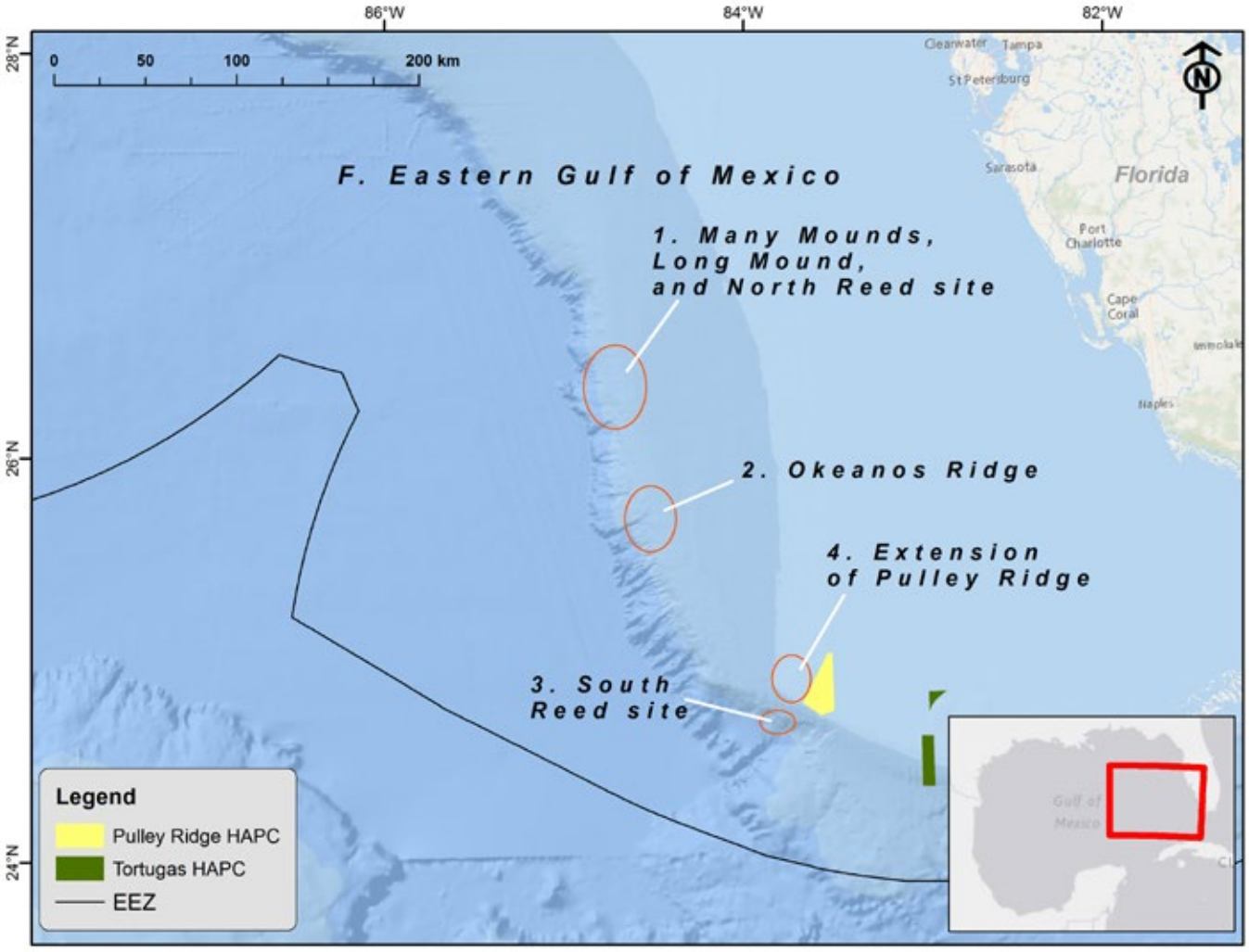
E. Northeastern Gulf of Mexico deepwater coral habitats:

1. Mississippi Canyon 118
2. Viosca Knoll 862/906
3. Viosca Knoll 826
4. DeSoto Canyon 583



F. Eastern Gulf of Mexico (off southwest Florida)

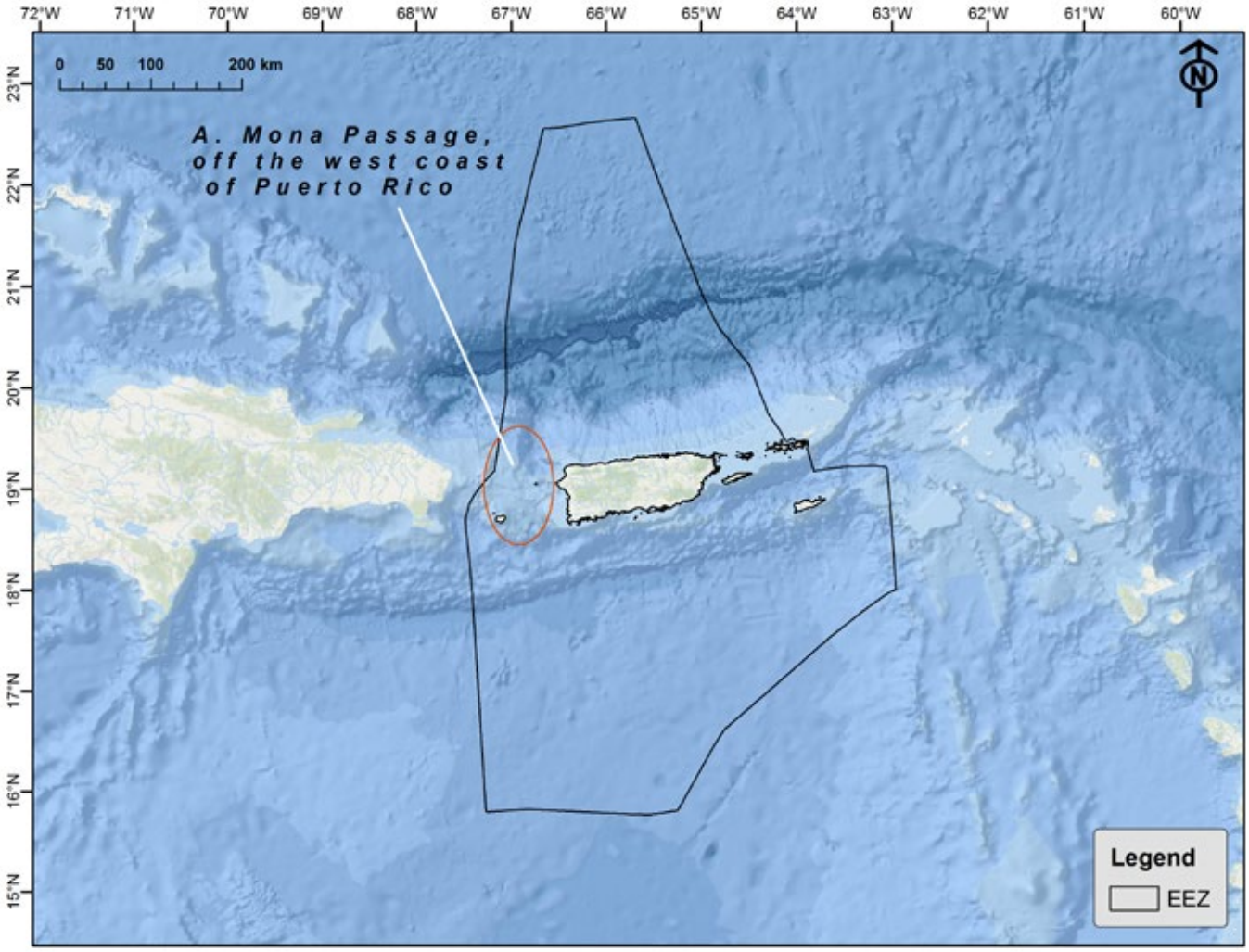
1. Many Mounds, Long Mound, and North Reed sites
2. Okeanos Ridge
3. South Reed site
4. Extension of Pulley Ridge outside the existing HAPC



U.S. Caribbean

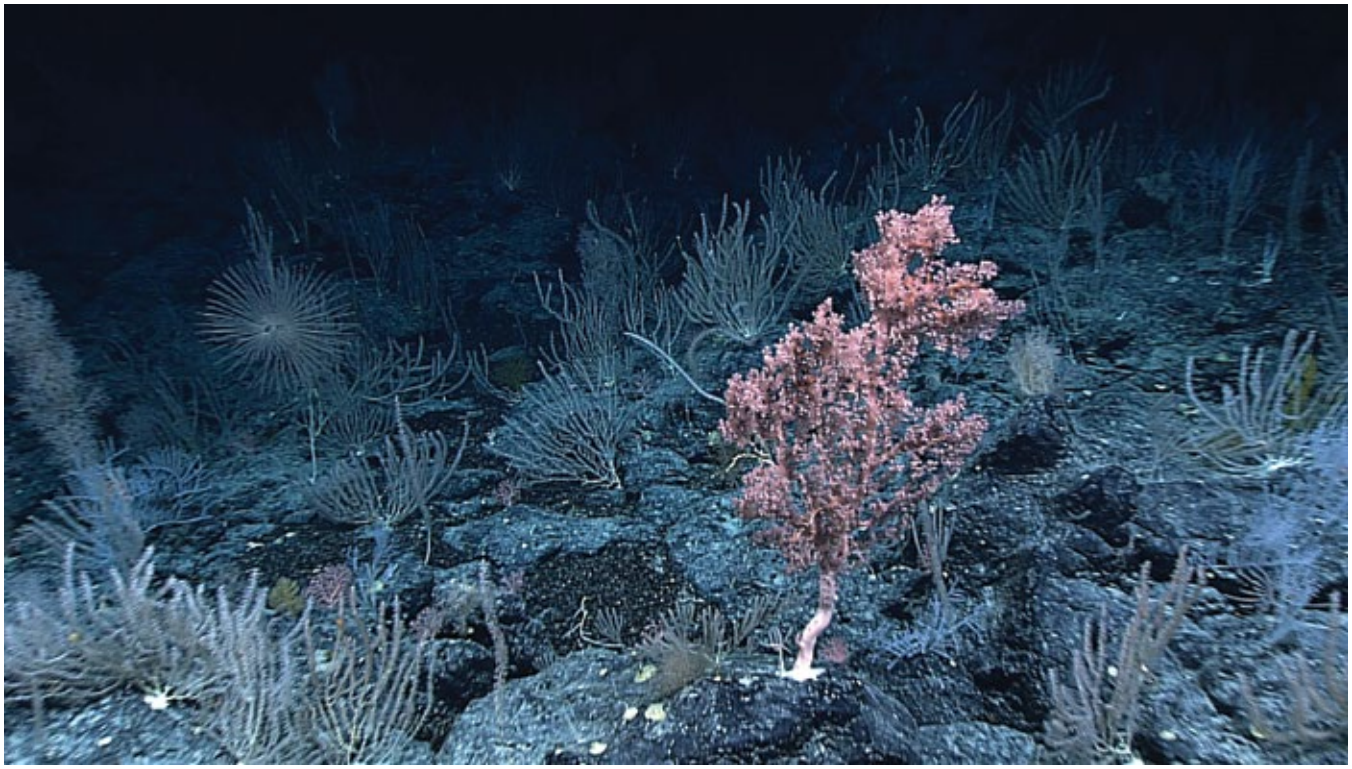
Research on deep-sea habitats in the U.S. Caribbean to date is limited, and specific locations of deep-sea corals and whether fishing gear come in contact with them are not well known. However, a major area of deep-sea coral aggregations open to bottom fishing is:

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



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 here.



References for Appendix 3

Alaska – Regional summary in: Stone, R.P., and S. K. Shotwell. 2007. State of Deep Coral Ecosystems in the Alaska Region: Gulf of Alaska, Bering Sea and the Aleutian Islands. pp. 65–108. In: S.E. Lumsden, T.F. Hourigan, A.W. Bruckner, and G. Dorr (eds.). The State of Deep Coral Ecosystems of the United States. NOAA Technical Memorandum CRCP-3. Silver Spring, MD.

A. **Gulf of Alaska Red Tree Coral Areas:**
- Stone RP, Masuda MM, Karinen JF (2014) Assessing the ecological importance of red tree coral thickets in the eastern Gulf of Alaska. ICES J Mar Sci 72:900-915.
- Stone and Shotewell (2007).

B. **Aleutian Island coral areas:**
- Deep Sea Coral Research and Technology Program – Alaska Coral and Sponge Initiative 2012-1014.
- NMFS Alaska Fisheries Science Center Groundfish Observer Data (http://www.afsc.noaa.gov/maps/fma/datamap/obsmap.html)
- NMFS Alaska Fisheries Science Center Groundfish Trawl Survey and Longline Survey Data (http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm)
- Rooper CN, Zimmermann M, Prescott MM, Hermann AJ (2014) Predictive models of coral and sponge distribution, abundance and diversity in bottom trawl surveys of the Aleutian Islands, Alaska. Mar Ecol Prog Ser 503:157-176.
- Stone, R. P.(2014) The ecology of deep-sea coral and sponge habitats of the central Aleutian Islands of Alaska. NOAA Professional Paper.
- Stone and Shotewell (2007).

C. **Bering Sea Slope and Canyons:**
- Miller RJ, Juska C, Hocevar J. (2015) Submarine canyons as coral and sponge habitat on the eastern Bering Sea slope. Global Ecology and Conservation 4:85-94.
- Miller R J, Hocevar J, Stone R, Federov D (2012) Structure-forming corals and sponges and their use as fish habitat in Bering Sea submarine canyons. PLoS ONE 7(3): e33885.
- Rooper C, Sigler M, Goddard P, Malecha P, Towler R, Williams K, Wilborn R (2015) Validation of models of the distribution of structure-forming invertebrates in the eastern Bering Sea using an underwater stereo camera. A report to the North Pacific Fishery Management Council.
- Sigler MF, Rooper CN, Hoff GR, Stone RP, McConnaughey RA, Wilderbuer TK (2015) Faunal features of submarine canyons on the eastern Bering Sea slope. Mar Ecol Prog Ser 526:21-40.
- Sigler, M.F., Rooper, C.N., Hoff G.R., Stone R.P., McConnaughey R.A., Wilderbuer T.K. 2013. Are Bering Sea canyons unique habitats within the eastern Bering Sea? Draft paper presented for Review by North Pacific Fishery Management Council.

West Coast – Regional summaries in:
Whitmire, C. E., & Clarke, M. E. (2007). State of Deep Coral Ecosystems of the U.S. Pacific Coast: California to Washington. In S. E. Lumsden, T. F. Hourigan, A. W. Bruckner, & G. Dorr (Eds.), *The State of Deep Coral Ecosystems of the United States* (pp. 109-154). Silver Spring, MD: NOAA.

Clarke ME, Whitmire CE, Yoklavich MM (2015) State of Deep-Sea Coral and Sponge Ecosystems of the U.S. West Coast: 2015. In: Hourigan TF, Etnoyer PJ, Cairns SD, Tsao C-F (eds.) The State of Deep-Sea Coral and Sponge Ecosystems of the United States: 2015. NOAA Technical Memorandum. NOAA, Silver Spring, pp 5-1 – 5-42 (Prepublication version).

A. **High coral bycatch area bordering Nitinat Canyon**
   a. Groundfish Essential Fish Habitat Review Committee (GEFHRC) (2012) Pacific Coast Groundfish 5-Year Review of Essential Fish Habitat Report to the Pacific Fishery Management Council. Phase 1: New Information. September 2012. 427 pp.
   b. Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013) Proposal to the Pacific Fishery Management Council to Modify Groundfish Essential Fish Habitat Designation, Conservation, and Enforcement. 183 pp.

B. **Olympic Coast National Marine Sanctuary**
   a. Brancato, M. S., Bowlby, C. E., Hyland, J., Intelmann, S. S., & Brenkman, K. (2007) Observations of deep coral and sponge assemblages in Olympic Coast National Marine Sanctuary, Washington. Marine Sanctuaries Conservation Series NMSP-07-04. Silver Spring: NOAA.

b. Bowlby, CE, J. Bright, K. Brenkman, P. Etnoyer, S. Rooney, C. Brady. (2011) A characterization of deep-sea coral and sponge communities on the continental shelf of Olympic Coast National Marine Sanctuary, Northern Washington using a remotely operated vehicle in June 2010. A Report to NOAA's Deep Sea Coral Research and Technology Program. 21pp.
c. Bowlby E. and Culver M. (2013). Options for Potential Modifications to Olympic 2 Groundfish Essential Fish Habitat Conservation Area in Washington State. Proposal to the Pacific Fishery Management Council 28 pp. (and references therein).

C. **Parts of Astoria Canyon that have no special protections**
   a. Bianchi C. (2011) Abundance and distribution of megafaunal invertebrates in NE Pacific submarine canyons and their ecological associations with demersal fishes. MS Thesis, Washington State University, Vancouver.
   b. GEFHRC (2012).
   c. Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013).

D. **High coral bycatch areas off Central Oregon**
   a. GEFHRC (2012).
   b. Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013).

E. **High coral bycatch areas off Oregon/California border**
   a. GEFHRC (2012).
   b. Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013).

F. **Eel River Canyon coral bycatch area**
   a. GEFHRC (2012).
   b. Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013).

G. **Rittenburg and Cochrane Banks and Farallon Escarpment within Gulf of the Farallones National Marine Sanctuary**
   a. Etnoyer PJ, Cochrane G, Salgado E, Graiff K, Roletto J, Williams G, Reyna K, Hyland J (2014) Characterization of deep coral and sponge communities in the Gulf of the Farallones National Marine Sanctuary: Rittenburg Bank, Cochrane Bank and the Farallon Escarpment. NOAA Technical Memorandum NOS NCCOS 190.
   b. NOAA (2013a) A Proposal to Consider Options for New EFH HAPC(s) and Conservation Areas Submitted by Gulf of the Farallones National Marine Sanctuary. 42 pp. (and references therein).
   c. Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013).

H. **Monterey Bay National Marine Sanctuary deep-sea coral areas, including the Ascension and Año Nuevo Canyon Complex**
   a. NOAA (2013b) Collaborative Groundfish Essential Fish Habitat Proposal: Protecting Groundfish Essential Fish Habitat While Balancing Fishing Opportunities in Monterey Bay National Marine Sanctuary, South of Año Nuevo (and references therein).

Northeast – Regional summary in: Packer, D. B., Boelke, D., Guida, V., & McGee, L.-A. (2007). State of Deep Coral Ecosystems in the Northeastern U.S. Region: Maine to Cape Hatteras. In S. E. Lumsden, T. F. Hourigan, A. W. Bruckner, & G. Dorr (Eds.), The State of Deep Coral Ecosystems of the United States (pp. 195-232). Silver Spring, MD: NOAA.

A. **New England Seamounts:**
   - Packer et al. (2007).
   - Kilgour MJ, Auster PJ, Packer D, Purcell M, Packard G, Dessner M, Sherrell A, Rissolo D (2014) Use of AUVs to inform management of deep-sea corals. Marine Technology Soc. J. 48(1):21-27.
   - Watling, L., Auster, P. J., Babb, I., Skinder, C., & Hecker, B. (2003) A geographic database of deepwater alcyonaceans of the northeastern U.S. continental shelf and slope, Version 1.0 CD-ROM. Groton: National Undersea Research Center, University of Connecticut.

B. **New England Canyons:**
   - Packer et al. (2007).

- Hecker, B., & Blechschmidt, G. (1980) Final historical coral report for the canyon assessment study in the Mid- and North Atlantic areas of the U.S. outer continental shelf: epifauna of the northeastern U.S. continental margin. Appendix A. In Canyon Assessment Study. No. BLM-AA551-CT8-49. Washington, DC: U.S. Department of the Interior, Bureau of Land Management.
- Hecker, B., Logan, D. T., Gandarillas, F. E., & Gibson, P. R. (1983) Megafaunal assemblages in Lydonia Canyon, Baltimore Canyon, and selected slope areas. In Canyon and slope processes study: Vol. III, biological processes. Final report for U.S. Department of the Interior, Minerals Management Service (pp. 1-140). Washington, DC: Minerals Management Service.
- Kinlan BP, Poti M, Drohan A, Packer DB, Nizinski M, Dorfman D, Caldow C. (2013) Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions. Downloadable digital data package. NOAA. (http://coastalscience.noaa.gov/projects/detail?key=35)
- NOAA (2012) Deepwater Canyons 2012: Pathways to the Abyss (http://oceanexplorer.noaa.gov/explorations/12midatlantic/welcome.html)
- NOAA (2013a) Deepwater Canyons 2013: Pathways to the Abyss (http://oceanexplorer.noaa.gov/explorations/13midatlantic/welcome.html)
- NOAA (2013b) Okeanos Explorer Northeast U.S. Canyons Expedition 2013 (http://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/welcome.html)
- Watling et al., (2003).

C. **Gulf of Maine:**
- Auster PJ, et al. (2014) Imaging Surveys of Select Areas in the Northern Gulf of Maine for Deep-sea Corals and Sponges during 2013-2014. Report to the New England Fishery Management Council - 1 December 2014.
- Auster P.J., Kilgour M., Packer D., Waller R., Auscavitch S. and Watling, L. (2013) Octocoral gardens in the Gulf of Maine (NW Atlantic). Biodiversity, DOI: 10.1080/14888386.2013.8504469
- Auster, P. J. (2005) Are deep-water corals important habitats for fishes? In A. Freiwald, & J. M. Roberts (Eds.), Cold-water Corals and Ecosystems (pp. 747-760). Berlin: Springer.
- Packer et al. (2007).
- Watling et al., (2003).

South Atlantic: – Regional summary in: Ross S.W. and Nizinski M.S. (2007) State of Deep Coral Ecosystems in the Southeast Region: Cape Hatteras to Southeast Florida. Pages 233-269. In: Lumsden SE, Hourigan TF, Bruckner AW and Dorr G (eds.) The State of Deep Coral Ecosystems of the United States. NOAA Technical Memorandum CRCP-3, Silver Spring, MD.

A. **Pourtales Terrace** – Areas outside existing Deepwater Coral Habitat Area of Particular Concern.
- Reed, JK, Messing C, Walker BK, Brooke S, Correa TBS, Brower M, Udouj T, Farrington S. (2013) Habitat Characterization, Distribution, and Areal Extent of Deep-sea Coral Ecosystems off Florida, Southeastern U.S.A. Caribbean Journal of Science 47(1): 13-30.

B. **Agassiz and Tortugas Valleys**
- Reed et al. (2013).

Gulf of Mexico: – Regional summaries in:
- Brooke, S., & Schroeder, W. W. (2007) State of deep coral ecosystems in the Gulf of Mexico region: Texas to the Florida Straits. In S. E. Lumsden, T. F. Hourigan, A. W. Bruckner, & G. Dorr (Eds.), The State of Deep Coral Ecosystems of the United States (pp. 271-306). Silver Spring, MD: NOAA.
- Etnoyer, P. (2009) Distribution and Diversity of Octocorals in the Gulf of Mexico, PhD Dissertation. Corpus Christi: Texas A&M University. 187 pp.
- Gulf of Mexico Fishery Management Council (2013) Workshop on Interrelationships between Coral Reefs and Fisheries. May 20-22, 2013; Tampa, Florida. Summary Report 54 pp.
- Gulf of Mexico Fishery Management Council (2015) Joint Coral Scientific and Statistical Committee and Coral Advisory Panel Meeting Summary May 27, 2015. Tab N, No. 4 in Gulf of Mexico Fishery Management Council June 2015 Briefing Book.

A. **Eastern Gulf of Mexico**
- Reed, J. & Rogers S. (2011) Final Cruise Report – Florida Shelf-Edge Expedition (FLoSEE) Deepwater Horizon Oil Spill Response: Survey of deepwater and mesophotic reef ecosystems in the eastern Gulf Of Mexico and southeastern Florida. Harbor Branch Oceanographic Institute, Florida Atlantic University. 82 pp.

B. **Northeastern Gulf of Mexico mesophotic and shelf-edge banks:**

- Continental Shelf Associates, Inc. and Texas A&M University, Geochemical and Environmental Research Group (2001) Mississippi/Alabama Pinnacle Trend Ecosystem Monitoring, Final Synthesis Report. U.S. Department of the Interior, Geological Survey, Biological Resources Division, USGS BSR 2001-0007 and Minerals Management Service, Gulf of Mexico Regions, New Orleans, LA, OCS Study MMS 2001-080. 415 pp. +apps.
- Etnoyer PJ, Wickes LN, Silva M, Dubick JD, Salgado E, Balthis L, MacDonald IR (2015) Decline in condition of gorgonian octocorals on mesophotic reefs in the northern Gulf of Mexico: before and after the Deepwater Horizon oil spill. Coral Reefs. doi:10.1007/s00338-015-1363-2
- Peccini M.B. & MacDonald I.R. (2008) Correspondence of sea fan orientations with measured currents on hard bottom habitats of the Mississippi/Alabama continental shelf. Continental Shelf Research 28:302–308.
- Silva, M., P.J. Etnoyer, and I.R. MacDonald. (2015) Coral injuries observed at mesophotic reefs after the Deepwater Horizon oil discharge. Deep Sea Research Part II: Topical Studies in Oceanography. doi:10.1016/j.dsr2.2015.05.013
- Weaver D., Dennis GD, Sulak KJ (2001) Northeastern Gulf of Mexico Coastal and Marine Ecosystem Program: Community structure and trophic ecology of demersal fishes on the Pinnacles Reef Track. Final Synthesis Report. USGS BSR-2001-0008; and MMS Gulf of Mexico OCS Region Study MMS 20022-034. 92 pp.

C. & E. **Northeastern & Northwestern Gulf of Mexico deepwater coral habitats:**

- Brooks, J.M., C. Fisher, H. Roberts, E. Cordes, I. Baums, B. Bernard, R. Church, P. Etnoyer, C. German,E. Goehring, I. McDonald, Harry Roberts, T. Shank, D. Warren, S. Welsh, G. Wolff. (2012) Exploration and research of northern Gulf of Mexico deepwater natural and artificial hard-bottom habitats with emphasis on coral communities: Reefs, rigs, and wrecks—"Lophelia II": Interim report. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2012-106. 135p.
- Cordes, E. E., M. McGinley, E. Podowski, E. L. Becker, S. Lessard-Pilon, S. T. Viada and C. R. Fisher. (2008) Coral communities of the deep Gulf of Mexico. Deep Sea Res. I. 55:777-787.
- CSA International, Inc. (2007) Characterization of Northern Gulf of Mexico deepwater hard bottom communities with emphasis on Lophelia coral. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2007-044. 169 pp. + app.
- Schroeder, W.W. (2007) Seafloor characteristics and distribution patterns of Lophelia pertusa and other sessile megafauna at two upper-slope sites in the northeastern Gulf of Mexico. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2007-035. 49 pp.
- Sulak, K. J., M. T. Randall, K. E. Luke, A. D. Norem, and J. M. Miller (Eds.). (2008) Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on Lophelia Coral - Lophelia Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008-1148; OCS Study MMS 2008-015.
- White et al. (2012) Impact of the Deepwater Horizon oil spill on a deep-water coral community in the Gulf of Mexico. PNAS 109(50):20303-20308.

D. **Northwestern Gulf mesophotic and shelf-edge banks:**

- Gittings, S.R., Bright, T.J., Schroeder, W.W., Sager, W.W., Laswell, J.S., Rezak, R. (1992) Invertebrate assemblages and ecological controls on topographic features in the Northeast Gulf of Mexico. Bulletin of Marine Science 50(3): 435-455.
- NOAA (2012) Flower Garden Banks National Marine Sanctuary Final Management Plan. Silver Spring, MD. 130 pp.
- Nuttall M.F. (2013) Antipatharian diversity and habitat suitability mapping in the mesophotic zone of the Northwestern Gulf of Mexico. MS Thesis, Texas A&M University. 119 pp.
- Rezak, R., Bright, T.J., & McGrail, D.W. (1985) Reefs and Banks of the Northwestern Gulf of Mexico: Their Geological, Biological, and Physical Dynamics. New York: Wiley. 259 pp.

F. **Western Gulf of Mexico – South Texas Banks:**

- Nash, H. L., S. J. Furiness, and J. W. Tunnell, Jr. (2013) What is known about species richness and distribution on the outer-shelf South Texas Banks? Gulf and Caribbean Research, 25:9-18.

U.S. Caribbean:

A. Lutz, S. J., & Ginsburg, R. N. (2007) State of Deep Coral Ecosystems in the Caribbean Region: Puerto Rico and the U.S. Virgin Islands. In S. E. Lumsden, T. F. Hourigan, A. W. Bruckner, & G. Dorr (Eds.), The State of Deep Coral Ecosystems of the United States (pp. 307-365). Silver Spring, MD: NOAA.

USO, Unidentified Swimming Organism, east of Pacific's Johnston Atoll.

U.S. Secretary of Commerce
Penny Pritzker

Administrator of National Oceanic and Atmospheric Administration and Undersecretary of Commerce
Kathryn D. Sullivan, Ph.D.

Assistant Administrator for Fisheries
Eileen Sobeck

June 2016

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National Marine Fisheries Service
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Silver Spring, MD 20910