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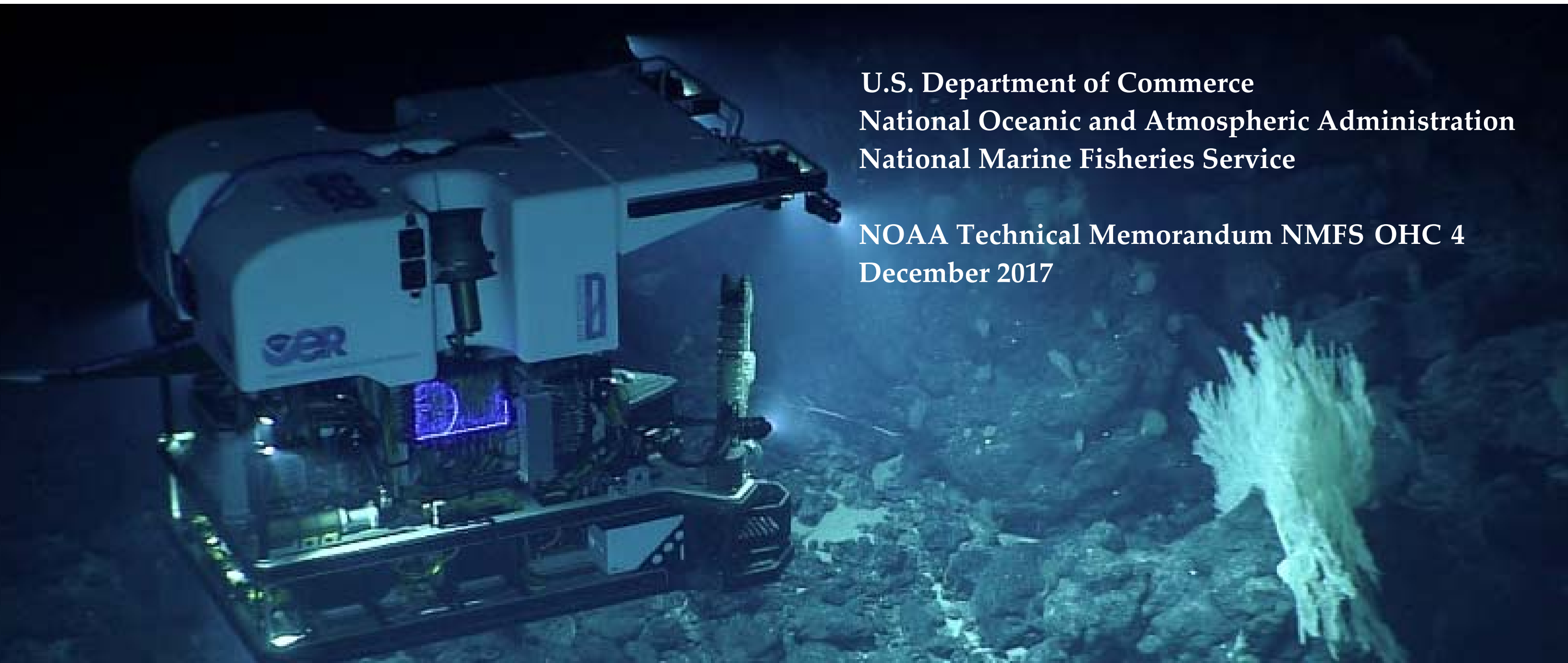

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Or online at:
http://deepseacoraldata.noaa.gov/library or http://spo.nmfs.noaa.gov/tm/

Cover photos: Top – A sculpin rests on a large red tree coral off Alaska's Glacier Bay National Park. Image courtesy of the Deepwater Exploration of Glacier Bay National Park expedition and University of Connecticut Northeast Underwater Research, Technology & Education Center. Bottom – View of remotely operated vehicle *Deep Discoverer* investigating a large primnoid coral colony. Image courtesy of the NOAA Office of Ocean Exploration and Research.

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Zoanthids overgrowing coral off the Northwest Hawaiian Islands. Courtesy of the NOAA Office of Ocean Exploration and Research.

Executive Summary

Corals and sponges create the most important biogenic habitats in the deep sea, and support ecosystems of incredible variety and biodiversity. In 2007, the United States National Oceanic and Atmospheric Administration (NOAA) published the first peer-reviewed report on the *State of Deep Coral Ecosystems of the United States* (Lumsden et al. 2007). The 2017 report on the *State of Deep-Sea Coral and Sponge Ecosystems of the United States* updates information on deep-sea coral ecosystems and management efforts to protect them over the last decade, and presents a first summary of information on U.S. deep-sea sponge ecosystems. It consists of an introduction, six regional chapters with accompanying on-line resources, and six spotlight chapters that highlight advances on crosscutting themes.

The introductory chapter (Hourigan et al., **Chapter 1**) outlines the purpose of the report and introduces deep-sea coral and sponge ecosystems. It presents national-level efforts since 2007 that have influenced regional-level research and conservation. NOAA's 2010 *Strategic Plan for Deep-Sea Coral and Sponge Ecosystems: Research, Management, and International Cooperation* guides the agency's approach. New research on these ecosystems has been led by NOAA's Deep Sea Coral Research and Technology Program, which began operations in 2009, and by NOAA's Office of Ocean Exploration and Research in partnership with the Department of the Interior's Bureau of Ocean Energy Management (BOEM) and U.S. Geological Survey (USGS). Chapter 1 concludes with a synthesis of the conservation status of U.S. deep-sea coral and sponge ecosystems as revealed by the regional chapters that follow.

Cairns et al. (**Chapter 2**) present a brief introduction to discovery of deep-sea coral and sponge species. As of 2016, 662 species of corals are known to occur in U.S. waters below 50 m. This list includes 62 new species and three new genera described since 2007. Octocorals (soft corals, gorgonians and sea pens) account for over half of deep-sea coral species richness, followed by the azooxanthellate Scleractinia (stony corals), Antipatharia (black corals), and the stylasterids (lace corals). The Gulf of Mexico has been the most extensively sampled region for deepwater corals and has the highest recorded species richness (227 species), but it is clear that a large number of undescribed species still occur in each U.S. region. In contrast to corals, the deep-water sponge fauna of the U.S. has not been systematically inventoried. It is likely that the species richness of deepwater sponges exceeds that of corals, and research over the last decade has resulted in many new collections in Alaska, the West Coast and Hawaiʻi. However most specimens remain to be described. New genetic techniques are complementing existing morphological analyses, and hold promise of expanding our knowledge of both the taxonomy and population genetics of deep-sea corals and sponges. The first ever *Comprehensive List of the Deep-Water Corals occurring in the EEZ of the United States and its Possessions* is an online supplement that documents all deepwater coral species reported to occur within U.S. waters as of 2016. The comprehensive list is derived from seven regional species lists, all of which are available on NOAA's Deep-Sea Coral Data Portal: https://deepseacoraldata.noaa.gov/library/2017-state-of-deep-sea-corals-report.

Stone & Rooper (**Chapter 3**) report on research conducted in Alaska since 2007, including extensive new surveys under NOAA's Deep Sea Coral Research & Technology Program. This research continues to show that the region is home to diverse ecosystems supported by extraordinary coral and sponge resources. Of particular importance are the rich deep-sea coral and sponge gardens in the Aleutian Islands and the red-tree coral groves in the Gulf of Alaska, both of which are more extensive than previously known. These aggregations appear to provide important habitat to several fisheries of national and international importance. Bottom-contact fisheries continue to be the primary threat to these habitats, and bycatch of corals and sponges is high compared to other U.S. regions, especially in certain Aleutian Islands bottom trawl fisheries.

Bottom-contact fishing, particularly bottom trawling, is the most immediate threat to deep-sea coral and sponge habitats in most areas where such fisheries are active. Rooper et al. (**Chapter 4**) summarize the known interactions between fishing gear and deep-sea corals and sponges in U.S. waters. They highlight studies on the effects of mobile and fixed-location fishing gears on deep-sea corals and sponges. Damage from mobile gear (e.g., bottom trawls) is well documented. Fewer studies have explored impacts of fixed gears, such as bottom-set longlines, gillnets and traps. These deserve additional attention, as they may be used in rougher habitats that are preferred by deep-sea corals and sponges, but are inaccessible to trawls. Many vulnerable deepwater areas in the U.S. exclusive economic zone (EEZ) have been closed to gears that impact deep-sea corals and sponges – considered the most effective management measure to address fisheries interactions. There has also been some success in modifying fishing gears and practices (e.g., reducing roller size or raising the sweeps on trawls) that may reduce impacts of these gears on deep-sea corals and sponges.

Clark et al. (**Chapter 5**) review information since 2007 that has advanced our understanding of deep-sea coral and sponge abundance and distribution off the U.S. west coast. This understanding has been catalyzed by new research under NOAA's Deep Sea Coral Research & Technology Program and data syntheses associated with the Pacific Fishery Management Council's 5-year review of Pacific coast groundfish essential fish habitat (EFH). Deep-sea corals on hard substrata are widely distributed and the composition of assemblages changes with depth. The dominant species in many areas are small and occur at relatively low densities, but in certain areas (e.g., ridges of seamount and certain banks, particularly in the Southern California Bight), large gorgonians may occur in patches of high density. As in other regions, information on deep-sea sponges is much more rudimentary, however, it appears that in many hard-bottom habitats in deeper waters, sponges are more abundant than corals.

Fishing with bottom-contact gear, especially bottom trawls, remains the most immediate threat to both deep-sea coral and sponge ecosystems. While many areas expected to be prime habitat for corals and sponges were protected from trawling either indirectly in 2001 or directly in 2006, continued bycatch in commercial trawl fisheries indicates that significant interactions remain, and in many cases are restricted to relatively discrete areas. Among other stressors, ocean acidification will be a major long-term concern for some corals. Since 2007, new protected areas have been established in state waters, and National Marine Sanctuaries (Monterey Bay and the Greater Farallones) have been expanded to include deeper habitats containing important deep-sea coral and sponge ecosystems.

Hawaiʻi is the only U.S. state with major black and precious coral harvest industries. Wagner et al. (**Chapter 6**) provide a brief history of the black coral fishery and its current management. They show how recent research on the taxonomy, distribution, reproduction and life history of black corals has increased our knowledge of these taxa and may inform future management.

The U.S. Pacific Island Region consists of more than 50 oceanic islands stretching over a vast area of the central and western Pacific. Parrish et al. (**Chapter 7**) summarize new information on the deep-sea coral and sponge ecosystems found on island slopes, oceanic ridges and seamounts of the region. As in the 2007 report, most of the information from the region is limited to the Hawaiian Archipelago, however, a major three-year NOAA campaign of exploration and research is underway, which will provide the first surveys of many deep-sea areas in the U.S. territories. The last ten years of research have used available data to study the taxonomy, biology, reproduction and growth of certain coral taxa – especially black corals. Habitat suitability models have been developed for deepwater corals, and the first steps to characterize the sponge community has begun. Hawaiʻi's deep-sea sponges represent a rich and diverse fauna that form important, and sometimes extensive, biogenic habitats.

In 2009, major areas of the U.S. Pacific Islands were included in three new Marine National Monuments (Marianas Trench, Rose Atoll, and Pacific Remote Islands Marine National Monuments [PRIMNM]). Portions of the PRIMNM were expanded in 2014, and the Papahānaumokuākea Marine National Monument was extended to encompass the entire EEZ around the Northwestern Hawaiian Islands in 2016, forming the largest contiguous fully protected conservation area in the U.S., and currently the largest marine conservation area in the world.

Predictive habitat modeling is increasingly used to help identify areas that are most likely to harbor deep-sea coral and sponge taxa. Guinotte et al. (**Chapter 8**) review modeling methodologies and their application in each U.S. region. The growth and adoption of these techniques are fueled by recent improvements in input data quality/quantity, the low cost of producing and updating the models, and the need to identify habitat across large spatial extents for management. The spatial resolution of model results has improved in the last decade to the point where model outputs are now used to target areas for field sampling efforts and to help inform regional Fishery Management Council management actions designed to protect deep-sea coral habitats. Both the North Pacific and Mid-Atlantic Fishery Management Councils have recently used predictive deep-sea coral habitat models to inform management decisions.

Packer et al. (**Chapter 9**) review research and management of deep-sea corals and sponges in the U.S. Northeast region since 2007. Multibeam mapping and initial visual surveys since 2010 have been conducted in almost all the submarine canyons off the Northeast coast, as well as the New England seamounts within the EEZ, and significant areas in the Gulf of Maine. Rich octocoral gardens were discovered at several sites within the Gulf of Maine that serve as habitat for large numbers of redfish. Studies in Baltimore and Norfolk Canyons off Virginia allowed more detailed descriptions of the distribution and life history of deep-sea corals. Knowledge gaps still exist for many of these organisms, especially for sponges, but these studies have contributed greatly to our regional knowledge of deep-sea coral diversity, distribution, and habitat characteristics.

Based on this new information, and recognizing that bottom-contact fisheries represent the most urgent threat to these habitats, the New England and Mid-Atlantic Fishery Management Councils have moved forward on plans for deep-sea coral habitat protection, especially those for the submarine canyons and the Gulf of Maine. This action led to the creation of the 99,000 km^2 Frank R. Lautenberg Deep-Sea Coral Protection Area in the Mid-Atlantic, and was a major factor behind creation of the Northeast Canyons and Seamounts Marine National Monument. The New England Fishery Management Council has proposed new deep-sea coral protections for the Gulf of Maine, and is working on additional protections for offshore canyon areas in 2017.

Deep-sea corals are among the slowest growing, longest-lived skeletal accreting marine organisms. Prouty et al. (**Chapter 10**) explore the new techniques that are yielding information about the age and growth of deep-sea corals. Studies over the last decade have revealed black and gold corals that can live for thousands of years. Understanding age, growth rate, and lifespan characteristics allows assessment of vulnerability and recovery from perturbations for coral habitats, and can thereby inform effective management and conservation strategies. The ability to accurately age deep-sea corals has allowed their use as biogeochemical proxies that provide a unique view of marine climate and environmental change over time. This progress has allowed scientists to look back into the coral's climate history using stable and radioisotope techniques, and incorporate this information into models of future climate change.

As described by Boland et al. (**Chapter 11**), the deep-sea coral habitats of the Northern Gulf of Mexico have received the most extensive research of any U.S. region over the last decade. This coverage includes major collaborative research programs led by BOEM, ongoing research by NOAA's Flower Garden Banks National Marine Sanctuary, as well as natural resource damage assessments following the Deepwater Horizon oil spill. The availability and interpretation of industry-provided seismic reflectivity data have enhanced our understanding of the relatively rare areas of hard substrata that define the distribution of most of the region's deep-sea corals. Studies have led to increased understanding of genetic diversity, age, growth, and reproduction of deep-sea corals. Sponge communities (at least high-density communities) appear to be relatively rare in the Gulf of Mexico compared to corals.

The Deepwater Horizon incident was a landmark event with major revelations related to deep spill impacts including the dynamics of deep plumes, and potential for impacts to deepwater habitats from horizontal transport of hydrocarbon plumes and from oiled marine snow. Octocoral habitats at both deep-sea and mesophotic depths were among the habitats damaged in the spill. The results of research and damage assessments have led to increased awareness among managers and the public.

BOEM has instituted new regulatory policies for the oil and gas industry dealing with biological communities in the Gulf, in addition to numerous changes in regulatory policies related to drilling safety. The Flower Garden Banks National Marine Sanctuary is currently exploring alternatives for boundary expansion to protect known high value benthic habitats and cultural resources in the north-central Gulf of Mexico.

Morrison et al. (**Chapter 12**) review research on population connectivity of deep-sea corals. Understanding connectivity through exchange of larvae among populations and the processes that influence connectivity can help inform conservation efforts. The authors provide an overview of concepts and discuss how new molecular genetic techniques are being used to understand the population structure of deep-sea corals. They review a number of studies in U.S. waters, including the first ocean basin-scale description of the population structure of the most important reef-forming deep-sea coral, *Lophelia pertusa*. They conclude by identifying specific research questions that may guide future studies of connectivity among deep-sea corals.

Hourigan et al. (**Chapter 13**) review how new research has improved our understanding of deep-sea coral and sponge ecosystems of the Southeast U.S., and how this new understanding has informed major new management efforts. New mapping and surveys have confirmed that the Southeast U.S. harbors the nation's highest concentration of deep-sea coral reefs, and probably ranks among the top such provinces globally. In addition to branching stony corals, gorgonians, black corals and sponges are important contributors to habitat structure in areas of hard bottoms, enhancing local biodiversity by providing habitat for a large number of associated species. Despite research progress, much of this region remains unexplored. The last decade has also seen regional-scale actions to protect deep-sea coral reef provinces from fishing impacts through a series of deepwater Coral Habitat Areas of Particular Concern. A new network of shallower marine protected areas is providing similar benefits to shelf-edge coral and sponge habitats. These new fishing measures, developed by the South Atlantic Fishery Management Council and implemented by NOAA, have significantly reduced the scope for fishing damage to deep-sea coral and sponge habitats.

Thank you for reading. We look forward to the next ten years of deep-sea exploration and discovery.

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