Deep Sea Coral Research & Technology Program 2014 Report to Congress

“Deep-sea coral communities play an important role in the marine ecosystem and provide habitat for many species of fish and invertebrates. Most deep-sea corals are slow-growing and fragile, making them particularly vulnerable to damage from certain types of fishing gear, such as bottom trawls. A wide variety of species have been discovered off the Atlantic coast…
Many recent deep-sea coral discoveries have been the result of NOAA’s Deep Sea Coral Research and Technology Program. Launched in 2009, the program has conducted in-depth, deep-water coral research on specific regions of the U.S., including the South Atlantic (2009-2011) and the Northeast (2013-2015).”

New England, Mid-Atlantic, and South Atlantic Fishery Management Councils joint press release “East Coast Fishery Managers Sign Agreement to Coordinate Deep Sea Coral Conservation” July 29, 2013

Table of Contents

Executive Summary 6
About Deep-Sea Corals 9
Alaska Research Explores One of the World's Richest Deep-Sea Coral Areas 11
West Coast Research Supports Fishery Management 17
    Video: 2012 West Coast Coral Research Cruise 21
East Coast Research Leads to Habitat Conservation 23
    Video: 2013 Northeast Canyons Expedition 27
NOAA Develops Gulf of Mexico Deep-Sea Coral Habitat Suitability Models 30
U.S. Caribbean Research Explores Deep Waters 33
U.S. Pacific Islands Research is Set to Begin in 2015 33
Nationwide Efforts 34
Looking Forward 42
Appendix 1: 2012-2013 projects under the Deep Sea Coral Research and Technology Program 43
Appendix 2: Deep-Sea Coral Areas with Potential for Interaction with Fishing Gear 45

Cover Photo:

Bamboo coral with yellow crinoids observed more than 9,000 feet deep on Mytilus Seamount, off New England, in 2013.

A Message from the Assistant Administrator for Fisheries

NOAA's National Marine Fisheries Service (NMFS) is responsible for the stewardship of our nation's living marine resources through science-based conservation and management and the promotion of healthy ecosystems. Some of the most biologically diverse ecosystems we seek to conserve are found in the deep sea where corals thrive beneath the reach of sunlight. NOAA's Deep Sea Coral Research and Technology Program harnesses capabilities across NOAA to provide the scientific information needed to conserve these ecosystems.

Many deep-sea corals form large, complex habitats used by fish, crabs, and other marine species in every region of U.S. waters. These biodiversity hotspots are vulnerable to human disturbance because the corals grow extremely slowly. Once damaged, it might take them centuries or longer to recover. As stewards of these important yet fragile ecosystems, our agency is undertaking a range of activities to study and protect them.

To conserve deep-sea coral ecosystems, it is critical to minimize the physical impacts on the corals. Some fishing operations use gear that contacts the seafloor and can potentially damage deep-sea corals. In collaboration with the Regional Fishery Management Councils, NMFS is working to reduce such interactions between fishing gear and corals. Doing so requires scientific information on the corals' location, density and abundance. In recent years, our Deep Sea Coral Research and Technology Program has generated a growing body of knowledge on this subject through a broad array of partnerships with researchers and resource managers nationwide.

In this report, we present the Program's research accomplishments in 2012 and 2013, and the progress we have made with the Councils to apply these findings to conserve and manage deep-sea coral habitats. We will continue to advance deep-sea coral science to enable habitat conservation actions under our stewardship mission for the benefit of the nation.

Eileen Sobeck
Assistant Administrator for Fisheries

About this Report

The National Oceanic and Atmospheric Administration (NOAA) 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 2006. 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's work, including this report, is developed in consultation with the Regional Fishery Management Councils, and is enhanced by the research and ongoing collaborations 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, and the National Centers for Coastal Ocean Science. These programs and offices support exploration, research, and management activities critical to understanding and managing deep-sea corals and other trust resources. The Program actively works to leverage the activities conducted by these NOAA groups.

This report describes the 2012 and 2013 research activities executed by NOAA project teams with funding provided by the Program. It also briefly describes progress during this period in MSA-related management actions that contribute toward protecting deep-sea coral areas. This report is supplemented by summaries of individual Program-funded projects available online at www.habitat.noaa.gov/deepseacorals.

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

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.

Executive Summary

At $2.46 million in FY 2012 and $2.37 million in FY 2013, NOAA's Deep Sea Coral Research and Technology Program is cost-effective in generating information of immediate use to Regional Fishery Management Councils and other resource managers in conserving structurally complex habitats formed by deep-sea corals.

In every region, off of every coast, deep-sea corals can be found growing slowly on the seafloor below the photic (sunlight) zone in U.S. waters. While some of these corals are solitary and never grow bigger than a baseball, other species form colonies shaped like branching trees more than 10 feet tall, or build extensive reefs resembling the shallow, tropical, coral reefs that attract fish and divers. The three-dimensional structures of deep-sea corals provide shelter, feeding sites, and nursery grounds to a wide range of marine life. Not only do they represent areas of locally high biodiversity essential to our ocean's health, they also support commercially important fish stocks in several regions.

Throughout the country, the Councils are increasingly engaged in developing methods to manage potential impacts of fisheries to deep-sea coral areas, recognizing these habitats' role in the ecosystem. And yet, the geographic distribution of deep-sea corals and the full extent of their function as fish habitats have not been adequately studied in a coordinated fashion, thus limiting some Councils' ability to design management measures. In 2012 and 2013, the Program has made considerable progress in filling these knowledge gaps by locating and characterizing deep-sea coral sites and submitting the findings to the Councils.

In the Southeast, the South Atlantic Fishery Management Council used the results from Program-funded fieldwork to amend its Coral Fishery Management Plan in 2013 with measures that increase coral protection areas by 843 square miles and maintain the viability of the existing deepwater shrimp and golden crab fisheries.

In the Northeast, the Mid-Atlantic, and New England Fishery Management Councils are considering using their discretionary authority under the MSA to designate deep-sea coral protection zones in submarine canyons, on seamounts, and at hard-substrate sites on the continental shelf where corals are likely to exist. To support the Councils, research cruises sponsored by the Program in 2012 and 2013 surveyed these areas of interest and documented coral presence and their associated species.

Off the West Coast, fieldwork at sea and shore-based analyses supported by our Program generated a large amount of new information on the distribution of corals and sponges and their associated habitats which was submitted to the Pacific Fishery Management Council for the periodic review of Essential Fish Habitat (EFH) for groundfish. This information included not just underwater observations of corals but also aggregated data from fishery observers that help illustrate the degree of interactions between fishing gear and corals.

In Alaska, home to some of the nation's most abundant and diverse deep-sea coral communities, our Program is funding a 3-year fieldwork initiative to ascertain the extent of deep-sea coral distribution and habitat value in the Aleutian Islands and Gulf of Alaska. The research to date has expanded our knowledge of coral presence and absence at about 100 sites in the Aleutians and four areas in the Gulf. The science team supported by the Program is also analyzing fish populations in coral and non-coral sites, and determining the extent of interactions between bottom longlines and seafloor organisms. We expect these studies to inform the North Pacific Fishery Management Council's 2015 review of groundfish EFH and other ecosystem-based management processes.

Meanwhile, the Program is preparing for a 3-year fieldwork initiative in the Pacific Islands region starting in 2015.

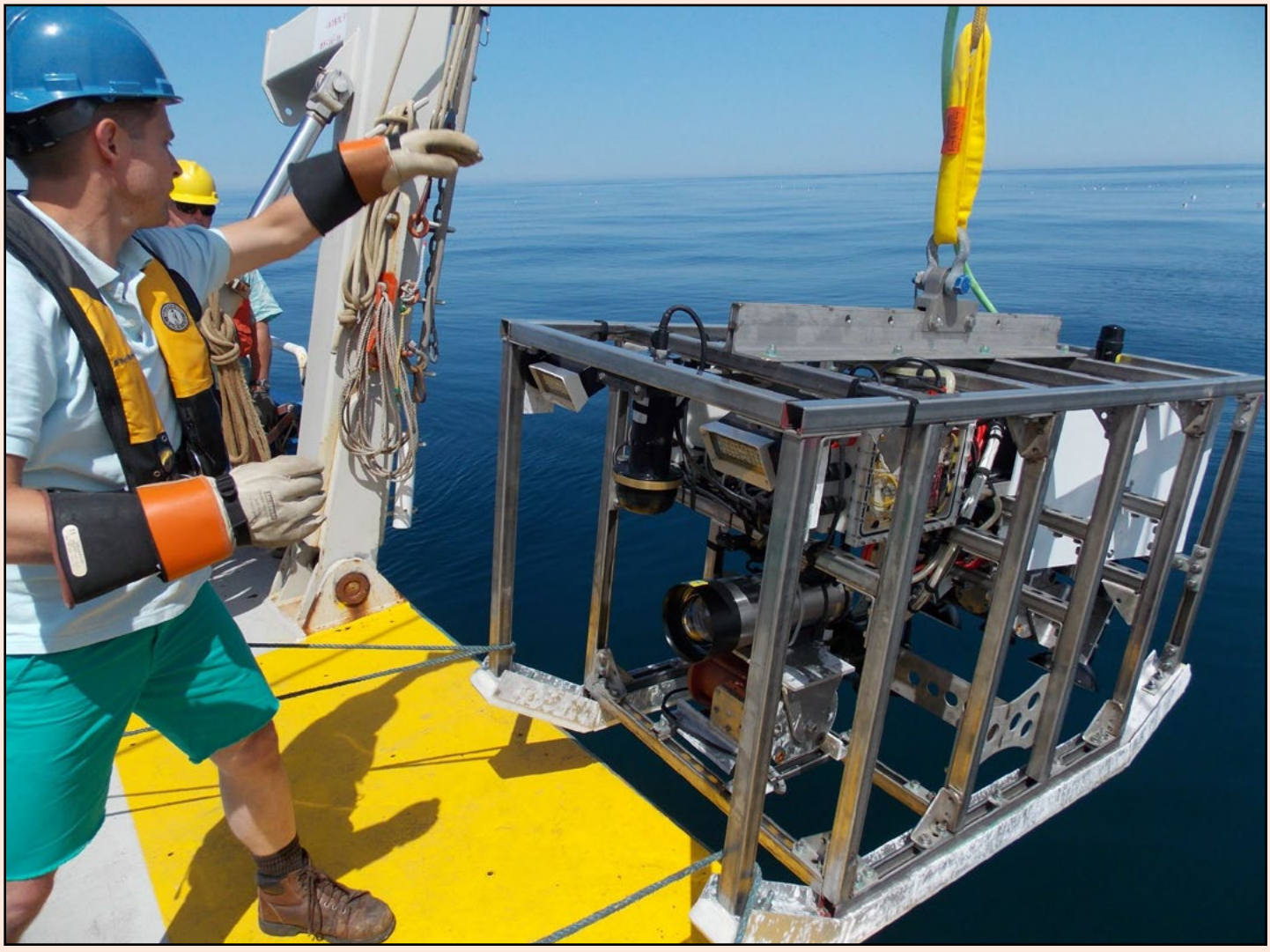
Parallel to these regional studies, we are collating records of deep-sea coral locations—derived from both historical data and recent fieldwork from around the country—into a national geographic database. The database, containing more than 200,000 deep-sea coral records of consistent format and quality, will be publicly available online in 2014 to supplement and enhance our ongoing efforts to submit information to the Councils. The Gulf of Mexico Fishery Management Council, in particular, expects to use the database in evaluating the need to protect deep-sea coral areas.

Executive Summary (*continued*)

This report describes these management-relevant research activities conducted by offices throughout NOAA with funding from the Deep Sea Coral Research and Technology Program. It also briefly describes the progress in deep-sea coral management in the regions as it relates to the Program's research findings. A full list of funded projects appears in Appendix 1.

We hope to continue this progress through collaborations with the Councils and internal and external research partners to fulfill the Program's mandate.

Scientists deploying a camera sled to survey coral habitats in the northern Gulf of Maine in 2013.



NOAA's Deep Sea Coral Research and Technology Program 2012 & 2013

by the numbers

$2.46M 2012 FUNDING

$2.37M 2013 FUNDING

4,200+ yrs
ESTIMATED AGE OF SOME BLACK CORALS

156
DAYS OF AT-SEA RESEARCH

8
REGIONAL FISHERY MANAGEMENT COUNCILS

200,532
RECORDS IN THE NATIONAL DEEP-SEA CORAL GEODATABASE

6
COUNCIL REGIONS THAT HAVE PREDICTIVE DEEP-SEA CORAL MODELS

6,193
SQUARE MILES MAPPED BY SONAR

200-10,000 ft.
DEPTHS OF FIELDWORK RESEARCH

About Deep-Sea Corals

Deep-sea corals can live for hundreds or thousands of years, creating remarkably complex communities in the depths of the oceans from where the light is dim down to more than 10,000 feet. In the United States, deep-sea coral habitats have been discovered in all regions on continental shelves and slopes, canyons, and seamounts. Their full geographic extent is still unknown because most areas have yet to be adequately surveyed.

A few deep-sea coral species form reefs that, over millennia, can grow more than 300 feet tall. Many other species shaped like bushes or trees 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 activities that disturb the seafloor. In addition, ocean acidification—a result of the ocean absorbing increased carbon dioxide—can adversely affect corals' ability to grow or maintain their structures.

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

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

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

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

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

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

Alaska Highlights

- The Alaska region has abundant, large deep-sea corals and sponges that are used by commercially important species as habitat.

- Bycatch records indicate that for certain fisheries in certain discrete areas there are fishing gear interactions with deep-sea corals and sponges.

- The Program's 2012–2014 fieldwork expands the scientific knowledge on the distribution of deep-sea coral and sponge habitats and their associations with commercially fished species.

Alaska Research Explores One of the World's Richest Deep-Sea Coral Areas

Deep-sea corals occur throughout Alaska's Pacific waters, including the Bering Sea, Aleutian Islands, and the continental shelf and upper slope of the Gulf of Alaska. Fishes and crabs, particularly juveniles, are commonly observed in coral habitats, presumably using the coral areas to hide from predators or to seek prey. The Aleutian Islands, in particular, are home to the most abundant high-latitude, non-reef-building deep-sea corals in the world and has the highest coral diversity in Alaska. Southeast of the Aleutians, in the Gulf of Alaska, red tree coral (*Primnoa pacifica*) can grow to several meters tall and form dense thickets, and the coral's associations with commercially important rockfish species have been well documented. Deep-sea sponges, either alone or in association with corals, also create complex habitats in these regions. Deep-sea corals and sponges are caught as bycatch in certain areas off Alaska, indicating interactions between fishing gear and the habitats created by these structure-forming organisms.

A 3-year fieldwork initiative to study deep-sea coral and sponge ecosystems in Alaska began in 2012 with funding from the Deep Sea Coral Research and Technology Program. The initiative was designed to support fishery managers with spatially explicit and quantitative scientific findings so they can make informed decisions to reduce bycatch, conserve habitats, and maintain sustainable fisheries. The research results are expected to be incorporated into the North Pacific Fishery Management Council's 5-year groundfish essential fish habitat (EFH) review, Aleutian Islands Fishery Ecosystem Plan, and Ecosystem Considerations report—an annual summary of new information about the Alaska marine ecosystem. The initiative's science team also provides annual presentations to the Council on the fieldwork progress and solicits Council input on the research activities for the following year.

In the first 2 years of the initiative, scientists surveyed areas in the Aleutian Islands and the Gulf of Alaska to characterize coral and sponge communities as well as associated fish populations. Several surveys were conducted in cooperation with fishing industry participants on fishing vessels.

Aleutian Islands

Effective management of deep-sea coral and sponge ecosystems in Alaska requires knowledge of where these organisms occur and where they are absent. Given the vastness of Alaska's marine waters, not every part of it can be visually surveyed under the Program's budget and time constraints. Therefore, a systematic approach to predict the presence or absence of corals and sponges is needed. A team of scientists with support from the Deep Sea Coral Research and Technology Program developed a predictive model for coral and sponge distribution using data from NMFS bottom-trawl surveys in the Aleutian Islands. The model outputs include coral and sponge presence, abundance, and diversity.

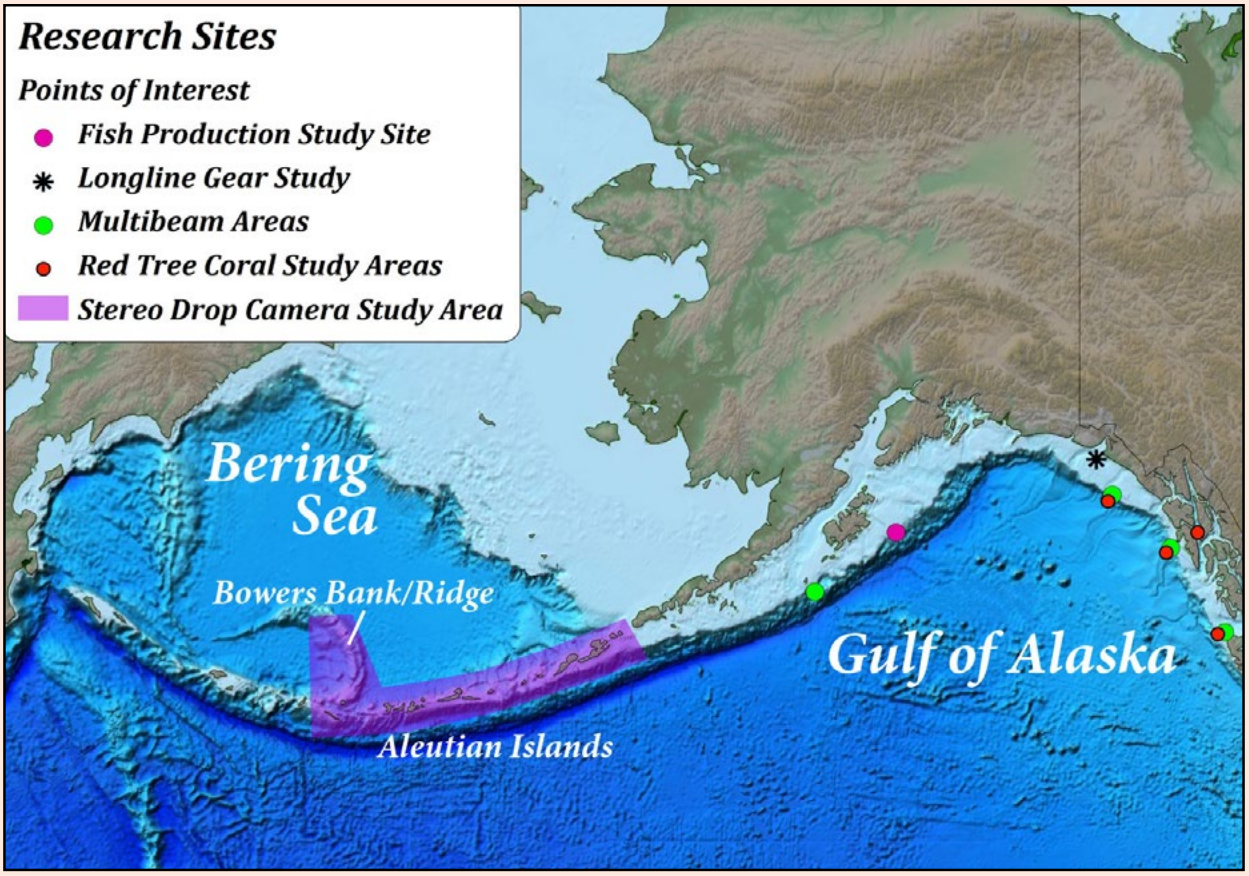
In August 2012, the science team conducted a research cruise in the eastern and central Aleutian Islands, aboard the fishing vessel *Sea Storm*, to assess the accuracy of the model. The fieldwork used a drop camera system to document coral presence/absence and abundance at 106 randomly selected sites ranging from 164 to more than 2,645 feet deep. Images captured by the camera indicated presence of corals at about 50 sites, and sponges at over 70 sites. Detailed analysis is ongoing to produce accurate numbers of coral abundance and diversity with species identification. These results will be used to improve the model's predictions.

With support from our Program, scientists conducted the first camera surveys along Bowers Ridge and Bowers Bank, an area that was closed to mobile bottom fishing gear in 2007. Preliminary findings indicated much of Bowers Ridge was composed of sand substrates in deep waters (1,640 to 2,645 feet). At the summit of Bowers Bank, the seamount-like feature at the north end, sponges and corals were attached to hard substrates. Fish observed in coral and sponge habitats included Pacific ocean perch, shortspine thornyhead, shortraker rockfish, and king crab.

The Aleutian Islands fieldwork was scheduled to continue in 2013 and 2014 at 300 additional sites to further groundtruth and strengthen the model. Unfortunately, the cruise planned for October 2013 did not occur due to the federal government shutdown.

Gorgonian corals and demosponges observed by a stereo drop-camera system at a site near the Islands of Four Mountains at a depth of 328 feet in 2012.

Locations of field research conducted in 2012-2013.



Gulf of Alaska

In Alaska waters, many commercially important species are associated with coral and sponge habitats. For example, based on NMFS stock assessment surveys, the amount of juvenile Pacific ocean perch caught in the Aleutian Islands is higher in areas where corals and sponges are also caught. These complex habitats provide both protection from predators and increased prey availability. However, the relative importance of coral and sponge habitats as compared to other non-living complex structures (e.g., boulders) for commercially important species remains unknown.

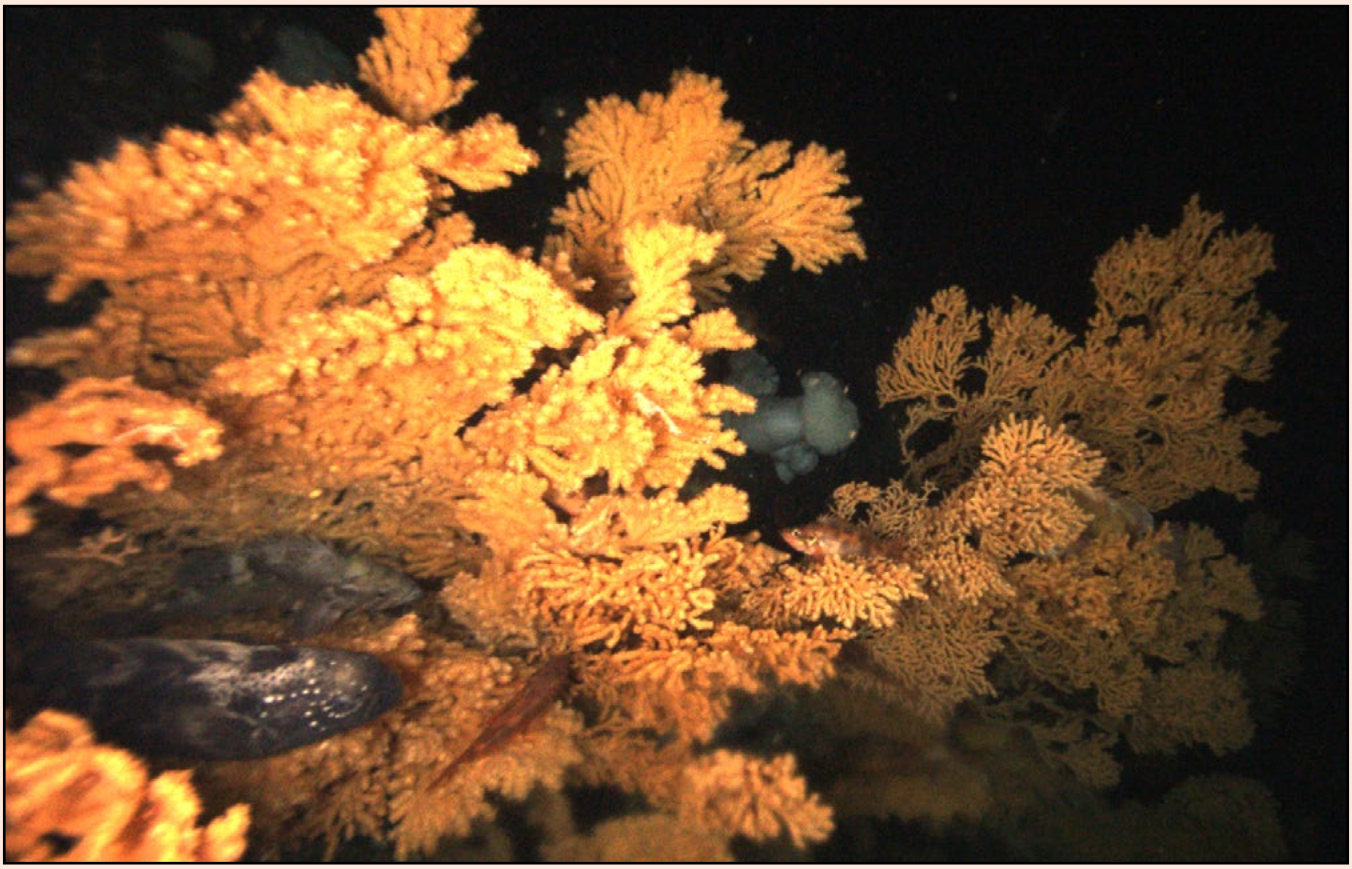
To fill this knowledge gap, our Program supported a project to examine the productivity of commercially important rockfish species at a coral site, a boulder site, and a low-relief site off Kodiak in the central Gulf of Alaska. At each location, drop-camera video transects document the density and diversity of corals and sponges as well as the abundance and composition of the fish species. The project team also collected oceanographic data and rockfish samples from these sites in 2012 for food web, diet, reproductive maturity, and age-and-growth analyses. Additional sampling and laboratory analyses will continue in 2014.

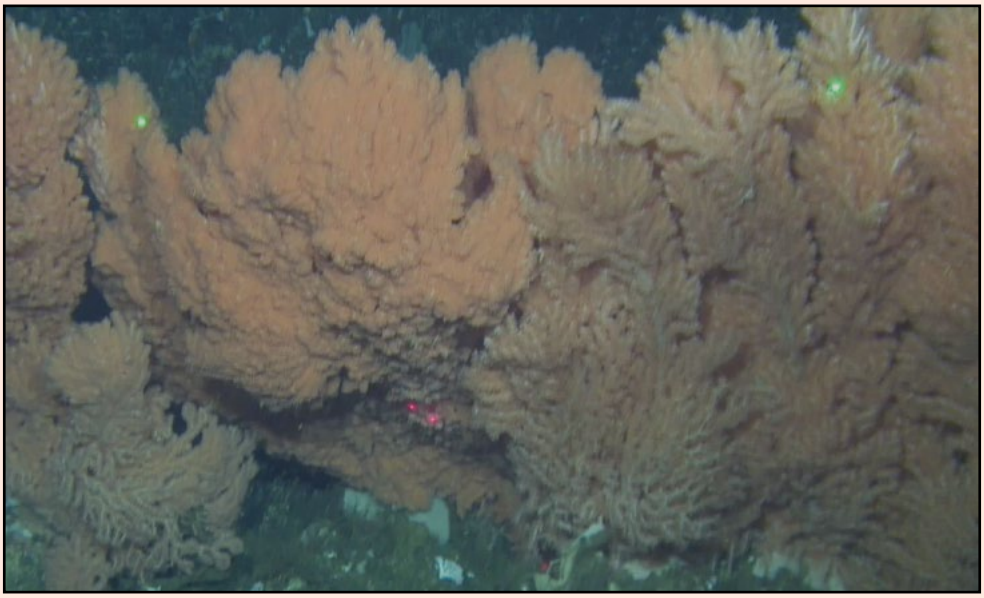
The Program is also supporting a project that investigates the interactions between fishing gear and deep-sea corals. Disturbance from longline fishing to sensitive coral and sponge habitats has been documented in Alaska, but the extent and mechanism of the disturbance have not been well studied compared to bottom trawling. Therefore, the project team is examining the behavior of longline gear *in situ* in coral and sponge habitats in the Gulf of Alaska. The team constructed a camera system to be attached to longline and pot gear to collect images of the gear's interactions with the seafloor habitats. The camera was deployed on the fishing vessel *Ocean Prowler* in July 2013 off Yakutat, Alaska. The recorded images will be analyzed to determine the distance the longline traveled along the seafloor during deployment, fishing, and retrieval. Work in 2014 will focus on deploying longlines fitted with a camera in the coral and sponge habitats to examine the interaction of the gear with those organisms. These data can then inform fishing impacts modeling and analysis in the EFH review process beginning in 2014.

In addition, the Program has supported a suite of research activities to characterize the distribution and ecology of red tree corals, which form large complex thickets, in the Gulf of Alaska. This work began with multibeam and backscatter mapping in 2012 at four sites where red tree coral thickets occur, or are suspected to occur, based on fisheries and survey data. In total, 167 square nautical miles were mapped, at depths ranging from 328 to 4,222 feet. Based on these mapping results, a 2-week cruise aboard the fishing vessel *Alaska Provider* collected high-definition videos and samples using a remotely-operated vehicle (ROV). Sixty-seven coral samples were collected for studies of population connectivity, trophic ecology, and reproduction. Six whole colonies were collected for studies of age, growth, and recruitment. Sponges were collected for taxonomy and biomedical products studies. Meanwhile, a companion cruise, using the Alaska Department of Fish and Game's vessel, *Medeia*, conducted drop-camera surveys and deployed settlement plate arrays in red tree coral thickets. When the settlement plates are retrieved in future years, they will yield information on coral recruitment rates and larval dynamics—key information to understanding how or if habitats might recover after disturbance.

The Program is also supporting long-term monitoring of oceanographic conditions at a shallow red tree coral site in Tracy Arm—a glacial fjord that supports a population of red tree corals that has provided a wealth of information on reproductive ecology and the development of genetic markers for population-level studies. This monitoring effort deploys remote sensors that measure ocean temperature, salinity, pH, and dissolved oxygen in a red tree coral thicket. The goal is to establish a baseline to gauge the potential effects of climate change and ocean acidification on marine processes affecting the corals in the future.

Many species of fishes, including rockfishes (*Sebastes* spp.) and prowfish (*Zaprora silenus*), are associated with red tree corals in the eastern Gulf of Alaska. This thicket, which included these approximately 5-foot tall specimens, is located at a depth of 722 feet near Cape Ommaney, Baranof Island, and was observed using a stereo drop camera aboard the research vessel *Medeia*.





Red tree corals observed with an ROV deployed from the fishing vessel *Alaska Provider* near Cape Ommaney in the Gulf of Alaska at a 548-foot depth. The red laser dots are 4 inches apart. The green laser dots are separated by 3.7 feet.

Bering Sea Canyons

In 2013, the North Pacific Fishery Management Council requested the Program's support for fieldwork in the Bering Sea canyons to groundtruth a coral and sponge distribution model developed by NMFS' Alaska Fisheries Science Center. The model builds on approaches used by the Program in the Aleutian Islands. The model and surveys will inform a Council-requested study on whether the canyons have unique ecological characteristics that merit further protection. The Program is coordinating with the Science Center and NMFS' Alaska Regional Office on this request and expects to fund part of the fieldwork.

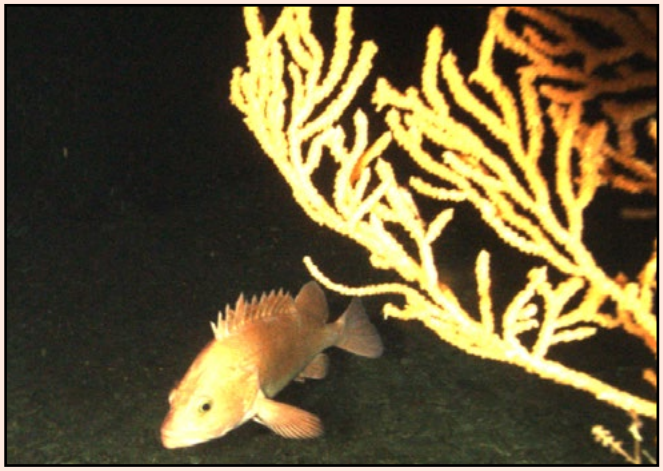
Additional studies

Other studies in the Alaska fieldwork initiative include collecting long-term data sets of oxygen and pH from summer stock assessment trawl surveys; improving the taxonomy of corals and sponges through special collections of bycatch specimens; collecting data and specimens for paleoclimatological, microbial, and marine natural product studies; and compiling a geologically-based substrate map for the Gulf of Alaska and Aleutian Islands that can help predict where deep-sea coral and sponge habitats may occur.

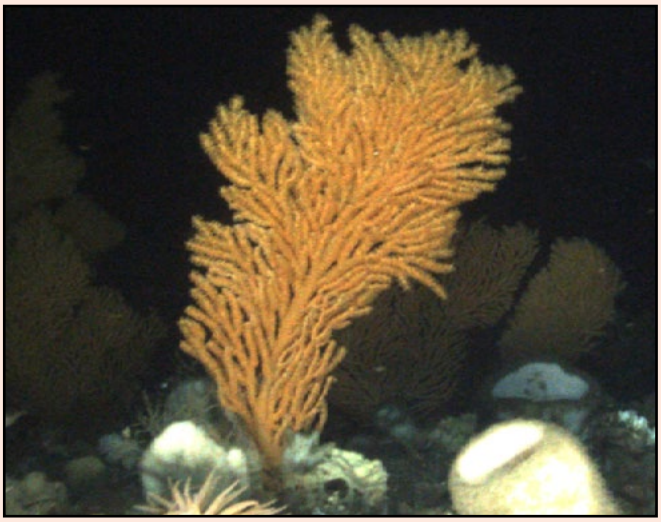
Besides the fieldwork, the Program supported a pilot project to train fishery observers to better identify and document corals and sponges to improve the documentation of bycatch in commercial fisheries. Nearly 200 observers in the North Pacific Groundfish Observer Program received a taxonomic identification guide for corals and sponges and training to identify these species. These observers documented corals on about 100 hauls on fishing vessels in 2013 and collected about 50 coral samples, which were then expertly identified in the laboratory. A report summarizing the results and lessons learned from this pilot project is being prepared. In 2014, coral bycatch will be recorded in the observer database at a finer level of detail than previously recorded.

In addition, the Program supported DNA sequencing of corals to study the connectivity of coral populations and to improve the species identification of corals caught as bycatch. A portion of coral samples caught during stock assessment surveys has been sent to the Northwest Fisheries Science Center for genetic analysis. To date, preliminary sequencing has been completed on all survey samples. Voucher sequences—DNA sequences of particular specimens used as a reference in species identification—have been established from a portion of samples that have also been identified by taxonomists, and their sequences have been uploaded to the National Center for Biotechnology Information's GenBank database. These vouchers have been used to confirm shipboard identifications made on trawl surveys.

More detailed descriptions of projects funded in 2012 and 2013 are available online at http://www.habitat.noaa.gov/protection/corals/deepseacorals/projects/index.html



Deep-sea coral communities in Alaska.



West Coast Highlights

- Deep-sea coral and sponge habitats have emerged as one of the major issues in the Pacific Fishery Management Council's groundfish EFH review, and the Program provided new information to support the review.

- Program-supported research has expanded our understanding of the abundance of deep-sea corals and sponges and those environmental factors that influence their distribution in the West Coast region.

West Coast Research Supports Fishery Management

In the 2012–2013 reporting period, the Deep Sea Coral Research and Technology Program concluded a 3-year fieldwork initiative off the West Coast to examine coral and sponge communities. A key purpose of this research, which began in 2010, was to provide new scientific information for use in the 5-year periodic review of EFH for groundfish species. A number of groundfish species have been observed in coral and sponge habitats in various locations along the entire coast, but the extent and nature of the habitat associations had not been fully studied. The fieldwork funded by the Program has begun to fill this information gap.

Pacific Fishery Management Council's Groundfish EFH Review

The MSA requires that fishery management plans describe and identify EFH for managed species and minimize—to the extent practicable—the adverse effects of fishing on EFH. The regulatory guidelines for implementing the EFH provisions recommend that Councils and NMFS review the EFH designations and management measures at least once every five years.

The Pacific Fishery Management Council began its 5-year review of Pacific groundfish EFH in 2010 with a phased approach. In Phase 1, the Council issued a data call and compiled new and newly available information relevant to habitats for groundfish. In Phase 2, the Council requested proposals from the public in 2013 for potential changes to groundfish EFH. The Council recently initiated Phase 3, where alternatives will be developed to consider revising EFH designations and/or management measures.

Scientific information generated by the Deep Sea Coral Research and Technology Program was a key part of the EFH review. For example, 14 of the 39 data products the Council received in Phase 1 were developed from fieldwork and analyses funded by the Program. Among these products are:

- Six site characterization reports describing the coral and sponge species, their abundance and density, and their associated species at Piggy Bank off Southern California, Cordell Bank off Northern California, a sponge field near Grays Canyon off Southern Washington, and coral areas in the Olympic Coast National Marine Sanctuary off Northern Washington.
- About 174,000 coral and sponge records from the Program's national deep-sea coral geodatabase, derived from direct *in situ* observations and from analysis of catch records in stock assessment surveys.
- Maps showing the extent and intensity of commercial fishing effort using bottom trawl, midwater (pelagic) trawl, and fixed gear, as well as bycatch of corals and sponges in commercial fishing operations. Together, these products illustrate areas of potential interactions between fishing gear and vulnerable coral and sponge habitats.

Sponges, anemones, and soft corals on Rittenburg Bank at a depth of 315 feet, observed on the 2012 deep-sea coral cruise in the Gulf of the Farallones National Marine Sanctuary. The red sea fan in the center is a new genus and species *Chromoplexaura markii*.

In Phase 2, five of the seven EFH proposals submitted to the Council, including all three proposals from National Marine Sanctuaries, used the Program's data products as a foundation and proposed additional protections for deep-sea coral or sponge habitats.

Separate from the EFH authority, the Council also has discretionary authority to designate deep-sea coral zones pursuant to MSA Section 303(b)(2)(B) although the Council has not yet decided on the use of this discretionary authority. Regardless of the management authority the Council chooses to exercise, the Program will continue to support the Council with needed data and analyses in the process.

Research cruises

In this reporting period, the Deep Sea Coral Research and Technology Program supported three research cruises. Data collected from the fieldwork are being analyzed, and a final report will be prepared in 2014.

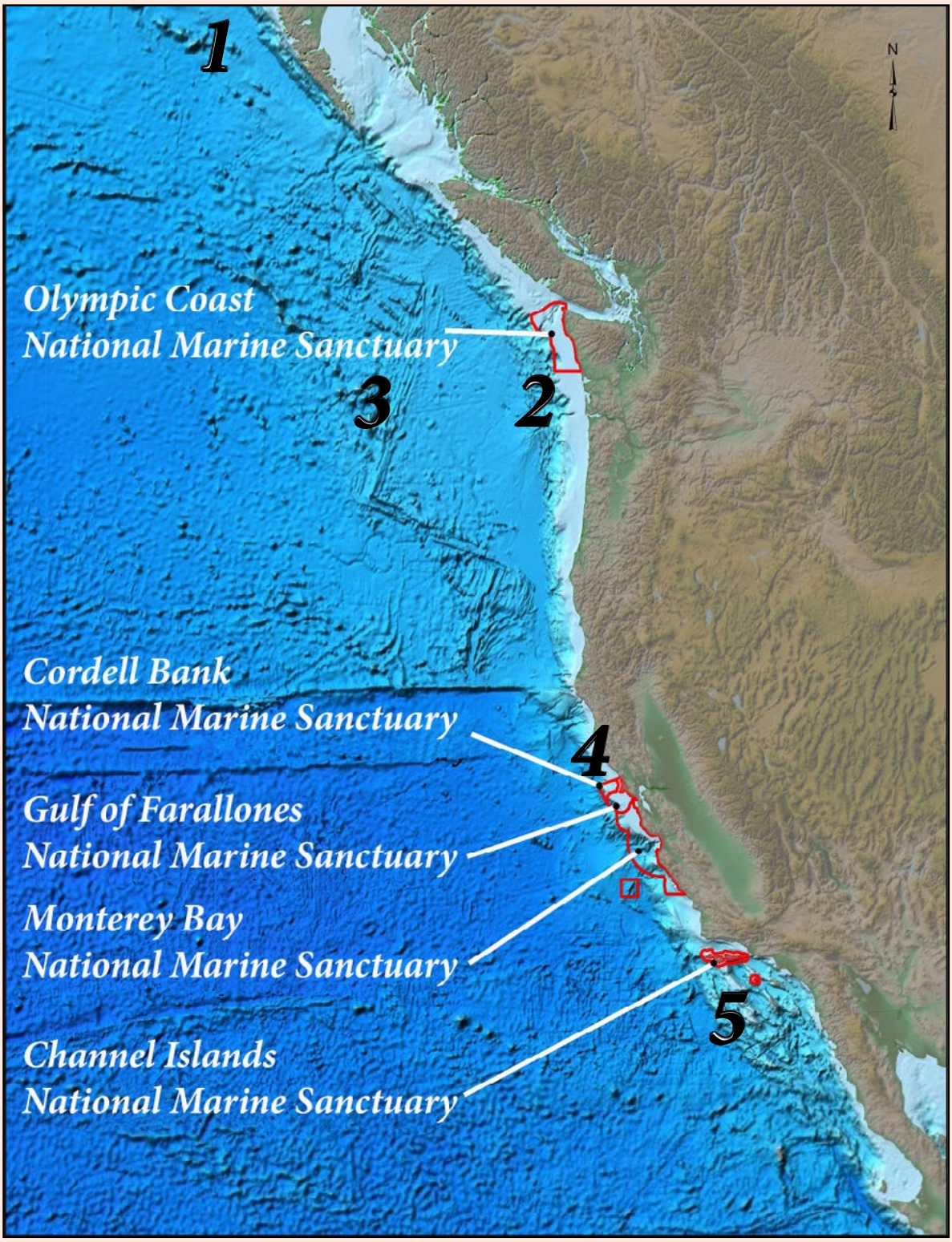
In the Gulf of the Farallones National Marine Sanctuary, multibeam maps from 2011 were used to target ROV surveys of Rittenburg Bank, Cochrane Bank, and the Farallon Escarpment in 2012. The science team on this ROV cruise conducted 28 transects revealing rich and abundant coral and sponge habitats never seen before in the sanctuary, including a large colony of black coral (*Antipathes dendrochristos* or Christmas tree coral) on Cochrane Bank. In addition, the research documented extensive sponge habitats, discovered a new species of sea pen, and determined the substrate types of previously multibeamed areas. These observations formed the basis of the Gulf of the Farallones Sanctuary's EFH proposal submitted to the Pacific Fishery Management Council.

We continued collaborative seamount research with the Canadian Department of Fisheries and Oceans, begun in 2011 with a survey of Canada's Bowie Seamount. In 2012, NOAA and Canadian scientists completed six ROV dives and four autonomous underwater vehicle (AUV) dives on Cobb Seamount just outside the U.S. Exclusive Economic Zone (EEZ). These surveys documented presence of black and gorgonian corals, and fish species that co-occur with the corals. This research will inform management of future bottom fisheries on Cobb Seamount under the new North Pacific Fisheries Commission agreement now being finalized.

In 2013, NOAA scientists used an ROV to survey likely coral and sponge habitats on escarpments south of San Miguel, Santa Rosa, and Santa Cruz Islands in the Channel Islands National Marine Sanctuary. The selection of the survey sites was informed by high-resolution deep-water mapping data collected by the NOAA ship *Okeanos Explorer* in 2011. The 2013 ROV cruise observed large sponges, small corals, abundant rockfishes, and other marine species at depths between 490 and 970 feet. Most of the deep habitats in the sanctuary had not been previously explored. The 2013 fieldwork in this area has improved scientific understanding of these ecosystems.

A black coral (*Antipathes dendrochristos*) with a rosy rockfish (*Sebastes rosaceus*) in it was observed on Cochrane Bank, at a depth of 312 feet, on a cruise to the Gulf of the Farallones Sanctuary in 2012. This coral is 7 feet across and estimated to be at least 100 years old. The coral had many crabs and juvenile fish living in it. The stems/skeletons of black corals are black, but the living tissue is usually orange or white.

Locations of field studies of deep-sea corals and sponges off the Pacific coast include: 1) Bowie Seamount (Canada; 2011); 2) Grays Canyon sponge grounds (2010 & 2011); 3) Cobb Seamount (2012); 4) Bodega Canyon (2011); 5) Piggy Bank, Hidden Reef and the Footprint Marine Reserve (2010). Field studies also took place in four National Marine Sanctuaries: Olympic Coast (2010 & 2011), Cordell Bank (2010), Gulf of the Farallones (2011 & 2012), and Channel Islands (2013).



The 3-year initiative discovered and characterized significant deep-sea coral and sponge ecosystems off the West Coast, contributing to the Pacific Fishery Management Council's EFH review process and informing management of the region's National Marine Sanctuaries. However, it also encountered challenges, many of which are inherent in deep-sea research far offshore. Three research cruises scheduled in 2012 were postponed due to inclement weather or equipment failure, and some images collected on the Cobb Seamount cruise were lost when the AUV was damaged on the final dive. In addition, the Program's final major cruise to conduct ROV and AUV surveys of deep-sea corals and sponges off northern California and Oregon was canceled due to the federal government shutdown in October 2013.

Additional studies

The Deep Sea Coral Research and Technology Program has supported DNA sequencing of samples of deep-sea corals caught during NOAA's West Coast Groundfish Bottom Trawl Surveys and collected by the West Coast Groundfish Observer Program. These sequences are used to confirm or correct identifications made shipboard, and establish a set of voucher sequences for specific coral species that can improve the speed and accuracy of future identification. To date, sequences from 44 vouchers have been uploaded to the National Center for Biotechnology Information's GenBank database. These and an additional catalog of sequences with confirmed morphological identification have been used as a reference library for DNA barcode identification of deep-sea coral samples caught in the trawl surveys. using this library, initial genetic identification has been completed for a large number of samples collected from the 2006–2010 trawl surveys. These results will be provided to the databases for both the Deep Sea Coral Research and Technology Program and the West Coast Groundfish Surveys, and used to improve the identification guides for the survey and observer programs.

In addition, the Program supported a study on how the distribution and abundance of Christmas tree coral are related to environmental factors using predictive models and broad-scale seafloor maps. Christmas tree corals are long-lived black corals that reach large sizes and represent one of the most important coral habitats off Southern California. The study revealed that high surface primary productivity in combination with depth and January currents are important predictors of Christmas tree coral density. Higher coral density coincided with greater chlorophyll persistence and optimal depths near 1,312 feet. Surface productivity increasingly was associated with Christmas tree corals at shallower depths. The results supported the hypothesis that ocean currents affect coral density via larval dispersal mechanisms. The selected coral size models responded to similar covariates, corroborating coral density results. Fish and invertebrate ordinations indicated that Christmas tree corals were widely distributed across environmental gradients and that Christmas tree corals co-occurred with several demersal fish and invertebrates. Several predicted coral hotspots are in areas that have not been surveyed and should be targeted by future studies to confirm the presence of Christmas tree coral communities and to evaluate their vulnerability.

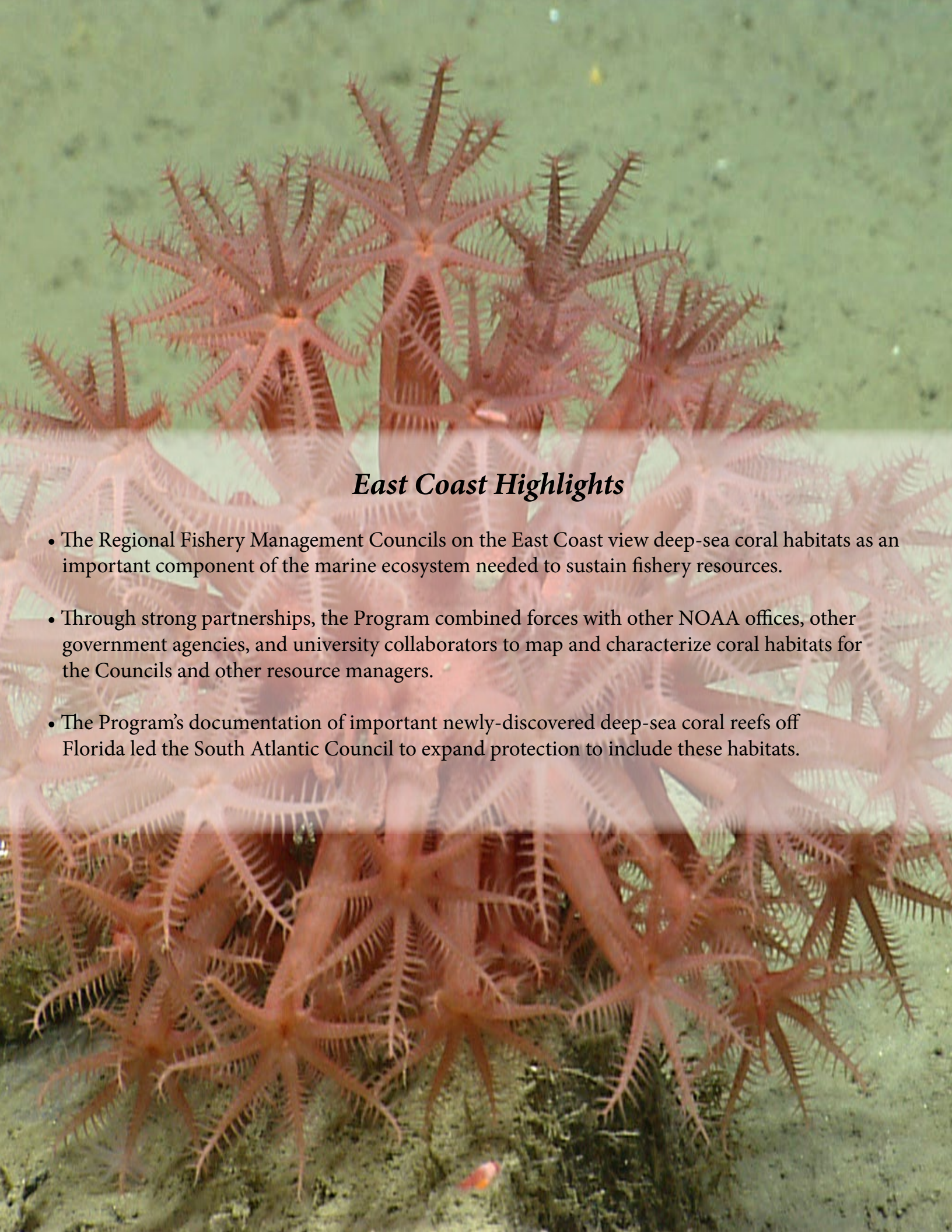
More detailed descriptions of projects funded in 2012 and 2013 are available online at http://www.habitat.noaa.gov/protection/corals/deepseacorals/projects/index.html

A rockfish orienting to a large barrel sponge at a depth of 1,804 feet near Santa Cruz Island in the Channel Islands National Marine Sanctuary. Rockfish such as these are important members of the West Coast groundfish assemblage whose stocks have proven difficult to assess with trawl surveys.

Video: 2012 West Coast Coral Research Cruise

Click on the photo below to view a two minute video from the first days of the research cruise aboard the NOAA research vessel *Fulmar* to Rittenburg Bank, Cochrane Bank, and Farallon Escarpment in the Farallones National Marine Sanctuary in 2012.

Having trouble viewing this video?
Go to: http://www.habitat.noaa.gov/media/videos/west_coast_coral_cruise.mp4



East Coast Highlights

- The Regional Fishery Management Councils on the East Coast view deep-sea coral habitats as an important component of the marine ecosystem needed to sustain fishery resources.

- Through strong partnerships, the Program combined forces with other NOAA offices, other government agencies, and university collaborators to map and characterize coral habitats for the Councils and other resource managers.

- The Program's documentation of important newly-discovered deep-sea coral reefs off Florida led the South Atlantic Council to expand protection to include these habitats.

East Coast Research Leads to Habitat Conservation

In July 2013, the New England, Mid-Atlantic, and South Atlantic Fishery Management Councils on the East Coast signed a Memorandum of Understanding (MOU) to coordinate efforts on the protection of deep-sea corals from Maine to the Florida Keys. The MOU will serve as a framework for cooperation across the three Councils during the development and implementation of management measures to protect deep-sea corals. The agreement acknowledges that many deep-sea coral species provide complex, three-dimensional habitats for fish and invertebrates, enhancing local biodiversity, but because the corals tend to be fragile and slow-growing, they are vulnerable to disturbance caused by fishing gear.

In this context, the MOU recognizes the need to protect coral habitats with each Council using a combination of appropriate authorities under the MSA, including the discretionary authority to designate coral protection zones described in Section 303(b)(2)(B), the EFH authority, the bycatch reduction mandate, and the South Atlantic Council's fishery management plan for corals. In announcing the MOU, the Councils highlighted that many recent deep-sea coral discoveries have been the result of the Deep Sea Coral Research and Technology Program.

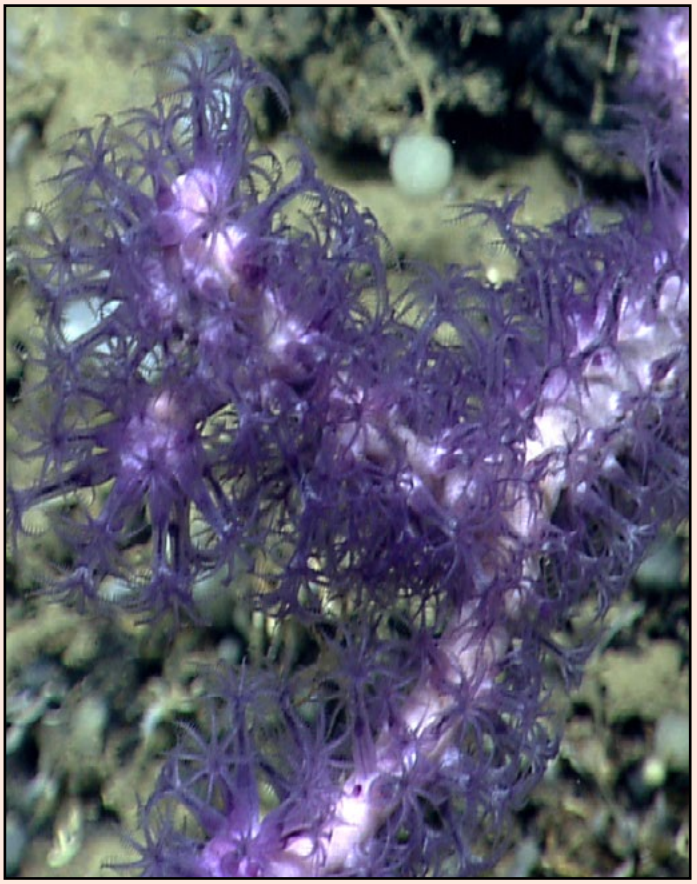
The MOU also recognizes the coral observations made by NOAA's Office of Ocean Exploration and Research (OER) in this region. These OER accomplishments are described in more detail at oceanexplorer.noaa.gov and are outside the scope of this report.

In 2009-2011, within the South Atlantic Fishery Management Council region, the Deep Sea Coral Research and Technology Program sponsored underwater research to characterize the distribution, abundance, and ecological functions of deep-sea coral habitats. In 2013, the Program initiated a 3-year fieldwork initiative in the Northeast region to provide new data to the New England and Mid-Atlantic Fishery Management Councils to support their management actions. Both Councils are considering using their discretionary authority to designate zones to protect deep-sea corals from the impacts of fishing gear. Areas where fishing gear could impact deep-sea corals in this and other regions are listed in Appendix 2.

Northeast Research Cruises

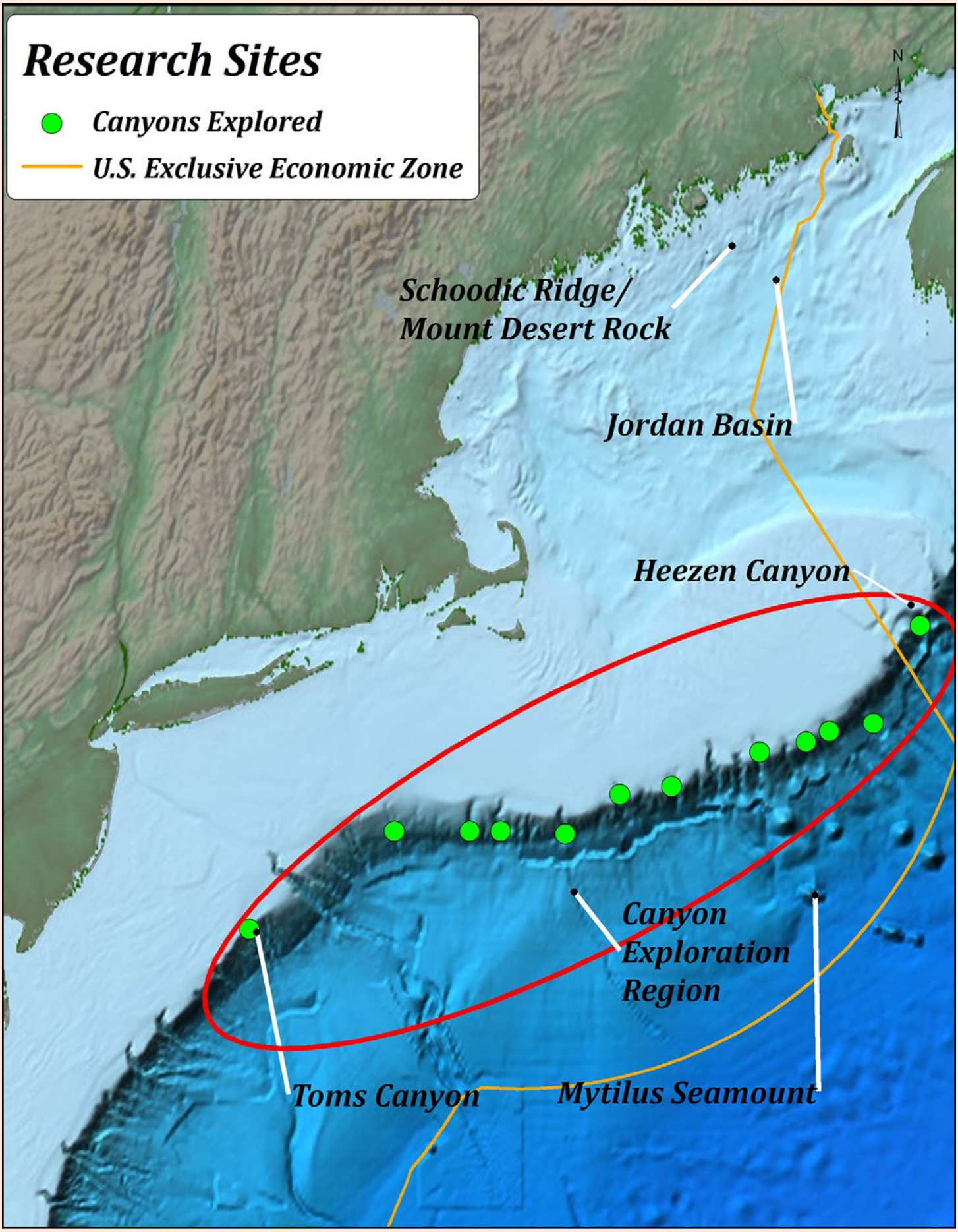
In the past two decades, research on the diversity, abundance, and distribution of deep-sea corals in the Northeast region has been limited. Therefore, management decisions related to deep-sea coral habitats were based on historical records, some dating back to the 1800s, and information from expeditions conducted in the 1980s, whose data quality was inconsistent.

Understanding the need for spatially explicit, updated information on coral habitats, the Deep Sea Coral Research and Technology Program began a 3-year fieldwork initiative to locate and characterize the coral and sponge communities in the Northeast region. Through data mining, developing habitat suitability models, acoustic mapping, and visual surveys, the Northeast regional science team has generated extensive new findings of coral and sponge habitats in the first year of the initiative, and provided much needed contemporary data to resource managers in the region.



A striking purple coral, Clavularia sp., seen in Nygren Canyon during Leg 2 of the U.S. Northeast Canyons 2013 Expedition aboard NOAA ship *Okeanos Explorer*.

Locations of field research conducted in 2012–2013



Bubblegum corals observed in Heezen Canyon during Leg 2 of the U.S. Northeast Canyons 2013 Expedition aboard NOAA ship *Okeanos Explorer*.

The Deep Sea Coral Research and Technology Program's 3-year field work initiative builds on a larger NOAA-wide partnership, the Atlantic Canyons Undersea Mapping Expeditions (ACUMEN; http://oceanexplorer.noaa.gov/okeanos/explorations/acumen12/), which commenced in 2012. Led by OER in partnership withour Program, the Office of Coast Survey, the Office of Marine and Aviation Operations, and Sea Grant, a group of NOAA and external partners conducted a series of five coordinated expeditions to map and characterize priority canyons along the continental shelf and slope between Virginia and New England. This baseline information was crucial to the Deep Sea Coral Research and Technology Program's planning for visual survey cruises in 2013 and future years. OER-led mapping of the canyons off the Northeast coast has continued since ACUMEN, and by the end of August 2013, mapping of all canyons from the Virginia border to the Canadian border—more than 56,000 square miles—was completed. The mapping effort provides essential baseline data that continues to inform follow-on expeditions.

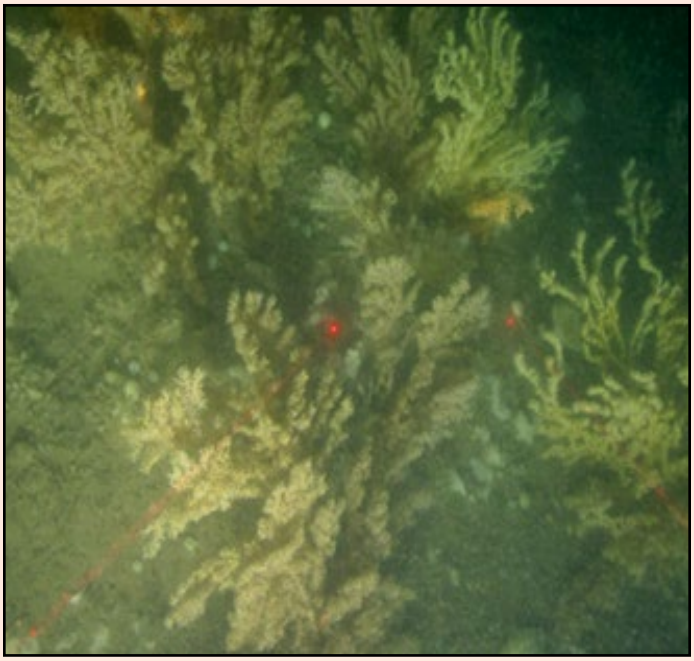
In 2012 and 2013, the Deep Sea Coral Research and Technology Program partially supported four research cruises in collaboration with other NOAA offices and academic partners:

- In 2012 and 2013, two NOAA cruises were conducted in partnership with Woods Hole Oceanographic Institution. Visual surveys using a towed camera system examined submarine canyons and areas on the continental slope between canyons. Survey sites were selected based on Council priorities and to validate a deep-sea coral habitat suitability model developed by NOAA. More than 78,000 high-definition photographs were taken during transects conducted in eight canyons ranging from Toms Canyon in the Mid-Atlantic to Munson Canyon in New England. Canyons surveyed during these cruises host diverse and abundant deep-sea coral communities, including gorgonian and black corals. At least 20 species of corals, mostly gorgonians, were observed in the canyons, expanding the known distribution of deep-sea corals in this region.

- In July 2013, a cruise in partnership with the University of Connecticut used a towed camera to survey areas in the northern Gulf of Maine. The surveys documented rich gorgonian coral gardens at depths between 591 and 853 feet in Jordan Basin and the Schoodic Ridge/Mount Desert Rock areas within the Gulf. Areas with steep and vertical rock faces had the highest densities of gorgonian coral, primarily *Paramuricea placomus*, which grows to be more than 3 feet tall, along with lower densities of two other species. The corals occur in high densities, approximately 15 to 39 colonies/m^2. These deep-sea coral communities are habitats for the Acadian redfish in the Gulf of Maine, and the findings from this cruise may help the New England Fishery Management Council in managing the newly reopened redfish fishery.
- Also in 2013, a telepresence-enabled expedition aboard the NOAA *Okeanos Explorer* used an ROV to conduct visual surveys in the canyons and a seamount. The Program provided partial funding for the second leg of this expedition. During this expedition, 31 ROV dives, ranging in depth from 1,608 to 10,827 feet, were completed at 10 named canyons (Block, Alvin, Atlantis, Veatch, Hydrographer, Nygren, Heezen, Oceanographer, Lydonia, and Welker), two minor unnamed canyons, several inter-canyon sites, and Mytilus Seamount. Many of the ROV dives represented the first contemporary exploration and visual examination of these features. Submarine canyons investigated were diverse and dramatic environments, with no two canyons appearing to be exactly alike in geology or biology. Analysis of these results will expand our understanding of the spatial distributions, both geographic and bathymetric, of species along the continental margin and slope. A number of coral species not previously reported from the region were observed, and species once considered rare occurred in higher abundances than expected. The live Internet broadcast allowed scientists and the public from around the world to join the exploration, receiving approximately 660,000 views throughout the duration of the expedition.

Looking ahead, our Program plans to fund at least two more cruises in 2014 using an ROV that can collect coral samples so the observed species can be more accurately identified.

Dense gorgonian corals (*Paramuricea placomus* and *Acanthogorgia* cf. *armata*) at 787-foot depth in western Jordan Basin. The laser dots are 8 inches apart. Credit: Auster et al. 2013.



In addition, an interagency collaboration by OER, the Bureau of Ocean Energy Management (BOEM), and the U.S. Geological Survey (USGS) is providing environmental baselines in Norfolk, Washington and Baltimore Canyons in advance of potential offshore oil and gas leases. These accomplishments are described in more detail at oceanexplorer.noaa.gov and are outside the scope of this report.

The Northeast regional science team, supported by the Deep Sea Coral Research and Technology Program, is analyzing the results from the 2012 and 2013 fieldwork and coordinates closely with Regional Fishery Management Council staff and advisory bodies to ensure that the findings are submitted to the Councils in a timely manner. Specifically, the Mid-Atlantic Council is developing an amendment to the Mackerel, Squid and Butterfish Fishery Management Plan, that would include management options to: 1) protect coral habitats with an emphasis on those in the canyons, and 2) temporarily prohibit the expansion of bottom fishing into greater depths until scientific surveys determine that bottom-contact gear would not cause negative impacts on corals in the deeper habitat. To the north, the New England Council plans to develop similar management options in a deep-sea coral omnibus amendment. The Program's funded research is expected to help ground the Council deliberations in quantitative, spatially explicit information to the extent possible.

Video: 2013 Northeast Canyons Expedition

Click on the image below to view a 5 minute video of highlights from Leg 2 of the U.S. Northeast Canyons 2013 Expedition aboard NOAA ship *Okeanos Explorer*. Please allow time for video to load.

Trouble viewing this video?
Go to: http://bcove.me/w7k9gi45

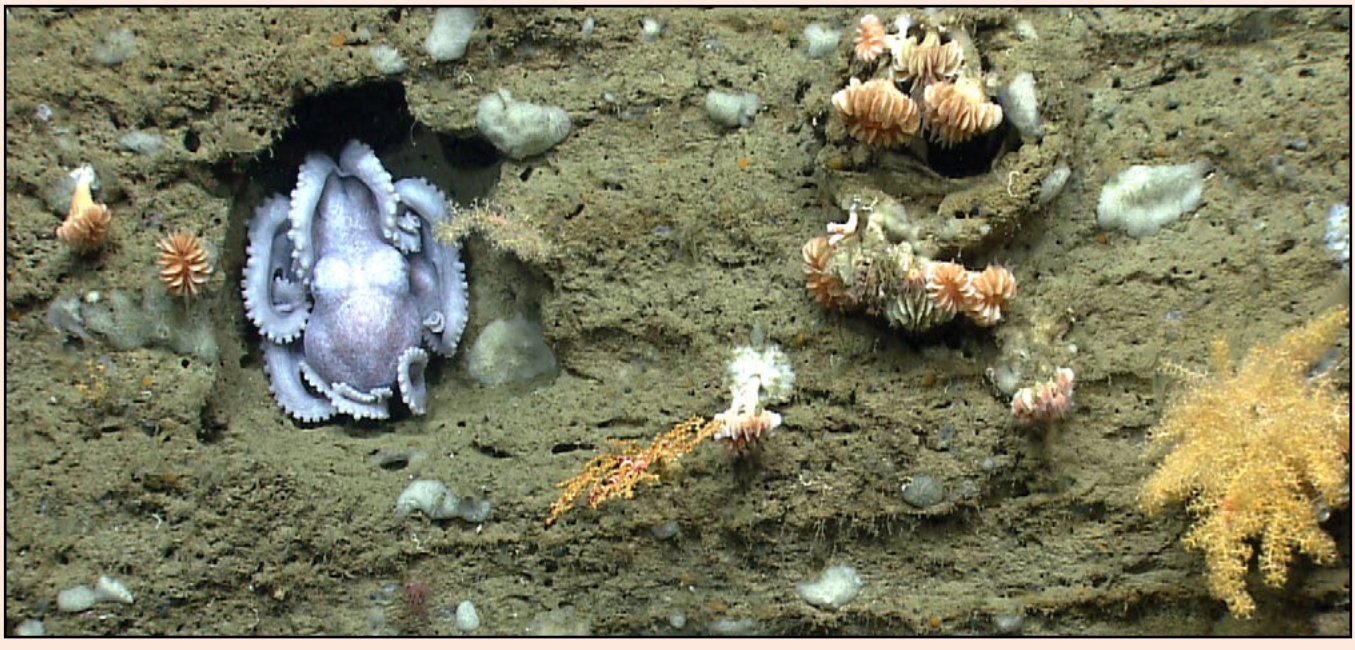
Additional Studies in the Northeast

Besides the successful fieldwork, the Program also supported enhanced training for fishery observers to improve the documentation of coral bycatch. As a result, nearly 150 observers in the groundfish and scallop fisheries received training in 2013 to distinguish stony corals, soft corals, and sea pens, and to properly preserve coral samples. Deep-sea coral identification is now part of all initial certification training at the Northeast Fisheries Training Center. The database that holds bycatch records has also been upgraded to accommodate more detailed coral observations. During commercial fishing trips, the observers take photos of all corals brought up by fishing gear, record them under the three categories, and bring back samples when possible. The photos and samples are later reviewed by experts to validate the observer records and to identify the coral with finer taxonomic resolution. Since the training, the observers documented seven instances of sea pen bycatch—as many observations as had been reported over the 18 years before the training. Also, two instances of soft coral bycatch were recorded in the observer database. This would not have been possible before 2013 because the observer database had not been designed to distinguish coral types. This project improved the quantity and quality of data on coral bycatch, which will be highly valuable in guiding future research and conservation actions.

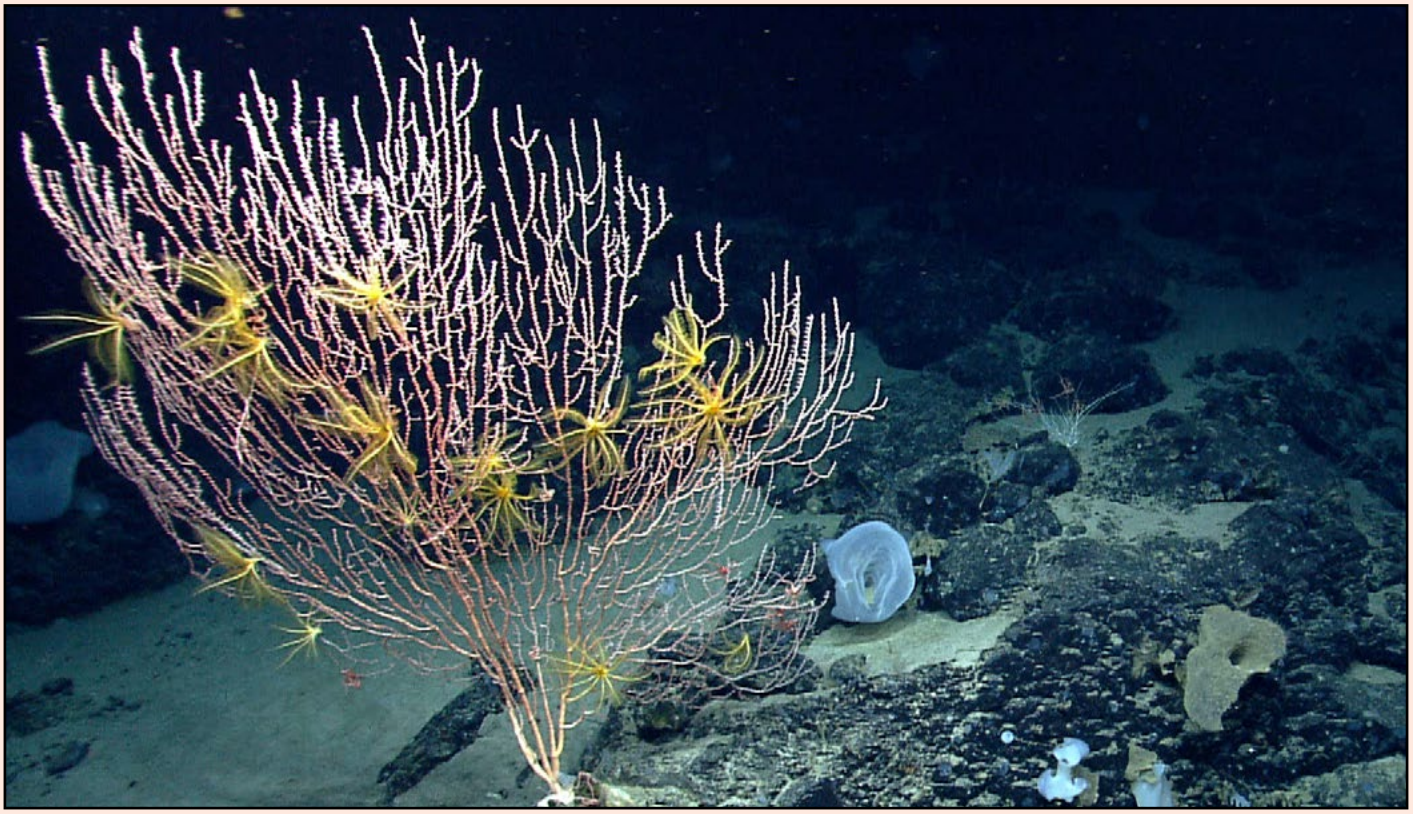
More detailed descriptions of projects funded in 2012 and 2013 are available online at http://www.habitat.noaa.gov/protection/corals/deepseacorals/projects/index.html

A *Paramuricea* coral as habitat for anemones and brittle stars.

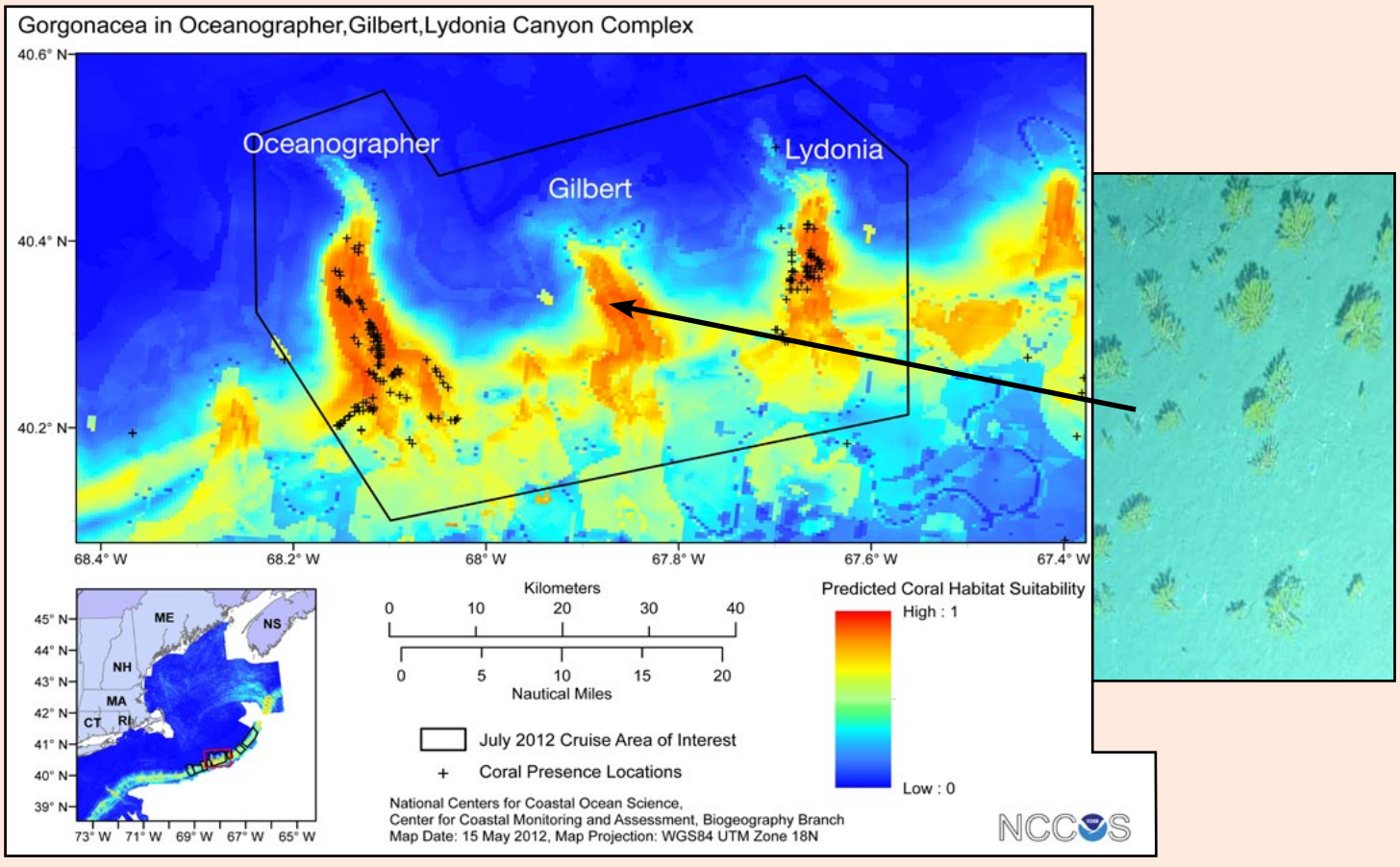
Octopus and corals in Welker Canyon observed in 2013.



Large colony of a bamboo coral (*Jasonisis* sp.) observed on Mytilus Seamount at a depth greater than 6,562 feet. Several colonies of this species were observed during Leg 2 of the U.S. Northeast Canyons 2013 Expedition aboard NOAA ship *Okeanos Explorer*.



Predicted suitable habitat for gorgonian deep-sea corals in Gilbert Canyon was validated by towed camera surveys in 2012 which discovered large fields of gorgonians.



South Atlantic Council Region

The Deep Sea Coral Research and Technology Program funded a deep-sea coral fieldwork initiative in the South Atlantic Fishery Management Council region in 2009–2011. In the 2012–2013 reporting period, the Program's investment in this region resulted in analysis of the fieldwork findings and compiling the results into a published report and scientific papers. The 3-year initiative has expanded our understanding of the distribution of the region's deep-sea corals, their growth and reproduction, and the extent that populations in the region are genetically distinct from populations elsewhere in the Atlantic.

Prompted by new discoveries of deep-sea coral habitats resulting from our fieldwork, the South Atlantic Council approved Amendment 8 to its Coral, Coral Reef, and Live/Hardbottom Habitats Fishery Management Plan. The Council submitted the amendment to the Secretary of Commerce for final review in late 2013.

When finalized, the amendment will expand the Oculina Bank Habitat Area of Particular Concern (HAPC), the Stetson-Miami Terrace Coral HAPC, and the Cape Lookout Coral HAPC. As a result of the amendment, the seafloor protected from bottom-contact gear in the HAPCs will increase by 843 square miles. The amendment will also allow the existing deepwater shrimp fishery to remain viable by providing vessels the opportunity to transit through the Oculina Bank HAPC and designating a Shrimp Fishery Access Area to be used as a gear haul back/drift zone in the Stetson-Miami Terrace Coral HAPC. In addition to using the new *in situ* observations of coral habitats when choosing preferred alternatives, the Council also considered vessel monitoring system data and rock shrimp trawl track information, thus maximizing the area where fishery operations may continue and coral habitats are protected. These vessel monitoring system data sets were enhanced with partial support from the Deep Sea Coral Research and Technology Program.

NOAA Develops Gulf of Mexico Deep-Sea Coral Habitat Suitability Models

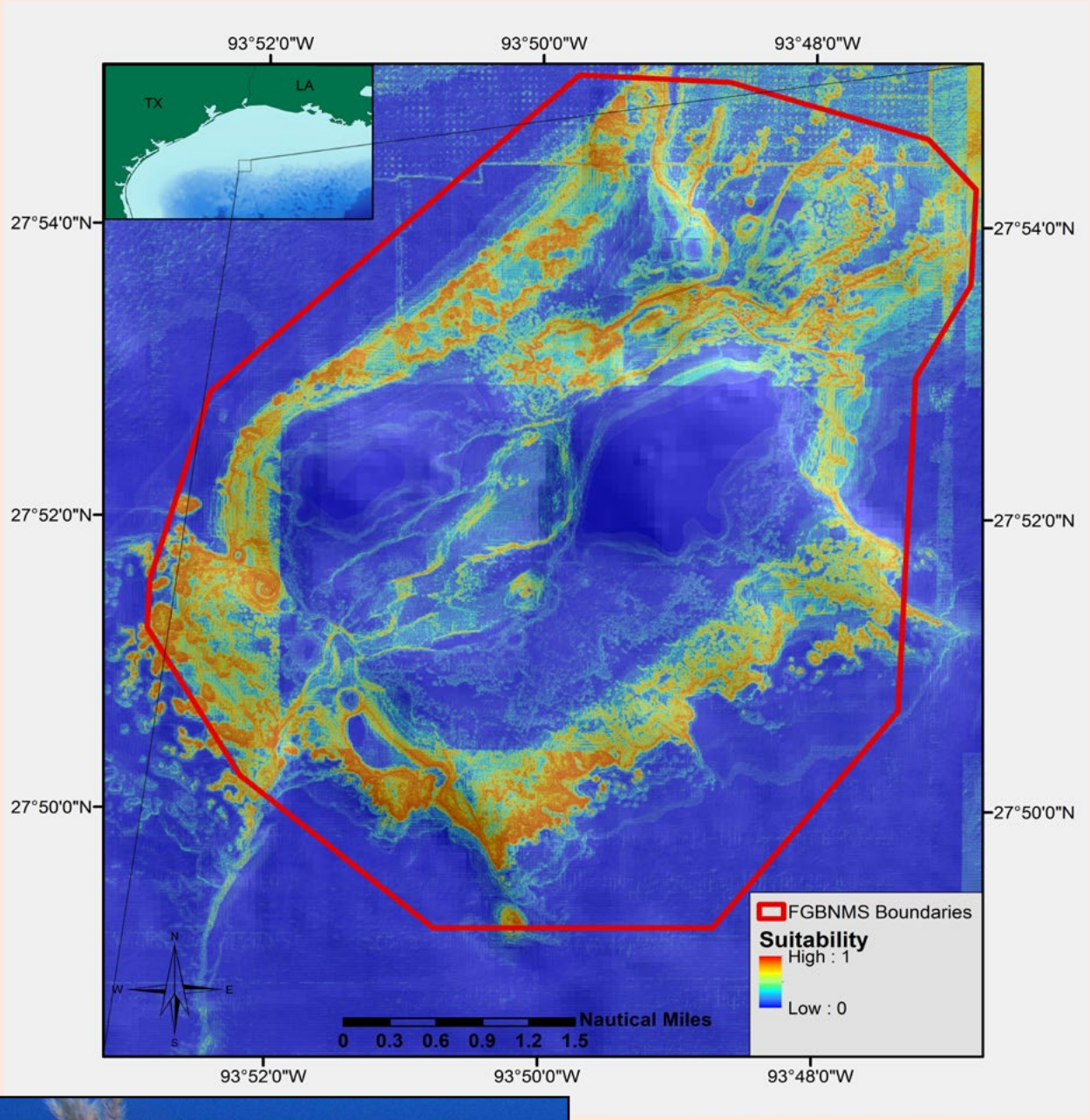
In this reporting period, the Deep Sea Coral Research and Technology Program supported two predictive modeling studies focused on the Gulf of Mexico. Both studies predict likely deep-sea coral habitats. (See Box 1 for more background on predictive habitat modeling.) One study focused on black corals in the northwestern Gulf, and the other involved more taxonomic groups and covered all of the northern Gulf. The results from these studies will help scientists select future focus areas for research and help resource managers identify conservation priorities. More detailed descriptions of these projects are available online at: http://www.habitat.noaa.gov/protection/corals/deepseacorals/projects/index.html

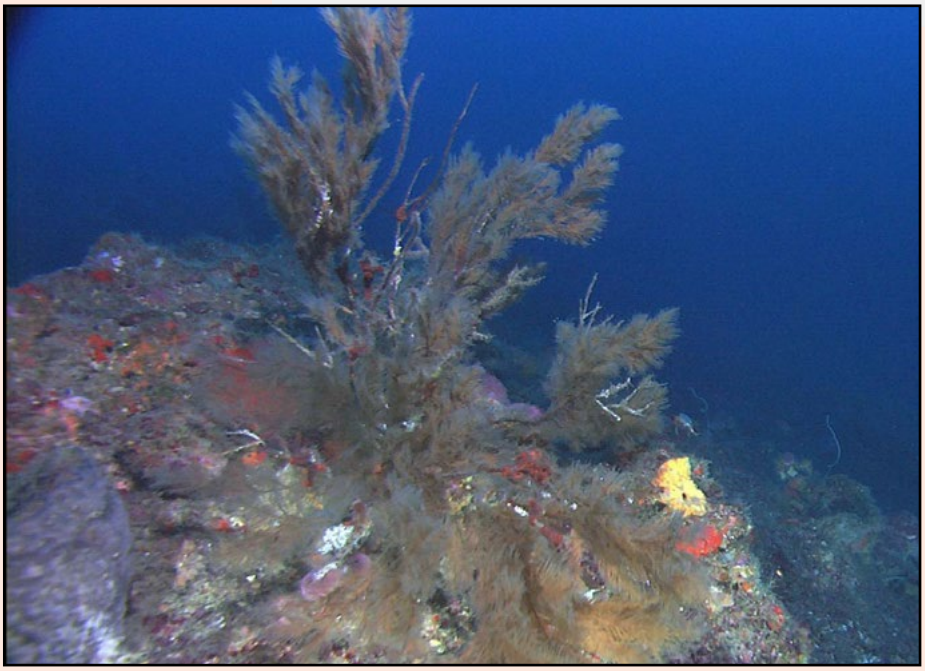
Managers in the Gulf of Mexico are increasingly interested in identifying vulnerable deep-sea coral habitats. The Gulf of Mexico Fishery Management Council held a workshop in 2013 that reviewed the latest research on Gulf of Mexico deep-sea corals. Participant recommendations included establishing new deep-sea coral HAPCs. The Council is obtaining further expert review and advice from its Special Coral Scientific and Statistical Committee regarding these recommendations.

The Flower Garden Banks National Marine Sanctuary's 2012 Management Plan has proposed expanding sanctuary boundaries to include additional reefs and banks in the northwestern Gulf of Mexico, likely encompassing additional deep-sea coral habitats.

The 2010 Deepwater Horizon oil spill damaged deep-sea corals up to 6 nautical miles from the wellhead,[1] further highlighting the vulnerability of these resources. In 2012, OER and BOEM completed fieldwork for the 4-year "Lophelia II Project: Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard-Bottom Habitats with Emphasis on Coral Communities: Reef, Rigs and Wrecks," which provided a wealth of information on deep-sea coral habitats in the Gulf of Mexico. These accomplishments are described in more detail at oceanexplorer.noaa.gov and are outside the scope of this report.

[1] White HK, et al. (2012). Impact of the Deepwater Horizon oil spill on a deep-water coral community in the Gulf of Mexico. *Proceedings of the National Academy of Sciences* 109 (50): 20303-20308





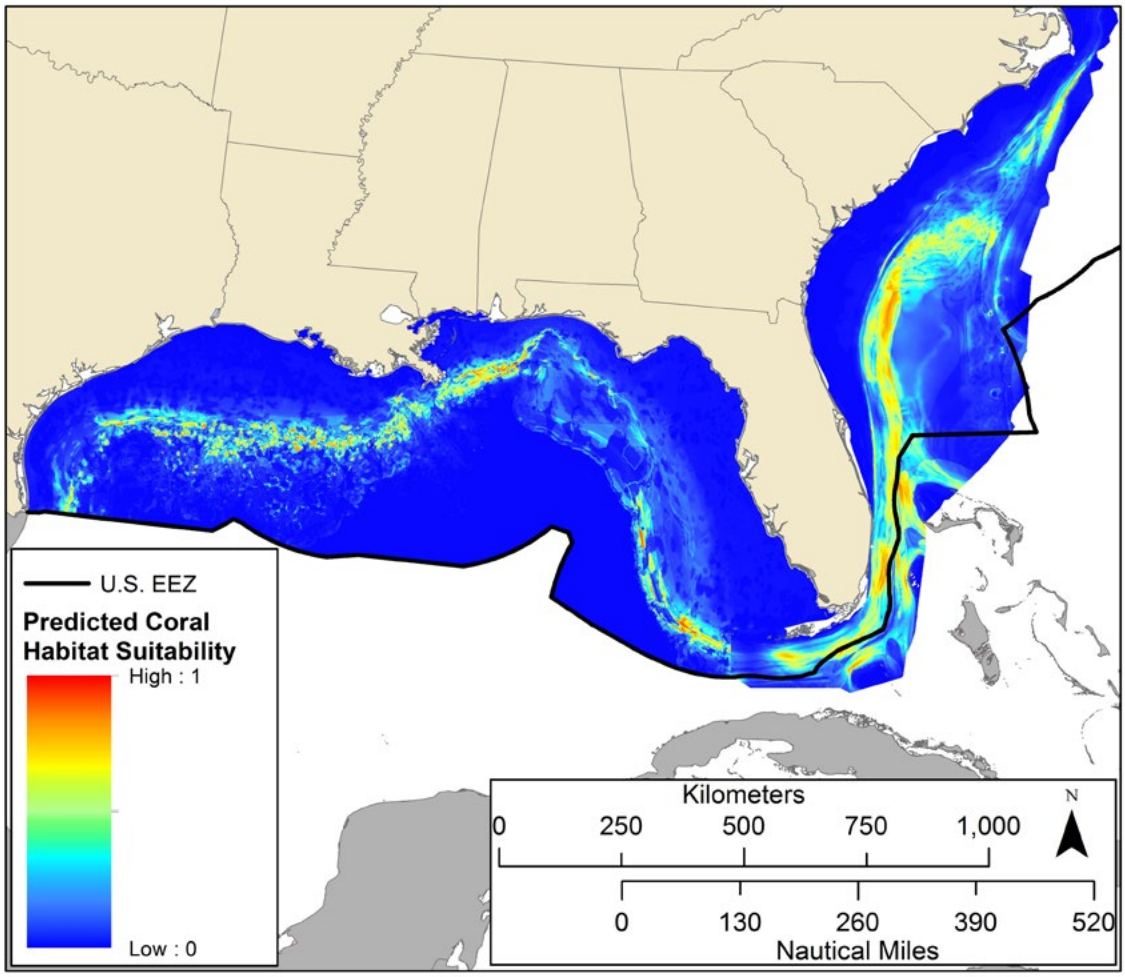
Habitat suitability model for the West Flower Garden Bank for the black coral genus *Tanacetipathes* in Flower Garden Banks National Marine Sanctuary. Suitability ranges from one (highly suitable habitat) to zero (unsuitable habitat). This map was created at a 16-foot spatial resolution and highlights the deep reef habitats surrounding the bank as highly suitable habitat for this genus.

Box 1

Predictive Modeling to Inform Management

The scarcity of observations of deep-sea habitats poses a major challenge for fisheries and sanctuaries managers and regional ocean planners. Most deep-sea scientific surveys or sampling cover only a couple acres at most, while managers must often plan for activities covering hundreds or thousands of square miles. Predictive habitat modeling for deep-sea corals and other vulnerable marine ecosystems provides a promising approach to bridge this mismatch in scale. Such modeling is a cost-effective method for extrapolating findings from field observations to identify deep-sea coral habitat in locations that have not been sampled. The Deep Sea Coral Research and Technology Program has supported predictive habitat models for deep-sea corals at both the regional level (e.g., the entire East Coast and Gulf of Mexico, West Coast, and Aleutian Islands) and more detailed modeling at smaller scales (e.g., Flower Garden Banks in the Gulf of Mexico and Channel Islands off California). Additional field surveys will further validate and refine these models, which have already accurately identified previously undiscovered deep-sea coral habitats.

Predictive habitat modeling will increasingly help target future research, as well as provide insights into the environmental conditions controlling deep-sea coral distribution, which will help us understand how these ecosystems may be influenced by future changes in climate and ocean acidification.



Predicted Habitat Suitability for Framework-forming Deep-Sea Stony Corals

National Centers for Coastal Ocean Science,
Center for Coastal Monitoring and Assessment
Biogeography Branch
Map Projection: WGS84 UTM Zone 17N

Gulf of Mexico and Southeast:
All Framework-forming stony corals

An example of deep-sea coral habitat suitability prediction maps developed by NOAA for framework-forming Scleractinians (stony corals) in the Southeast and Gulf of Mexico. Warm colors (e.g., red) denote areas more suitable for coral habitat and cooler colors (e.g., blue) denote areas less suitable for coral habitat. Values depict a relative index of habitat suitability that ranges from zero to 1. The values do not represent probabilities of coral occurrence.

U.S. Caribbean Research Explores Deep Waters

The deeper waters of the U.S. Caribbean remain largely unexplored. The Caribbean Fishery Management Council collaborated with U.S. Geological Survey (USGS), the Ocean Exploration Trust, and University of Puerto Rico in 2013 to explore depths between 377 and 9,843 feet at 7 sites in the northeastern U.S. Caribbean. This telepresence-enabled ROV cruise aboard the research vessel *Nautilus.* observed deep-sea corals, sponges, other invertebrates and fishes in the Puerto Rico Trench, Mona Passage, and other locations. More details about this cruise are available online at: http://www.nautiluslive.org/mission/2013. This research is out of the scope of this report, as it was not funded by the Deep Sea Coral Research and Technology Program.

The Council in partnership with the University of Puerto Rico plans to conduct an AUV cruise in 2014 in the U.S. Caribbean to describe the EFH of the queen snapper *Etelis oculatus* at depths to 2,297 feet, which encompasses deep-sea coral habitats.

U.S. Pacific Islands Research is Set to Begin in 2015

The U.S. Pacific Islands Region consists of more than 50 oceanic islands and atolls, including the Hawaiian Archipelago, the Commonwealth of the Northern Mariana Islands, and the territories of Guam and American Samoa, as well as the unincorporated U.S. Line Islands (Kingman Reef, Jarvis Island, and Palmyra Atoll), U.S. Phoenix Islands (Howland and Baker Islands), and Johnston and Wake Atolls. Because these islands and their surrounding habitats are isolated, this region is home to many endemic species.

Deeper waters of the U.S. Pacific Islands Region are largely unexplored, and nearly all the scientific observations of deep-sea corals in the region have been limited to the Hawaiian Archipelago. Historically, gold, black, and pink corals were harvested off Hawaii for the jewelry trade. In federal waters, this fishery is managed under the Western Pacific Fishery Management Council's Precious Coral Fishery Management Plan and is currently dormant. Some of the corals targeted in the fishery are extremely slow-growing. Gold corals in Hawaii, for example, can reach an age of 2,700 years. Due their slow growth, the Council placed a moratorium on gold coral harvests.

The U.S. Pacific Islands may harbor some of the most pristine deep-sea coral habitats in the world, thanks to early action by the Council in the 1980s to prohibit bottom-trawling and other damaging fishing operations throughout the region. Knowledge of the distribution of deep-sea coral habitats becomes increasingly important as offshore renewable energy development, open-ocean aquaculture, deep-sea mining, cable deployment, and other activities that can disturb the seafloor are being proposed for the region.

The region has four Marine National Monuments with extensive deep-water resources. Papahānaumokuākea Monument was established in 2006, and Marianas Trench, Pacific Remote Islands, and Rose Atoll Monuments in 2009. The new monuments have a mandate to protect the unique natural and cultural resources, but their deep-sea communities have not been explored.

The Deep Sea Coral Research and Technology Program is planning a concerted fieldwork effort to locate and characterize the deep-sea coral ecosystems in the Pacific Islands region in 2015–2017. A workshop in 2014 will identify research priorities, soliciting input from the Council, other federal agencies, and stakeholders. The main goal for the Pacific Islands 3-year fieldwork will be to provide information to the Council and Monuments to enhance the conservation of deep-sea coral habitats.

Nationwide Efforts

The Deep Sea Coral Research and Technology Program brings together the regional research discussed above and in previous reports to Congress into a cohesive whole by building and maintaining a national database of deep-sea coral locations, and preparing an updated report on the state of the nation's deep-sea coral and sponge ecosystems.

Report on the State of Deep-Sea Coral and Sponge Ecosystems

In 2007, NOAA published the first peer-reviewed report on the *State of Deep Coral Ecosystems of the United States*. In the ensuing 6 years, new information on deep-sea corals and sponges has expanded rapidly. In 2014, NOAA will publish a peer-reviewed *Update on Deep-Sea Coral and Sponge Ecosystems of the United States*. Leading scientists working in each U.S. region will summarize progress on our understanding and management of these resources since the 2007 report. These regional chapters will be complemented by thematic spotlight articles on emerging scientific topics, including the genetic connectivity of deep-sea coral populations, age and growth of deep-sea corals, trends in species discovery, understanding fishing interactions with deepwater coral and sponge habitats, and how new modeling approaches are informing our understanding of coral distributions. The report will also include lists of deep-sea coral and sponge species found in U.S. waters.

National Database of Deep-Sea Coral Locations

The Deep Sea Coral Research and Technology Program is tasked with identifying and mapping the locations of deep-sea corals. To meet this mandate, the Program has built a national geographic database that houses spatial records of deep-sea corals and deep-sea sponges derived from the research funded by the Program, results of other NOAA programs that study the deep sea, and data voluntarily contributed by other federal agencies, research institutions and international organizations.

The database has grown from records of 85,000 deep-sea corals in 2011, to more than 200,000 deep-sea corals and 67,000 deep-sea sponges in 2013. In addition to the locations of deep-sea corals, the database will incorporate associated information on the size and abundance of corals and sponges discovered by our research cruises, as well as the species of other associated organisms—important factors in determining the ecological importance of these habitats. In partnership with the USGS, in 2014 coral records from the database will be made publicly accessible through the USGS Ocean Biogeographic Information System USA (http://www.usgs.gov/obis-usa/). A companion NOAA portal will provide access to these records as well as other data products from our Program's research.

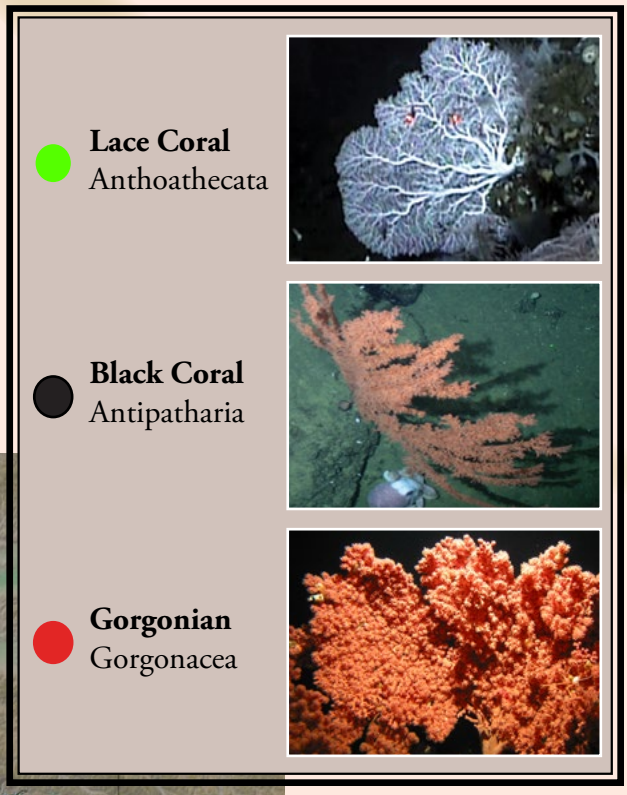
The national database is a central resource for the Regional Fishery Management Councils. As outlined in the regional sections above, deep-sea coral records from the national database have been provided to the New England, Mid-Atlantic, and Pacific Fishery Management Councils for their use in designing habitat conservation measures. Regional coral records have also been used by the Mid-Atlantic Regional Council on the Ocean and are served on their data portal (http://portal.midatlanticocean.org/portal/).

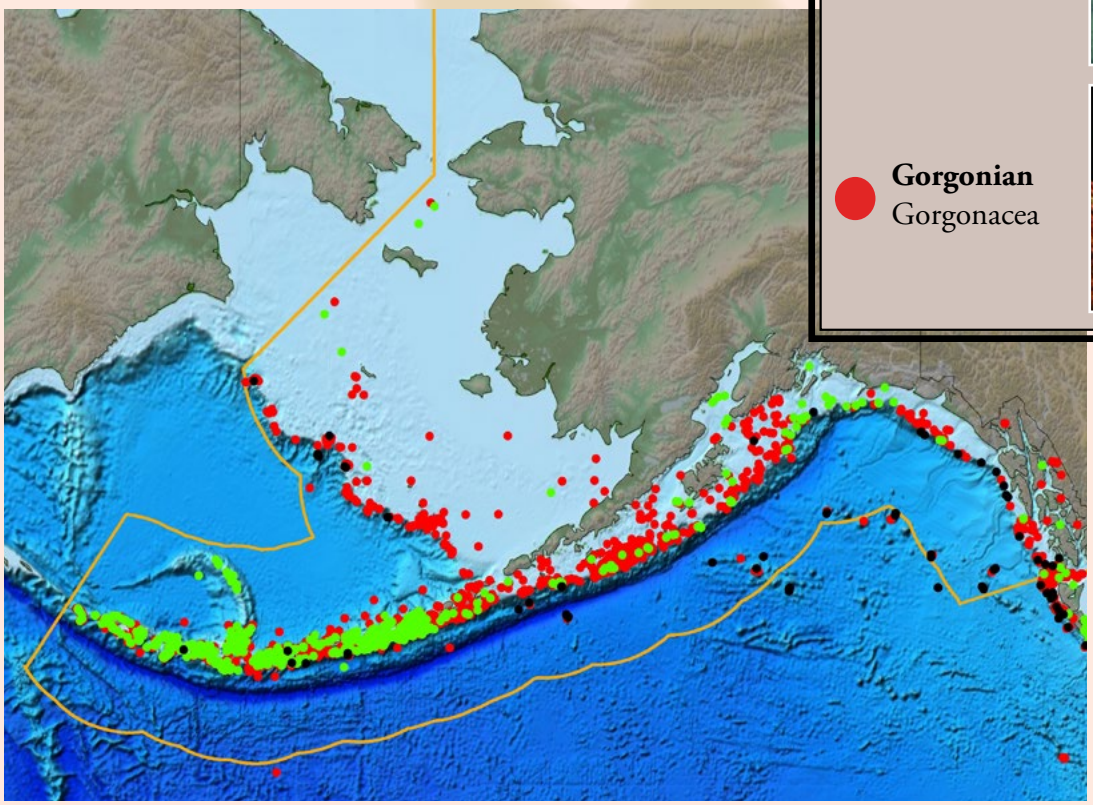
The following maps summarize known locations of deep-sea corals in selected U.S. regions from the national database.

The maps that follow are for illustrative purposes and are not meant to be used for management purposes. Due to the resolution of these maps, a single point may include more than one deep-sea coral record.

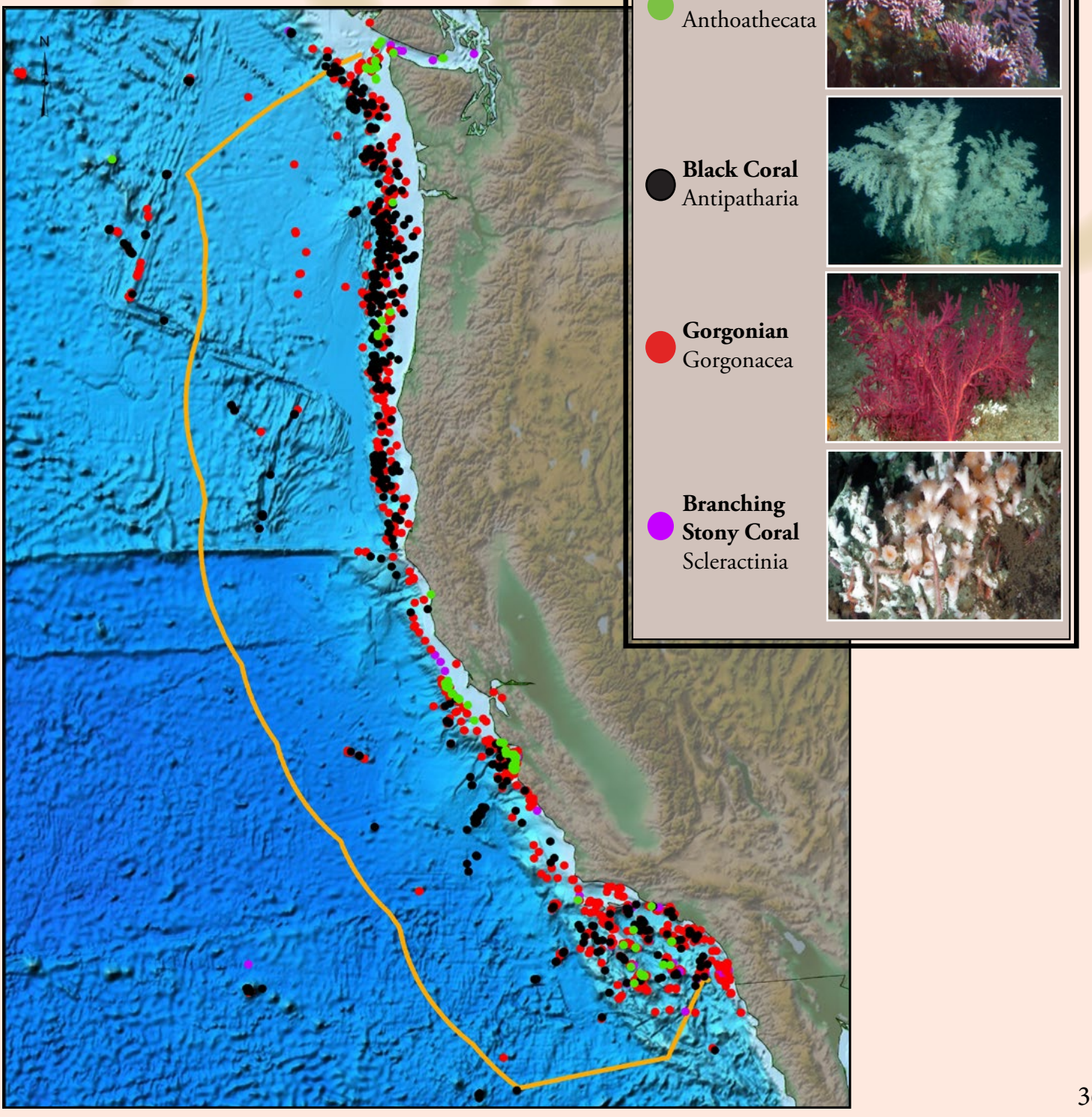
The data do not represent density of coral cover but rather known locations of corals that have been compiled by the Program to date and reported by taxonomic orders. Compilation of existing data is ongoing, and information on some orders may be incomplete. Reported coral locations are limited to where fishing or research has occurred. Areas where no corals are shown may reflect either an absence of corals or an absence of sampling. The data sources include NMFS bottom trawl survey and fisheries observer program databases, Regional Fishery Management Council databases, research cruise results, museum collections, and literature citations.

Structure-forming Deep-Sea Corals of Alaska

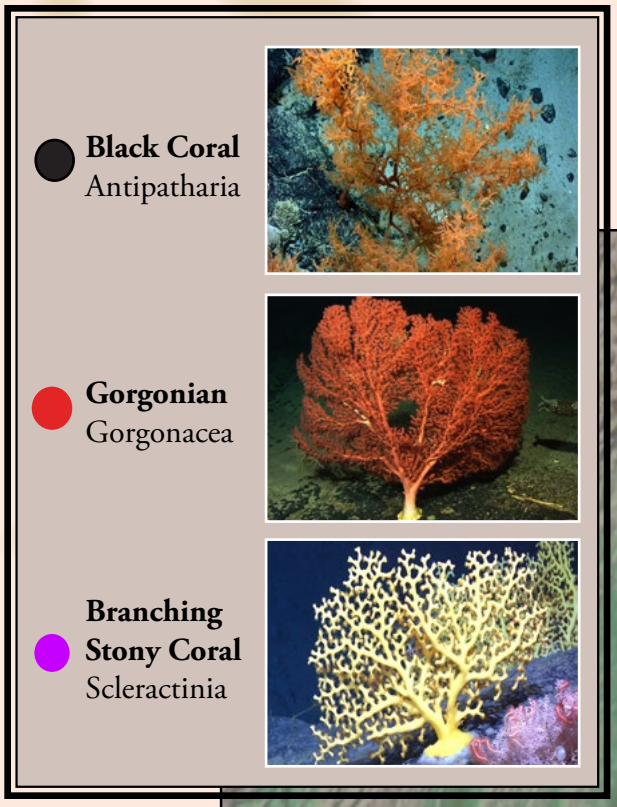




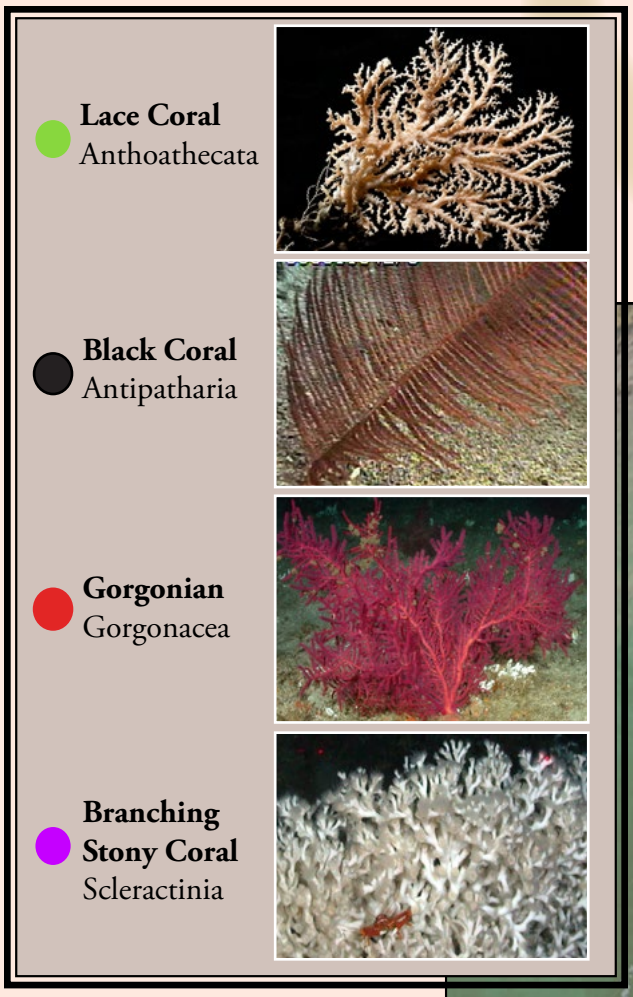
Structure-forming Deep-Sea Corals of the West Coast



Structure-forming Deep-Sea Corals of the Northeast



Structure-forming Deep-Sea Corals of the Southeast



Structure-forming Deep-Sea Corals of the Gulf of Mexico

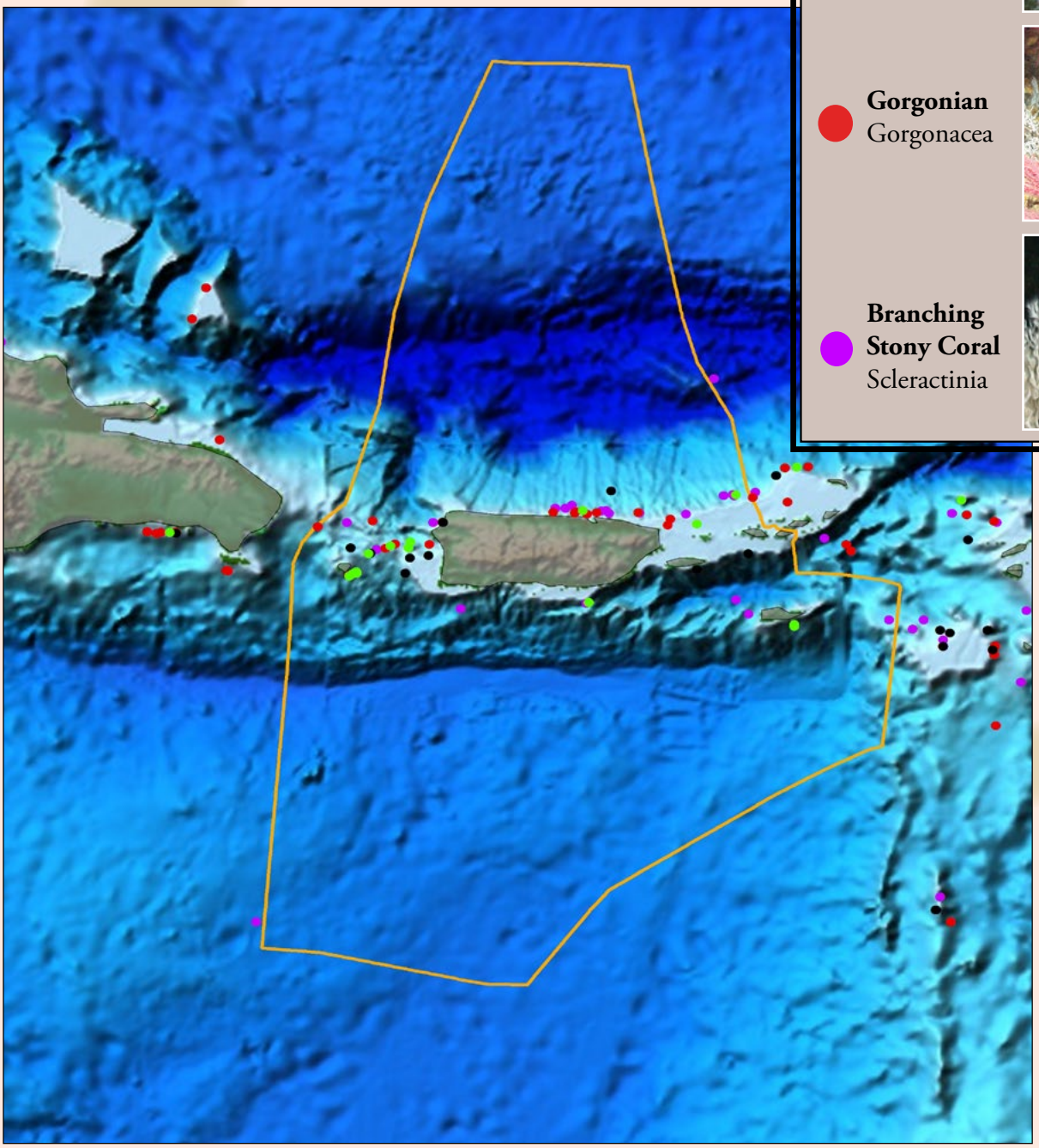
Lace Coral
Anthoathecata

Black Coral
Antipatharia

Gorgonian
Gorgonacea

Branching Stony Coral
Scleractinia

Structure-forming Deep-Sea Corals of the Caribbean



Lace Coral
Anthoathecata

Black Coral
Antipatharia

Gorgonian
Gorgonacea

Branching Stony Coral
Scleractinia

Structure-forming Deep-Sea Corals of the Pacific Islands

Lace Coral
Anthoathecata

Black Coral
Antipatharia

Gorgonian
Gorgonacea

Branching Stony Coral
Scleractinia

Gold Coral
Zoanthidea

Looking Forward

Building on the progress in 2012 and 2013, the Deep Sea Coral Research and Technology Program plans to take the following steps to advance deep-sea coral science and management:

Alaska

- Complete the 3-year fieldwork initiative, including the Aleutian Islands surveys that did not take place as planned in 2013.
- Submit findings to the North Pacific Fishery Management Council to inform the 5-year review of groundfish EFH and other management processes.

Pacific Islands

- Support a coordinated fieldwork initiative in 2015–2017, in consultation with the Western Pacific Fishery Management Council, to study the deep habitats in the mostly unexplored region.

West Coast

- Prepare a final report on the 2010–2012 fieldwork initiative.
- Support the Pacific Fishery Management Council's groundfish EFH review process with data and analysis as needed.

Northeast

- Continue the 3-year fieldwork initiative to locate and characterize deep-sea coral habitats, with at least two cruises in 2014.
- Supply information to the New England and Mid-Atlantic Fishery Management Councils to inform their efforts to designate deep-sea coral protection zones.

Gulf of Mexico

- Support the Gulf of Mexico Fishery Management Council's development of potential management options for establishing deep-sea coral HAPCs.

National deep-sea coral database

- Prepare nationwide deep-sea coral records for submission to the USGS to be published online in 2014.

While the Program continues to support all the Councils with the best available science to manage essential and vulnerable habitats, we will also assist with other ocean management initiatives (e.g., regional ocean planning and national marine sanctuary processes) by delivering high-quality scientific information that will help protect, maintain, and restore the health and biodiversity of the oceans.

Appendix 1: 2012-2013 projects under the Deep Sea Coral Research and Technology Program

2012

PROJECT	FISHERY MANAGEMENT COUNCIL REGION	AMOUNT
Alaska fieldwork initiative, year 1 of 3	North Pacific	$900,000
Assessment of coral bycatch from the Alaska groundfish trawl fleet in collaboration with the North Pacific Fisheries Observer Program	North Pacific	$48,427
Predictive habitat modeling for Alaska's deep-sea coral and sponge resources	North Pacific	$40,000
Predicting tidal currents for the Aleutian Islands and Gulf of Alaska	North Pacific	$30,000
West Coast fieldwork initiative, year 3 of 3	Pacific	$725,000
Taxonomic and genetic identification of deep-sea corals and sponges in bycatch and field surveys	Pacific; North Pacific	$100,000
Video analysis of *Okeanos Explorer* ROV dives in Channel Islands National Marine Sanctuary	Pacific	$33,500
Assessing deep-sea coral communities from archived video surveys: Year 2	Pacific	$33,313
Habitat suitability modeling and field validation for deep-sea corals in the Northeast	New England; Mid-Atlantic	$75,000
Deep-sea coral and sponge identification training for the Northeast Fisheries Observer Program	New England; Mid-Atlantic	$13,000
Final analysis for 2009-2011 fieldwork initiative	South Atlantic	$65,000
Antipatharian distribution and suitability mapping in the mesophotic zone of the northwestern Gulf of Mexico	Gulf of Mexico	$39,900
Predictive modeling for the Gulf of Mexico: presence/absence component	Gulf of Mexico	$30,000
National deep-sea coral geodatabase and data management	National	$150,000
Program coordination	National	$109,085
NMFS management and administration	National	$61,493
Advancing deep-sea coral video identification	National/International	$7,000
TOTAL		**$2,459,718**
**Incorporating Hawaiian deep-sea coral records into the national geodatabase*	*Pacific Islands*	*$15,000**

2013

PROJECT	FISHERY MANAGEMENT COUNCIL REGION	AMOUNT
Alaska fieldwork initiative, year 2 of 3	North Pacific	$850,000
Northeast fieldwork initiative, year 1 of 3	New England; Mid-Atlantic	$800,000
Determination of the impacts of trap fishing on mid-Atlantic benthic habitats, with emphasis on structure-forming invertebrates	Mid-Atlantic	$50,000
Taxonomic and genetic identification of fisheries bycatch of deep-sea corals and sponges	Pacific; North Pacific	$65,000
Pacific Islands research priority workshop	Pacific	$20,000
Fieldwork data stewardship	Pacific; North Pacific; New England; Mid-Atlantic; South Atlantic; Atlantic	$125,000
National deep-sea coral geodatabase and data management	National	$135,000
Program coordination	National	$136,952
NMFS management and administration	National	$190,841
TOTAL		**$2,372,793**
**Predictive models and distribution maps of deep-sea corals off Northern California*	*Pacific*	*$45,427**

*Projects administered by the Deep Sea Coral Research and Technology Program but sponsored by other funding sources.

Descriptions of these projects are available online at www.habitat.noaa.gov/protection/corals/deepseacorals/projects/index.html.

Due to sequestration budget cuts, fewer projects were funded in 2013 than in 2012. The 3-year regional fieldwork initiatives remained a high priority and continued to be supported in 2013, but the number of small, shore-based projects was reduced.

Appendix 2: 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 where fishing gear interactions with deep-sea corals have been documented or are possible because the coral habitats are in areas 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 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)). NOAA is developing guidance on the application of this authority.

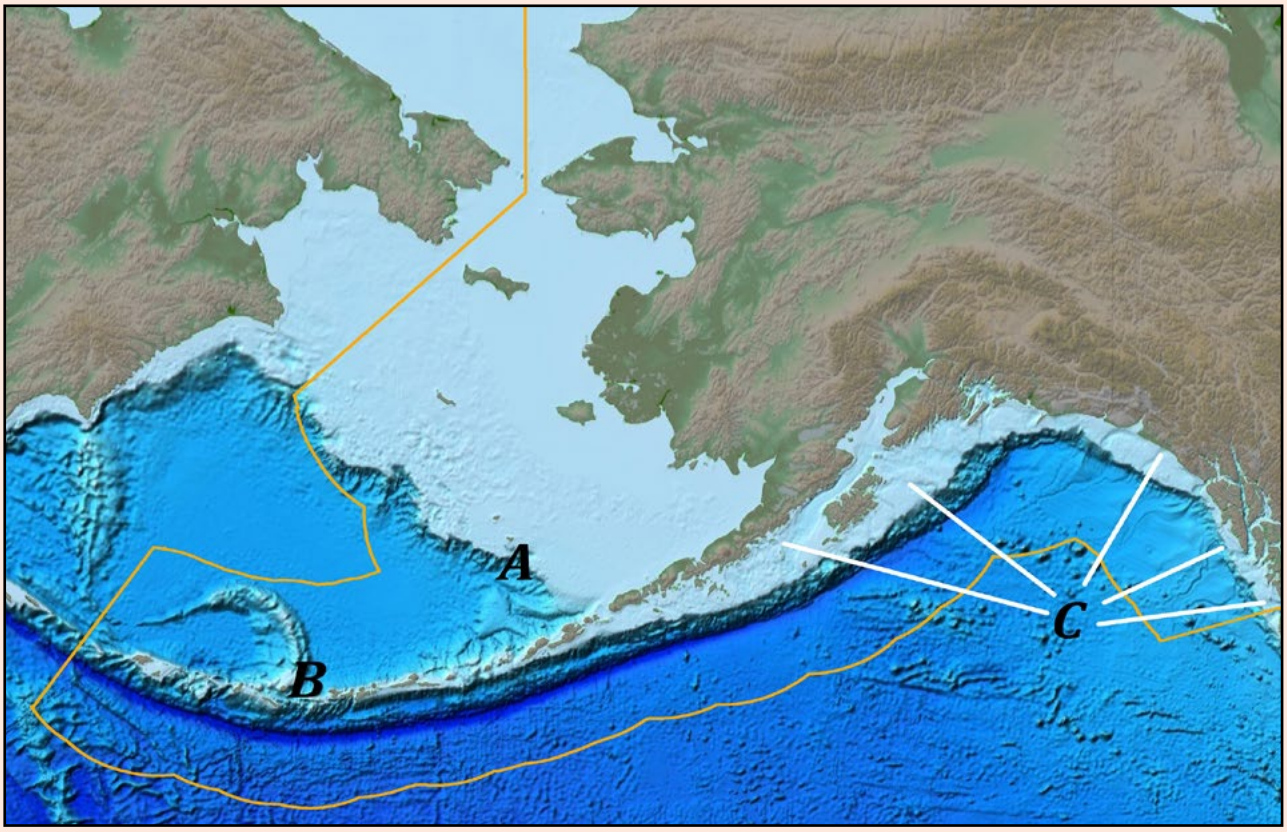
Alaska Region

The North Pacific Fishery Management Council has established a large Aleutian Islands Habitat Conservation Area and a number of HAPCs in the Gulf of Alaska, where coral habitats are protected from fishing gear impacts to varying degrees. Coral aggregations outside of these areas could be considered for additional protection, including:

A. Parts of the Bering Sea slope, particularly Pribilof Canyon. NOAA is planning additional deep-sea coral surveys in the Bering Sea, particularly in the Bering Sea canyons.

B. Deep-sea coral areas of the Aleutian Islands and Petrel Bank and Spur (identified by high coral catches in NMFS trawl surveys and/or coral bycatch in commercial fisheries as reported by the Alaska Groundfish Observer Program) that are outside the Aleutian Islands Habitat Conservation Area (e.g., selected areas between Attu and Kiska Islands).

C. 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. These areas are closed to bottom-trawling, but corals are vulnerable to other gear types operating in the region (e.g., longline gear.)



West Coast Region

Although a significant extent of the West Coast EEZ is protected from bottom trawling (e.g., via EFH protections or the Rockfish Conservation Areas), additional areas of documented deep-sea coral presence are also 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 northern Oregon

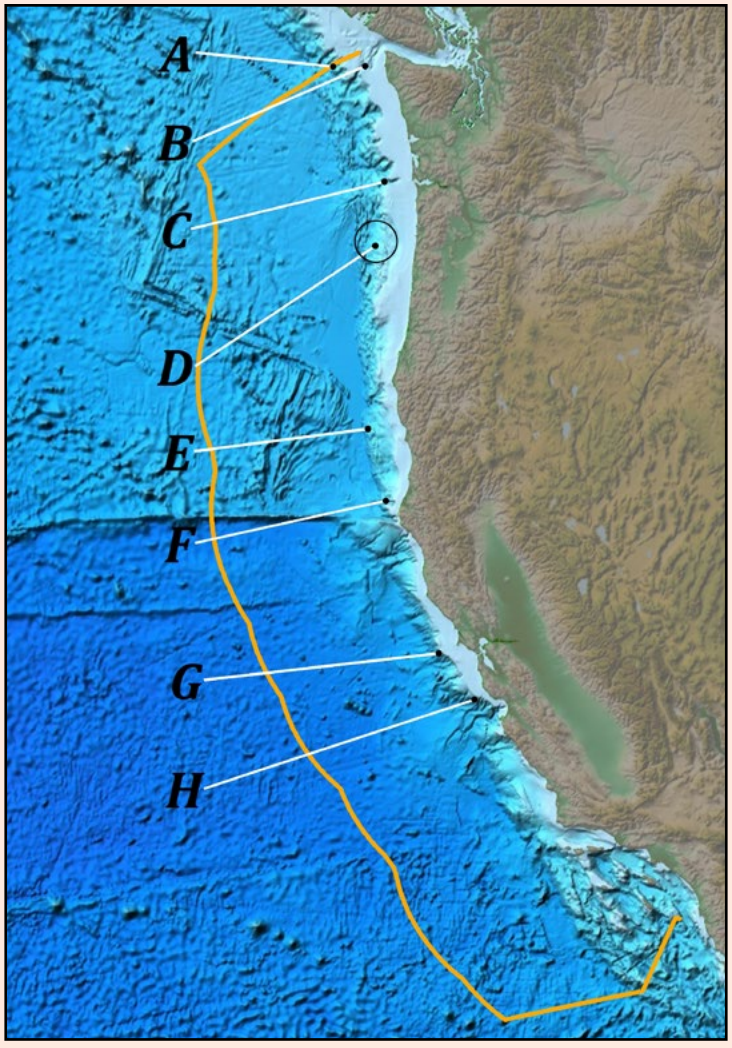
E. High coral bycatch areas off Oregon/California border

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.



Northeast Region

Prior to this reporting period, the New England and Mid-Atlantic Fishery Management Councils collectively have closed Lydonia, Oceanographer, Veatch, and Norfolk canyons to bottom trawling to protect the EFH of some commercially fished species. These closures may have ancillary effects of protecting deep-sea corals that occur in these canyons. Coral aggregations outside of these closures could be considered for additional protection, including:

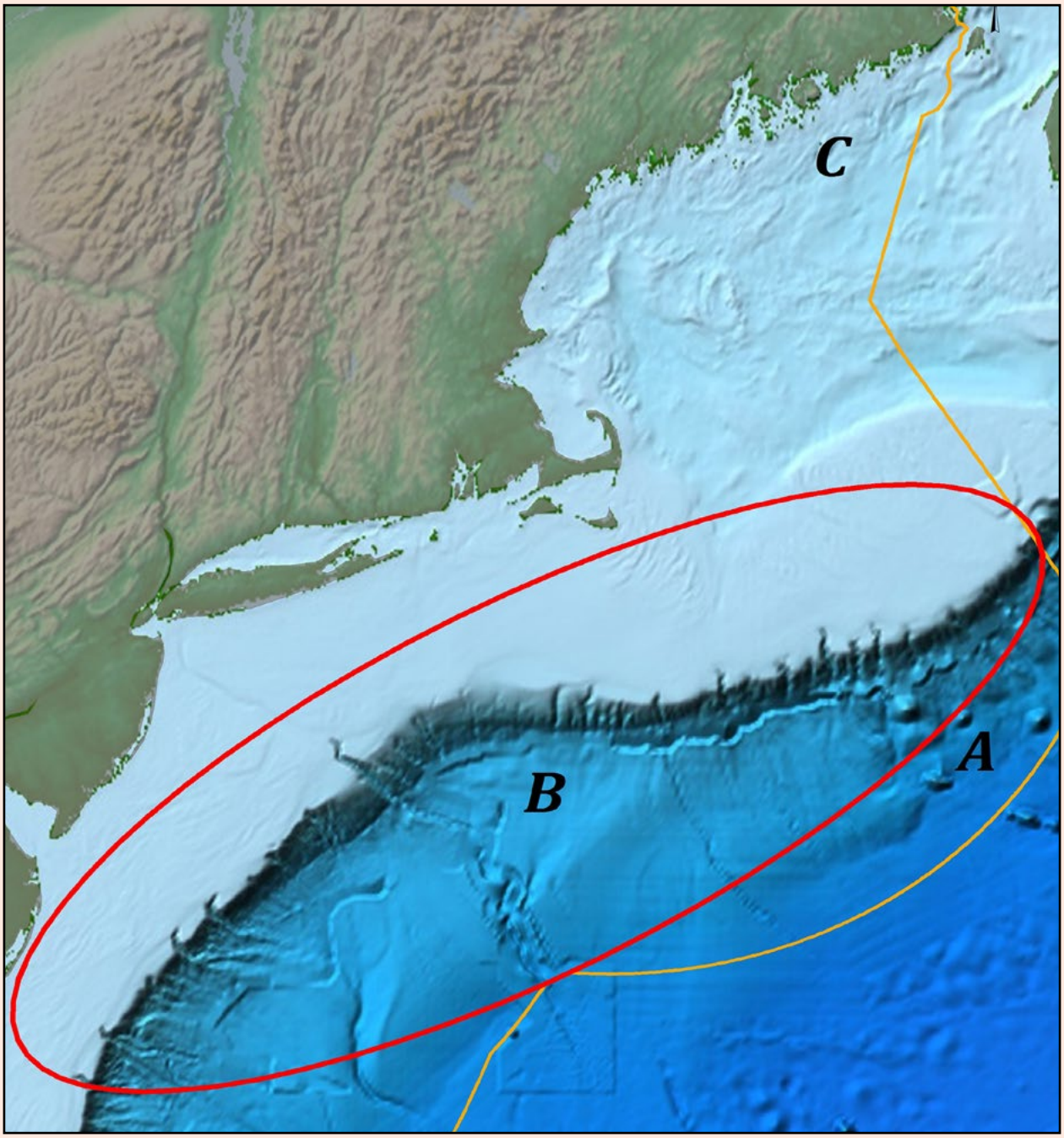
A. New England Seamounts within the U.S. EEZ: Bear, Retriever, Physalia and Mytilus Seamounts.

B. Certain New England and Mid-Atlantic canyons, including Munson, Powell, Gilbert, Welker, Hydrographer, Atlantis, Alvin, Block, Hendrickson, Toms complex, Carteret, Wilmington, Washington, and Baltimore Canyons; and the slope near Alvin Canyon.

C. Three areas in the Gulf of Maine: Western Jordan Basin, Schoodic Ridge, and Mount Desert Rock.

The Mid-Atlantic Fishery Management Council is developing management measures for some of the canyons as an amendment to the Mackerel, Squid, and Butterfish Fishery Management Plan.

The New England Fishery Management Council has tasked its Habitat Plan Development Team to review the management needs for some of the canyon and slope areas in the region.



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. They include five Deepwater Coral HAPCs and the Oculina Bank HAPC. Coral aggregations outside of these areas could be considered for additional protection, including:

A. *Oculina varicosa* mounds off Daytona Beach, Florida, extending north and west outside the current *Oculina* HAPC boundaries. (Proposed for protection in the South Atlantic Fishery Management Council Amendment 8 to the Coral Fishery Management Plan.)

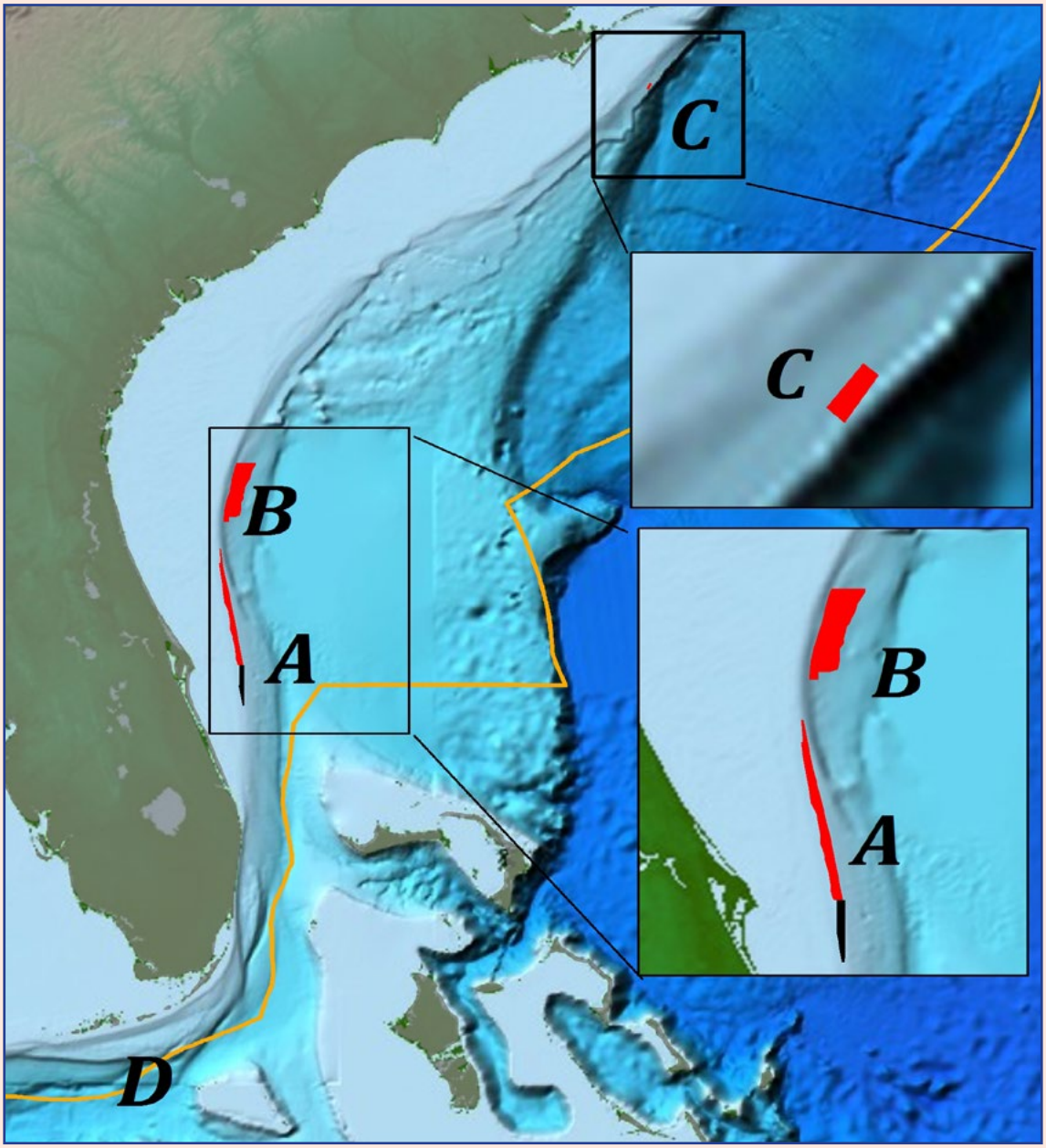
B. *Lophelia pertusa* coral mounds off Jacksonville, Florida, extending west of the current Stetson-Miami Terrace Coral HAPC. (Proposed for protection in the South Atlantic Fishery Management Council Amendment 8 to the Coral Fishery Management Plan.)

C. *Lophelia pertusa* coral mounds extending Northeast west of the current Cape Lookout Coral HAPC (Proposed for protection in the South Atlantic Fishery Management Council Amendment 8 to the Coral Fishery Management Plan.)

D. Deep-sea coral areas outside the Pourtales Terrace Coral HAPC

E. Agassiz and Tortugas Valleys

Currently, Amendment 8 to the Coral Fishery Management Plan is under Secretary of Commerce review.



Gulf of Mexico Region

In the Gulf of Mexico, deep-sea coral aggregations in areas open to bottom-fishing include:

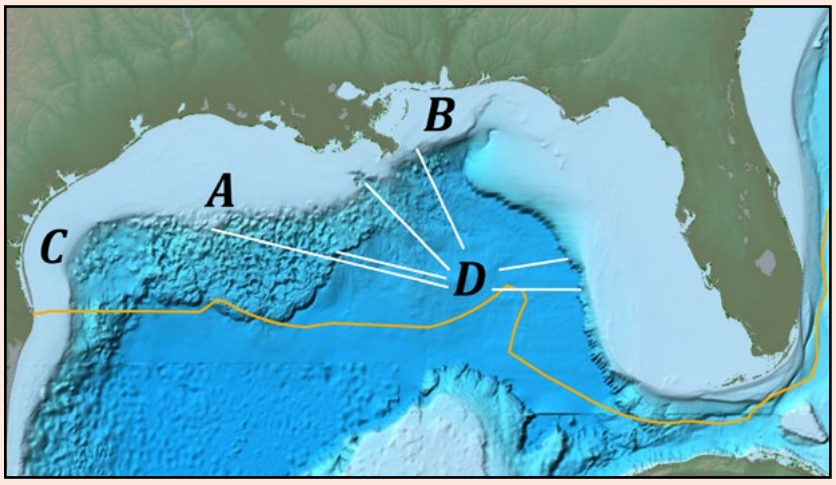
A. Certain areas in the northwest Gulf of Mexico that harbor significant populations of deep-sea corals and have been identified as HAPC but do not carry any protection measures against the impacts of bottom fishing, including 29 Fathom, Sonnier, MacNeil, Rankin, and Bright Banks.

B. Shelf-edge mesophotic banks in the central and eastern Gulf of Mexico, including the Mississippi-Alabama Pinnacles and "Coral Trees"

C. Shelf-edge South Texas Banks

D. Deep-sea coral sites, principally identified during the BOEM/NOAA/USGS Lophelia I & II Research Programs, including:

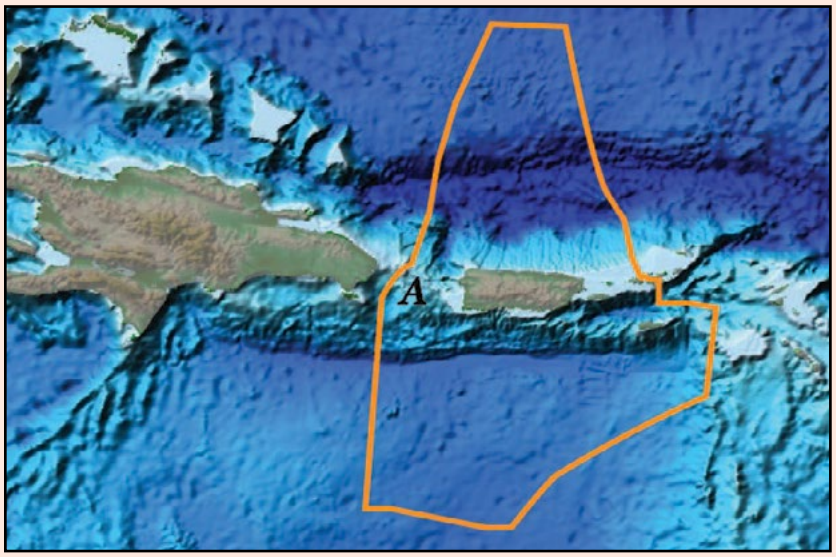
- West Florida Slope
- Florida Escarpment (DC 538)
- Viosca Knoll – VK 826; VK862/906
- Mississippi Canyon – MC 751, MC 855
- Green Canyon – GC 140, GC 234, GC 235, GC 338
- Garden Banks – GB 299, GB 535



U.S. Caribbean

In the U.S. Caribbean, deep-sea coral aggregations in areas open to bottom-fishing include:

A. Mona Passage, off the west coast of Puerto Rico, where deep-sea corals have been documented. There is no bottom-trawling in the U.S. Caribbean EEZ, but other bottom-contact gear could be of concern for these corals.



References for Appendix 2

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. **Bering Sea Slope and Canyons:**

- 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*.
- 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.

B. **Aleutian Island coral areas:**

- Stone, R. P.(In press). *The ecology of deep-sea coral and sponge habitats of the central Aleutian Islands of Alaska*. NOAA Professional Paper.
- Stone and Shotwell (2007)
- Deep Sea Coral Research and Technology Program – Alaska Coral and Sponge Initiative.
- NMFS Alaska Fisheries Science Center Groundfish Observer Data
- NMFS Alaska Fisheries Science Center Groundfish Trawl Survey Data

C. **Gulf of Alaska Red Tree Coral Areas:**

- Stone, R. P., Karinen, J. F., & Masuda, M. M. (In prep.). *The ecology of red tree coral thickets in the eastern Gulf of Alaska*.
- Stone and Shotwell (2007)

West Coast – Regional summary 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.

A. **High coral bycatch area bordering Nitinat Canyon:**

- 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.
- 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:**

- 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.
- 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 Researach and Technology Program. 21pp
- 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:**

- 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.
- GEFHRC 2012.
- Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013)

D. **High coral bycatch areas off Northern Oregon:**

- GEFHRC 2012.
- Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013)

E. **High coral bycatch areas off Oregon/California border:**

- GEFHRC 2012.
- Oceana, Natural Resources Defense Council, and Ocean Conservancy (2013)

F. **Eel River Canyon coral bycatch area:**

- GEFHRC 2012.
- 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:**

- 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)
- 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:**

- 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 (in review). use of AUVs to Inform Management of Deep-Sea Corals.
- 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 and Mid-Atlantic 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.
- Watling et al., (2003)
- 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)

C. **Gulf of Maine:**

- 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: 10.1080/14888386.2013.850446
- Packer et al. (2007).
- 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.
- 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, Maryland

A. ***Oculina varicosa* mounds:**

- South Atlantic Fishery Management Council Amendment 8 to the Coral Fishery Management Plan
- David, A. W. (2011). Southeast Deep-Sea Coral Research and Technology Program (SE-DSC) 2009-2011, presentation to the South Atlantic Fishery Management Council Coral Advisory Panel on October 25. North Charleston, SC.

B. ***Lophelia pertusa* coral mounds off Jacksonville, FL:**

- South Atlantic Fishery Management Council Amendment 8 to the Coral Fishery Management Plan
- David (2011)

C. **Cape Lookout *Lophelia pertusa* coral mounds:**

- South Atlantic Fishery Management Council Amendment 8 to the Coral Fishery Management Plan.

D. **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. (2013) Habitat Characterization, Distribution, and Areal Extent of Deep-sea Coral Ecosystems off Florida, Southeastern U.S.A. Journal of Caribbean Science 47:13-30.

E. **Agassiz and Tortugas Valleys:**

- Reed et al. (2013).

Gulf of Mexico

A. **Northwest Gulf of Mexico Banks:**

- 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.
- 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.
- Etnoyer, P. (2009). Distribution and Diversity of Octocorals in the Gulf of Mexico, PhD Dissertation. Corpus Christi: Texas A&M University. 187 pp.
- 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.

B. **Pinnacles Reef Track shelf-edge mesophotic banks in the central and eastern Gulf of Mexico:**

- 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. http://pubs.er.usgs.gov/publication bsr20010007
- 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.
- 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

C. **Shelf-edge South Texas Banks:**

- 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.
- 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.

D. **Deep-sea coral sites:**

- 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: NOAA.
- 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.
- 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. http://www.gomr.mms.gov/PI/PDFImages/ESPIS/4/4264.pdf
- 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
- 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.
- 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.
- 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.
- 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

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.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