State of Deep-Sea Coral and Sponge Ecosystems of the U.S. Pacific Islands Region

Chapter 7 in The State of Deep-Sea Coral and Sponge Ecosystems of the United States Report

Available online: http://deepseacoraldata.noaa.gov/library.
Iridogorgia soft coral located off the Northwest Hawaiian Islands. Courtesy of the NOAA Office of Ocean Exploration and Research.
STATE OF DEEP-SEA CORAL AND SPONGE ECOSYSTEMS OF THE U.S. PACIFIC ISLANDS REGION

I. Introduction

The U.S. Pacific Islands Region consists of more than 50 oceanic islands, including the Hawaiian Archipelago, the Commonwealth of the Northern Mariana Islands (CNMI), and the territories of Guam and American Samoa, as well as the Pacific Remote Islands (Kingman Reef; Palmyra Atoll; Jarvis Island; Howland and Baker Islands; Johnston Atoll; and Wake Island) and Rose Atoll. The Pacific Island States in free association with the United States, including the Republic of Palau, the Federated States of Micronesia, and the Republic of the Marshall Islands, encompass additional large portions of the central and western Pacific with close ties to the U.S. This region includes some of the most remote, unpopulated islands in the Pacific, as well as many densely populated islands, and it extends from the South Pacific (e.g., American Samoa; 14° S latitude) to the North Pacific (Kure Atoll 28° N latitude; Fig. 1). Corals, sponges and other members of the deepwater community are found in patchy distribution on these oceanic ridges and have some of the highest levels of marine endemism recorded anywhere on earth.

The 2007 State of Deep-Sea Coral Ecosystems report (Parrish and Baco 2007) detailed discovery and history of harvesting deep water Corallium spp., Kulamanamana haumeae (formerly Gerardia sp. (Sinniger et al. 2013)), Isidella sp., the mesophotic black corals
Figure 1. Map of the Pacific Basin showing U.S. islands, their Exclusive Economic Zones (EEZ), and Monument boundaries that comprise the Pacific Islands Region for the National Marine Fisheries Service. The yellow is the area of Marine National Monuments and the red is the U.S. EEZ. At the atolls of Johnston, Palmyra, and Wake the monument boundary is the same as the EEZ.

(antipatharians), and the associated development of a survey and monitoring program for the management of the “precious coral” fishery.

The chapter listed the inventory of the known structure forming corals and distinguished these colonies from the reef building cold-water coral complexes found in the Atlantic and the Gulf of Mexico. Also presented was information on the distribution of corals in the Hawaiian Archipelago and the absence of survey effort in the wider expanse of the Pacific Islands Region. As the harvesting and surveys of corals relied on in-situ visual observations much was reported on the species associations with deep-sea coral communities including fish, invertebrates, and even visitation by monk seals. Aside from the limited activities of the precious coral fishery, the list of potential anthropogenic impacts to deep-sea corals in the region included impacts from placement of undersea cables and cold seawater pipes, and
**Figure 2.** Map showing submersible (Pisces IV, Pisces V) and ROV (RCV-150) dive locations in the Hawaiian Archipelago and Johnston Atoll where deepwater corals and sponges have been found. The yellow line is the boundary of Marine National Monuments and the red is the U.S. EEZ. At Johnston Atoll the monument boundary is the same as the EEZ.

the potential destructiveness of future cobalt-rich manganese (Mn) crust mining.

Until 2015, deep-sea coral research in the Pacific Islands Region was still focused almost entirely in the Hawaiian Archipelago (Fig. 2). While coral fragments from incidental dredging and bycatch records indicates a wide distribution of deep-sea corals throughout the Pacific Island Region, Hawai‘i is still the only location in the region with assets to conduct such studies, and even there the progress was sporadic, dependent on when funding opportunities present themselves through various requests for proposals. Since the release of the 2007 national report the focus of deep-sea coral studies has shifted away from the intermediate depth range (300-500 m) where the commercial harvest of precious corals motivated most of the data collection, to coral/sponge communities that are both shallower and deeper, along with a greater emphasis on spatial modeling of existing data. Roughly half of the publications
produced since the 2007 report are taxonomic in nature. They include reviews of poorly understood families, some new descriptions, and some name changes. The rest of the papers are a mix of growth, distribution and life history studies. Work on the shallow water black corals was the best represented segment of the deep-sea coral community including both analysis of available data and some field surveys. New information on black coral and its history as a resource is presented in detail in chapter 6. This follow-up report differs from the 2007 report in that it includes information on deepwater sponges in the region that was not included in the first report.

II. Update on Scientific Information

II.1. New Research - Overview

Since the 2007 status report (Parrish and Baco 2007), there have been a number of research studies and publications on the region’s deepwater corals. A complete list of new publications is included at the end of this chapter. Between 2007-2014, there were a number of deepwater coral and sponge field projects concentrated in the Hawaiian Archipelago, using the submersibles and remotely-operated vehicle (ROV) assets of the Hawai‘i Undersea Research laboratory (HURL). These projects involved 15 cruises funded through HURL’s grant program and through awards from the Papahānaumokuākea Marine National Monument (PMNM), NOAA’s Center for Sponsored Coastal Ocean Research (CSCOR), Western Pacific Fishery Management Council (WPFMC), and the National Marine Fisheries Service (NMFS). Research topics included precious coral age and growth, habitat, distributions of coral and sponges, use of corals for climate studies, studies of black coral density and distribution, and effects of invasive species on black coral populations. There was also some shore-based work conducted using charter boats and three annual (2008-2010) research cruises using NOAA vessels to support surveys of mesophotic coral communities using remote cameras and mixed gas divers that overlapped and contributed new information to the status of shallow black coral populations.

In addition to this fieldwork, analysis of data from past expeditions and collections has contributed to better understanding of deep-sea coral biology and ecology. Significant new insights have been gained into the genetics (Baco and Cairns 2012, Sinniger et al. 2013, Figueroa and Baco 2014a,b), reproductive biology (Waller and Baco 2007, Wagner et al. 2011c, Wagner et al. 2012), growth and age (Parrish and Roark 2009, Roark et al. 2009), and community structure (Long 2011, Long and Baco 2014, Parrish 2015) of precious coral and black coral species. Finally, international collaborative efforts through the Census of Marine Life Program, A Global Census of Seamounts (Cen Seam) have also provided syntheses that provide a global context for the Hawaiian Archipelago fauna. These include analyses of global coral distributions and
Figure 3. The three-year CAPSTONE expeditions conducted mapping and deep-sea surveys throughout the U.S. Pacific Islands region.

In 2015, NOAA initiated CAPSTONE: the Campaign to Address Pacific monument Science, Technology, and Ocean Needs. This three-year campaign brought together resources from across NOAA to explore the nation’s new central and western Pacific marine national monuments and national marine sanctuaries aboard NOAA Ship Okeanos Explorer (Fig. 3). The campaign, led by NOAA’s Office of Ocean Exploration and Research, provided foundational science by discovering and describing unknown deep-sea habitats.

Science themes included the following:

- Acquiring data to support priority monument and sanctuary science and management needs;
- Identifying and mapping vulnerable marine habitats – particularly high-density deep-sea coral and sponge communities;
- Characterizing seamounts in and around the Prime Crust Zone, the area of the Pacific with the highest concentration of commercially valuable deep-sea minerals;
• Investigating the geologic history of Pacific seamounts, including potential relevance to plate tectonics and subduction zone biology and geology; and

• Increasing understanding of deep-sea biogeographic patterns across the Central and Western Pacific.

This three-year campaign consisted of 23 cruises, 13 using the NOAA Deep Discoverer ROV. Over 600,000 km² of bottom was mapped using multibeam, and 188 ROV dives explored habitats between 240m – 6,000 m deep. More than 360 samples of deep-sea corals and sponges were collected, a large proportion of which are expected to represent new species.

These expeditions provided a first look at deep-sea coral and sponge habitats in U.S. Island regions outside the Hawaiian Archipelago. Among the most important initial discoveries was the occurrence of numerous extremely high-density coral and sponge communities. Initial information from the exploration is available on NOAA’s Ocean Explorer website. Scientific analysis of this rich trove of data and information has just begun, and is not yet reflected in following sections of this chapter.

II.2. Taxonomy and Species Distributions
II.2.i – Corals
a. Coral taxonomy
Parrish and Baco (2007) reported 238 taxa of deepwater corals from the Hawaiian archipelago. The list included 75 taxa with incomplete taxonomy. A total of 6 new genera and 20 new species of octocorals, antipatharians, and zoanthids have been discovered in Hawai‘i since the 2007 report. These are either new to science, or new records for the Hawaiian Archipelago (Cairns and Bayer 2008, Cairns 2009, Opresko 2009, Cairns 2010, Wagner et al. 2011a, Opresko et al. 2012, Sinniger et al. 2013). Taxonomic revisions currently underway for several groups of corals, e.g., isidids, coralliids, plexaurids and paragorgiids, are also likely to yield additional species new to science and new records for Hawai‘i.

Recent molecular phylogenetic and morphologic studies of the family Coralliidae, including Hawaiian precious corals, have illuminated taxonomic relationships. These studies synonymized Paracorallium into the genus Corallium, and resurrected the genera Hemicorallium (Ardila et al. 2012, Figueroa and Baco 2014, Tu et al. 2015) and Pleurocorallium (Figueroa and Baco 2014, Tu et al. 2015) for several species, including several species in the precious coral trade.

A molecular and morphological analysis of octocoral-associated zoanthids collected from the deep slopes in the Hawaiian Archipelago revealed the presence of at least five different genera including the gold coral (Sinniger et al. 2013). This study describes the five new genera and species and proposes a new genus and species for the Hawaiian gold coral, Kulamanamana haumeaae, an historically important species harvested for the jewelry trade and the only Hawaiian zoanthid that appears to create its own skeleton.
b. Coral distribution and community structure

Much of the funded work in the Hawaiian Archipelago in the last decade has been related to simply documenting species distributions. In the 2007 status report, the Hawaiian coral beds were divided into 2 zones, one at depths < ~600-700 m, and one > ~600-700 m. The shallower zone was dominated largely by precious corals, but with a high diversity of other octocoral and antipatharian species. The deeper zone was dominated by a broad array of octocoral families. Scleractinians were relatively rare at all depths, and were primarily solitary (i.e. non-colonial) species. Records of colonial scleractinians in the Archipelago continue to be scarce. However, a large bed of dead scleractinian *Solenosmilia variabilis* was discovered in 2007 (Kelley unpubl. data), and live corals were collected from a seamount in the northwest end of the archipelago in 2016. Baco et al. (2017) have reported deep reef formations that appear to of constructed of this species (see below).

*Figure 4. Examples of structure-forming deep corals found in the Hawaiian Archipelago. a) Pleurocorallium secundum, b) Acanthogorgia sp., c) Iridogorgia magnispiralis, d) Antipathes grandis. Photo credit: HURL.*
From 2007 to 2014, little field work was directed at deep-sea corals (Fig. 4) and much of it was in coral beds that had been documented years prior. Consequently there was limited new information on the spatial distribution of deep-sea coral in the Pacific Islands Region (Table 1). Work includes cross contour surveys contracted by the PMNM and climate-related coral work by universities that improved sampling on seamounts in the central part of the Northwestern Hawaiian Islands and conducted the first exploration of the Necker Ridge which extends south southeast from the central part of the Hawaiian Archipelago (Morgan 2013, Morgan et al. 2015). Habitat suitability modeling studies as outlined below also provide some insights onto potential locations of deep-sea coral abundance in the vastly underexplored areas of this region.

Additional explorations as well as continued analyses of pre-2007 cruise video data and sampling records, have provided more insights into coral distributions and discoveries of new species. A global synthesis of available data on seamount coral taxa found that the Hawaiian Archipelago is a diversity hotspot for deep-sea corals (Rogers et al. 2007).

The number of studies of the deep slopes of the Hawaiian Archipelago is also beginning to reach the critical mass needed to address broader-scale ecological questions in a more quantitative way. The availability of the HURL video archive as well as their video log database have enabled these larger-scale efforts. The first of these efforts is a broad-scale synthesis of the HURL video log database, encompassing the Northwestern Hawaiian Islands and seamounts to the southeast of the Archipelago that have been sampled with the HURL submersible assets (Clark et al. 2011).

The goal of this study, funded by the International Seabed Authority, was to compare the megafaunal community structure of seamounts with cobalt-rich manganese (Mn) crusts to those lacking such crusts, with the southeast portion of the Hawaiian Archipelago falling into the “cobalt-rich” category. Over 30,000 records extracted from HURL’s database from the Northwestern Hawaiian Islands, Johnston Atoll, and Cross Seamount were analyzed. No correlation was found with cobalt or with feature type (island vs seamount, etc.), instead depth seemed to be the overriding factor related to the observed community structure, with communities distinguished into three depth groupings, those from dives with a median depth of 227-354 m, from dives with a median depth of 357-615 m and from dives with a median depth of 745-1799 m. Although this analysis focused on all megafaunal invertebrates, cnidarians made up about 30% of the total records and were the key species contributing to the differences among the 3 depth groups (Clark et al. 2011). Location was also a significant factor, but was a secondary factor to depth.
**Table 1.** Primary structure-forming deep-sea corals and general attributes. The overall rating in the right column is a synthesis of the rest of the attributes. **Note:** Hydrodendron gorgonoide is a chitinous hydroid, which while technically not a coral, nevertheless has similar characteristics.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Reef-Building</th>
<th>Abundance</th>
<th>Maximum Colony Size</th>
<th>Morphology</th>
<th>Associations with other Invertebrates</th>
<th>Colony Spatial Dispersion</th>
<th>Overall Rating</th>
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<td>Acanella dispar</td>
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<td>Large</td>
<td>branching</td>
<td>many</td>
<td>clumped</td>
<td>high</td>
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<td>High</td>
<td>Medium</td>
<td>branching</td>
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<td>High</td>
<td>Small</td>
<td>branching</td>
<td>clumped</td>
<td></td>
<td>high</td>
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<td>Small</td>
<td>branching</td>
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<td>Medium</td>
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<td>clumped</td>
<td></td>
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<td>Medium</td>
<td>Large</td>
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<td>Medium</td>
<td>branching</td>
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</tr>
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<td>Pleurocorallium niveum</td>
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<td>Small</td>
<td>branching</td>
<td>few</td>
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<tr>
<td>Coralliidae sp. (other)</td>
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<td>Medium</td>
<td>branching</td>
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<td>both</td>
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<tr>
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<td>Medium</td>
<td>branching</td>
<td>clumped</td>
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<td>high</td>
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<tr>
<td>Enallopsammia cf. pusilla</td>
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<td>High</td>
<td>Medium</td>
<td>branching</td>
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<td>high</td>
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<td>Eguchipsammia sp.</td>
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<td>Medium</td>
<td>Small</td>
<td>branching</td>
<td>clumped</td>
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<td>high</td>
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<td>High</td>
<td>Medium</td>
<td>branching</td>
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<td>Keratosis sp.</td>
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<td>Large</td>
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<td>both</td>
<td>high</td>
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<td>medium</td>
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<td>medium</td>
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<td>Madrepora oculata</td>
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<td>Medium</td>
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<td>dispersed</td>
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<td>high</td>
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<td>branching</td>
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<td>high</td>
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<td>Large</td>
<td>branching</td>
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<td>Thouarella hilgendorfi</td>
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<td>Large</td>
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<td>clumped</td>
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<td>medium</td>
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</table>
Another recent study synthesized ROV video from the Makapu’u precious coral bed on the island of Oahu (Long 2011, Long and Baco 2014). The bed extends from a depth of approximately 320 to 530 m. Despite the relatively narrow depth range, depth was again found to be the overriding factor correlated to community structure, with other physical parameters such as slope and rugosity also playing a minor role. Intriguingly, although this bed has always been referred to as a “precious coral bed”, this quantitative assessment indicated that the octocoral family Primnoidae was actually the most abundant coral family overall within the bed area. Coralliids did dominate in one of the six depth bands, with *Corallium secundum* (= Pleurocorallium secundum) being the most abundant species there. Interestingly, the peak in abundance of *C. secundum* began about 400 m, below the maximum depth of previous harvesting operations (Long 2011, Long and Baco 2014).

In contrast, surveys of deeper communities (1400-2000 m) on the Necker Ridge in 2011 revealed communities structured by factors other than depth (Morgan 2013, Morgan et al. 2015). This study surveyed 6 sites along the Ridge and found a significant difference in communities on the northern side of the ridge, which were dominated by octocorals, compared to the southern side of the ridge, which were dominated by crinoids. Diversity also increased from south to north along the ridge. A multivariate analysis of community structure in relation to environmental factors found that latitude, sediment cover, rugosity, oxygen, salinity, and temperature, but not depth, were most strongly correlated with observed patterns.

Baco et al. (2017) recently reported the first observations of deep-sea scleractinian coral reefs (bioherms) from the central North Pacific. The reefs were found at depths of 535-732 m on six seamounts in the Northwestern Hawaiian Islands and Emperor Seamounts, three of which were within U.S. waters.

c. Coral population connectivity

While species lists and habitat suitability provide first order insights into potential connectivity of deep-sea coral populations, the real key to assessing connectivity is using genetic methods. Genetic methods for assessing connectivity are well developed in general, but the paucity of sampling makes them challenging to apply in the deep sea. The topic is covered more broadly by Morrison et al. (this volume). However, within the Hawaiian Archipelago, phylogeographic and phylogenetic work has focused primarily on the precious corals and also on the primitoid octocoral *Narella. Hemicorallium laauense* (Ardila et al. (2012); Figueroa and Baco (2014) formerly *Corallium laauense*) is the only Hawaiian deep-sea coral species that has published studies using population genetics.

Data from three microsatellite loci in *H. laauense* from 8 sites in the Main Hawaiian Islands and southern end of the Northwestern Hawaiian Islands indicated strong heterozygote deficiency and no pattern of isolation by distance (Baco and Shank 2005, Baco et al. 2006). The deepest site, at Kauai, in the middle
of the sampled locations, showed genetic structure when compared to just about every other site in the study. The Makapu’u bed on the Island of Oahu also had some indication of isolation for comparisons within the bed on the scale of 1.6 km and for comparisons to most other beds. These results indicate that the scale of genetic structure within the Archipelago may be very complex, and that the connectivity of each feature or location should be assessed for any management activities (Baco and Shank 2005).

Other types of genetic analyses such as DNA barcoding and phylogeography may also yield insights into connectivity, species distributions and species ranges of Hawaiian corals. A study designed to help develop barcoding markers for octocorals found that species in the primnoid genus Narella that occur in Hawai’i tend to have different haplotypes (DNA sequences) within a single species that is found at different depths. Of all the Hawaiian Narella haplotypes, only one haplotype (from the far Northwestern Hawaiian Islands) was also found on Derickson Seamount, a deep seamount south of the Aleutian Archipelago in Alaska (Baco and Cairns 2012).

Taken together, this review of distributions of Hawaiian corals from both genetics and species lists, indicates that depth is a very strong factor structuring deep-sea coral communities, potentially even over very small spatial scales. Therefore depth structuring should be taken into consideration in future management efforts.

d. Modeling distribution and abundance of corals

Although considerable effort has gone into exploration and description of species to help understand coral distributions in the Hawaiian Archipelago, the continued high rate of species discovery indicates that despite it being the best studied Island group in the Pacific region, it too is still drastically under-sampled for deep-sea corals and other taxa. Several global syntheses of coral distributions and habitat suitability modeling included data from prior collections in the Hawaiian Archipelago (Rogers et al. 2007, Tittensor et al. 2009, Tittensor et al. 2010, Yesson et al. 2012). These provide a context for results from Hawai’i and also insights into the likelihood of finding corals in the vast and unexplored areas of the U.S. Pacific Islands region (Tittensor et al. 2009, Davies and Guinotte 2011, Yesson et al. 2012) and the potential impacts of ocean acidification on deep-sea corals (Tittensor et al. 2010).

The first of these models relevant to corals was by Tittensor et al. (2009) and focused on scleractinians on seamounts. The results of this modeling effort indicate very low habitat suitability for scleractinians below 500 m across the entire geographic range of U.S. territorial waters in the Pacific Ocean. This work was later expanded to other submarine features by Davies and Guinotte (2011) and focused on five of the most broadly distributed scleractinian framework-forming species (including Enallopsammia rostrata and Madrepora oculata, known to occur in Hawaii). They also concluded that the North Pacific had very little
suitable scleractinian habitat but a few features that fall into U.S. waters in the southern hemisphere did have a narrow depth band of higher habitat suitability for certain species. Yesson et al. (2012) focused on octocorals, splitting them up into the seven major suborders, and based on their model virtually all of the sites within the U.S. Pacific Islands region have high habitat suitability for octocorals. The predicted lack of scleractinians and high abundance of octocorals are consistent with observations in this region (Baco 2007, Parrish and Baco 2007), however a strong caveat to these modeling efforts is that they are done at relatively coarse geographic and taxonomic resolution, and all of the models remain to be ground-truthed with in situ explorations.

Besides providing insights into potential distributions of corals, the models also provide insights into the environmental parameters that influence coral distributions. Recent modeling efforts indicate the distributions of scleractinian corals are related to depth, temperature, aragonite saturation state, salinity, oxygen concentration and saturation and dissolved nutrients (Tittensor et al. 2009, Davies and Guinotte 2011). Temperature, slope, salinity, surface productivity, currents, oxygen and calcite saturation state are correlated to the distribution of octocorals (Bryan and Metaxas 2007, Yesson et al. 2012).

Habitat suitability modeling for precious corals in the Main Hawaiian Islands was funded by NOAA’s Deep Sea Coral Research and Technology Program. The project “Predictive Modeling of the Distribution of Deep-Sea Corals in the Main Hawaiian Islands” (PIs John Rooney, Amy Baco and Michael Parke) used data from the Main Hawaiian Islands in attempt to identify suitable habitat of *Corallium secundum* (pink coral; =*Pleurocorallium secundum*) and *K. haumeaeae* (gold coral), that are important targets in the precious coral fishery.

A total of 1227 observations of these taxa were made in the Main Hawaiian Islands during 102 of the more than 1100 submersible dives completed in the region by the Hawai‘i Undersea Research Laboratory. An analysis of circulation data from ocean general circulation models and tidal models indicates that in this region, at depths below the main thermocline (300 to 500 m), tidal velocities are an order of magnitude larger than the general circulation flows. Deep-sea coral growth is thought to be enhanced in areas with higher current velocities that would increase the availability of food. Accordingly, maximum baroclinic tidal velocities at a depth of 400 m were calculated using output from a tide model developed by Carter et al. (2008) for a portion of the Main Hawaiian Islands on a one by one kilometer grid (Fig. 5). A high resolution grid of all available bathymetry data was also obtained from the Hawai‘i Mapping Research Group at the University of Hawai‘i. The modeling effort was unable to identify any significant
predictions of coral occurrence but based on the observations it is hypothesized that these species of deep-sea corals prefer areas with current velocities 0.5 - 0.85 m/s (https://deepseacoraldata.noaa.gov/other-studies/fy10-08).

In a subsequent study, Bauer et al. (2016) modeled habitat suitability for 16 deep-sea coral groups, based on ecological importance, management considerations, and the number of presence records. Models included Corallium and the gold coral K. haumeae. The Corallium model was among the best fits, with distance to shore, total curvature at 5 km scale, and annual bottom temperature as the most important predictor variables.

II.2.ii - Sponges

a. Sponge taxonomy and distribution

Sponges in the phylum Porifera are presently divided into 4 classes: Calcarea, Demospongiae, Hexactinellida, and the “revived” class Homoscleromorpha, which until recently has been considered to be an order of demosponges (Gazave et al. 2010). In general, most sponges in depths above 50 m are either demosponges, calcareans, or homoscleromorphans, whereas most sponges below 400 m are hexactinellids (Reiswig unpub. data, HURL database).

Deepwater sponges in the Pacific Islands region are more poorly known than the deepwater corals and only those large enough to be considered structure-forming are included in this report (Table 2, Fig. 6). The major
transition between the hexactinellids and the other classes of sponges in this region appears to be below 200 m, perhaps as a result of higher water temperatures and light penetration above that depth (HURL database). However, this could also be a result of under-sampling within the 50-200 m depth zone, which for the most part falls between the routine operating depths of SCUBA and deepwater vehicles such as submersible and ROVs. For simplicity, this first inclusion of deepwater sponges in the report for the Pacific Islands Region will focus on species found at depths below 200 m, and is largely derived from the HURL on-line Deepwater Animal Guide (http://www.soest.hawaii.edu/HURL/) and related database records (Fig. 6).

Table 2. Structure-forming attributes of deep-sea sponges in Hawaii. The overall rating in the right column is a synthesis of the rest of the attributes.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Reef-Building</th>
<th>Abundance</th>
<th>Colony Size</th>
<th>Colony Shape</th>
<th>Spatial Dispersion</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolosoma sp. (all)</td>
<td>no</td>
<td>medium</td>
<td>large</td>
<td>pedunculate sphere</td>
<td>both</td>
<td>medium</td>
</tr>
<tr>
<td>Farrea near occa</td>
<td>no</td>
<td>high</td>
<td>medium</td>
<td>anastomosing tubes</td>
<td>clumped</td>
<td>medium</td>
</tr>
<tr>
<td>Poliopogon sp. (all)</td>
<td>no</td>
<td>high</td>
<td>large</td>
<td>hemispherical</td>
<td>clumped</td>
<td>high</td>
</tr>
<tr>
<td>Regadrella sp. 1</td>
<td>no</td>
<td>medium</td>
<td>medium</td>
<td>tube-like</td>
<td>clumped</td>
<td>medium</td>
</tr>
<tr>
<td>Saccocalyx cf. pedunculatus</td>
<td>no</td>
<td>medium</td>
<td>large</td>
<td>pedunculate cup</td>
<td>dispersed</td>
<td>medium</td>
</tr>
<tr>
<td>Semperella sp. (all)</td>
<td>no</td>
<td>high</td>
<td>medium</td>
<td>columnar</td>
<td>clumped</td>
<td>high</td>
</tr>
<tr>
<td>Sericolphus hawaiicus</td>
<td>no</td>
<td>high</td>
<td>medium</td>
<td>pedunculate spoon</td>
<td>clumped</td>
<td>high</td>
</tr>
<tr>
<td>Tretopleura sp. 1B and sp. 2</td>
<td>no</td>
<td>medium</td>
<td>large</td>
<td>elongated plate</td>
<td>both</td>
<td>medium</td>
</tr>
<tr>
<td>Walteria sp. (all)</td>
<td>no</td>
<td>medium</td>
<td>medium</td>
<td>tube-like</td>
<td>both</td>
<td>medium</td>
</tr>
</tbody>
</table>
a.(i) Calcarea and Demospongiae below 200 m
A single colony identified from a photograph as a calcarean species in the genus *Clathrina*, has been included in the HURL database and online identification guide for many years. In 2017, this rare species was encountered and collected during an *Okeanos Explorer* cruise to the Johnston Atoll monument area. Microscopic examination determined that it was actually a misidentified and potentially new species of hexactinellid in the family Tretodictyidae. Therefore, at the present time, there are no confirmed published or unpublished accounts of deepwater calcareans being found in the Pacific Islands region.

Chave and Malahoff (1998) listed seven species presumed to be demosponges that have been photographed from submersibles operated by HURL. One of these has subsequently been collected and identified as a species of hexactinellid. Another of these, *Corallistes* sp., has been only identified from photographs but is similar to confirmed species so is listed in the appendix as cf. *Corallistes* sp. The remaining

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*Figure 6. Examples of structure forming deep sponges found in the Hawaiian Archipelago: a) Sericolophus hawaiicus, b) Poliopogon sp4, c) Poliopogon sp1, d) Bolosoma sp2. Photo credit: HURL.*
five species were described with only descriptive names so are not included.

The HURL database has 9 species of demosponges including cf. *Corallistes* sp. that occur below 200m in Hawai‘i. Of these, 5 were collected and identified by spicule examination: *Penares* sp., *Poecillastra* sp. 1, *Poecillastra* sp. 2, *Hamacantha (Vomerula)* n. sp. and *Stelodoryx* sp. The remaining 4, cf. *Corallistes* sp., cf. *Petrosia* sp., cf. *Polymastia* sp. 1 and cf. *Polymastia* sp. 2 were identified from images only but all show clear similarities to confirmed species in those genera. During the preparation of this report, additional demosponge specimens were collected during HURL submersible and *Deep Discoverer* ROV dives that have not as yet been entered into the HURL or National Deep-Sea Coral and Sponge databases. These include a *Geodia* sp., an unidentified species in the order Haplosclerida, another *Poecillastra* sp., an unidentified species of *Characella*, an unidentified species of *Desmacella*, a dendoricellid in the genus *Pyloderma*, and several species in the family Cladorhizidae.

All were identified from spicules or spicule images by Dr. Rob van Soest in the Netherlands. Of these 18 total species, cf. *Corallistes* sp., *Penares* sp., *Poecillastra* sp. 2, *Polymastia* sp. 1, *Characella* sp., *Stelodoryx* sp. *Pyloderma* sp. were found in discrete beds that may have formed from localized settlement events. While several of these can found in moderate to high abundance, the colony sizes of these sponges are relatively small and few if any have been observed with associated fauna. None are therefore considered to be major structure forming species, however it is worth noting here that based on these new collections, there may be a greater prevalence of demosponges below 200 m than previously thought.

**a.(ii) Hexactinellida below 200 m**

Prior to 2015, 118 hexactinellid specimens had been collected in Hawaiian waters dating back to the Albatross expedition in 1902. Three of the five currently recognized orders (Amphidiscosida, Lyssacinosida, and Sceptrulophora) and seven of the currently recognized families (Pheronematidae, Uncinateridae, Euretidae, Farreidae, Tretodictyidae, Euplectellidae, and Rossellidae) are represented in these collections. At least 49 distinctly different taxa are among the specimens. However, to date, only three have been identified to the species level: *Sericolophus hawaiicus* Tabachnick and Levi 2000, *Walteria flemmingi* Schultze 1886, and *Farrea occa* Bowerbank 1862. Seven types are listed as being “near” a previously described species because spicule examination has shown they are close to but not an exact match and therefore may be different. The remaining 42 types are believed to be potentially new, undescribed species, which are the most of any region in the U.S. or for that matter, in the world (Reiswig unpub. data). A collaborative effort that includes two of the authors of this report (Kelley and Reiswig) in addition to Dr. Craig Young and Dr. Martin Dohrmann is now underway to publish species descriptions for this somewhat “neglected” fauna. In addition to the collections, at least 8 additional distinctly different hexactinellids have been captured on video during HURL dives and are included in this report’s online
species list but have not as yet been collected. At the preparation of this report, there are believed to be at least 57 species of hexactinellids in Hawaiian waters that have been recorded from 330 m to over 2,000 m. However, recent CAPSTONE collections (that included from waters deeper than 2,000 m, as well as from U.S. Pacific Island areas outside the Hawaiian Archipelago) will significantly increase these numbers once the specimens have been carefully examined.

1.0 Order Amphidiscosida

1.1 Family Hyalonematidae

Chave and Jones (1991) and Chave and Malahoff (1998) reported the presence of two families of Amphidiscosida in Hawai‘i: Hyalonematidae and Pheronematidae. However, further investigation determined their unidentified species of Hyalonema was actually a pheronematid that was subsequently named Sericolophus hawaiicus (Tabachnick and Levi 2000). Two species of hyalonematids were recently collected during CAPSTONE dives around Hawai‘i. Therefore even though the initial report of this family being in Hawai‘i was found to be incorrect, its presence has now been confirmed.

1.2 Family Pheronematidae

All other Hawaiian amphidiscidosids identified to date are pheronematids, with representatives from three genera: Poliopogon, Semperella, and Sericolophus. Pheronematids have been both collected and recorded on video between 338 m and the 2000 m maximum operating depth of the Pisces submersibles. This group no doubt extends much deeper. While most species are found attached to hard rocky substrates, S. hawaiicus, the shallowest species, is found exclusively on soft substrates. S. hawaiicus has an elongate tuft that both anchors the sponge into the sediment as well as serving as a stalk (Fig. 6a). This species is considered to be structure forming because it is typically found in very high density beds and with a variety of commensals since it often provides the only firm elevated surfaces in the area. Some of the other pheronematids are both large and also form beds with densities close to 1/m². Large lateral oscula in many of these species attract commensal crabs and ophiuroids that appear to use them for shelter. Until the taxonomy of family is completely worked out, all species of pheronematids in Hawai‘i should be considered as structure forming due to both their size and abundance (Fig 6b,c).

2.0 Order Sceptrulophora

The order Sceptrulophora (formerly Hexactinosida, in part) is represented in this region by four families: Euretidae, Farreidae, Tretodictyidae, and Uncinateridae.

2.1 Family Euretidae

Three different species of euretids have been identified from specimens collected during HURL dives in Hawai‘i. The latest of these, a suspected new species of Lefroyella, was collected in 2013 and like its New Zealand congener, Lefroyella decorata, was found to have a large number of commensal anemones growing through its framework. These anemones are believed to be in the family Edwardsiidae
(Fautin, pers comm.), but this has not as yet been confirmed. Additional euretids were collected during CAPSTONE dives bringing the total number of species tentatively identified as being euretids to 9. However, these are all relatively uncommon and therefore are not considered major structure forming sponges in this region.

2.2 Family Farreidae

All of the farreid specimens collected during HURL submersible dives around Hawai‘i have similarities to 

Farrea occa, which has been tentatively identified as being in this region from a single specimen. These species are therefore described as Farrea near occa or Farrea near occa erecta based on whether their colony is bushy (the former) or taller and more upright (the latter). Farreids have been recorded from 350-2400 m in Hawai‘i and are relatively common. In some locations F. near occa, but not F. near occa erecta, can be found in beds of modest densities. Another interesting distinction between the two types is the presence of a commensal antipatharian found growing on F. near occa but not on F. near occa erecta. This antipatharian appears to be a new species and is presently under investigation. Other colonies of F. near occa have been seen completely covered with zoanthids which again has not been observed with colonies of F. near occa erecta. Collections of farreids during CAPSTONE have revealed the presence of at least 2 other genera around Hawai‘i: Aspidoscopulina and Lonchiphora as well as a possible third new genus that presently doesn’t match any of the known genera in this family.

Aspidoscopulina colonies are large and can be found in relatively dense beds. However, until these new specimens can be examined more carefully, F. near occa will be listed here as the only structure forming farreid in this region.

2.3 Family Tretodyctyidae

Although two species in this family are listed in this report’s online species list, only one has been positively identified in this region and has been assigned to the genus Tretodyctyum. The specimen is vase-shaped and was collected on hard substrate at a depth of 687 m. This species is neither large nor abundant and therefore is not considered to be structure forming. As mentioned previously, a potentially new species of branching tretodyctyid was collected several months ago, which had been previously identified from photographs as a calcarean. Colonies were moderately abundant at the CAPSTONE dive site and were furthermore found to have large numbers of what appeared to be commensal zoanthids. This is likely a new species however that determination requires additional investigation.

2.4 Family Uncinateridae

The presence of this order in Hawai‘i was unknown until 2011 when the identification of four specimens collected in 2003 were assigned with several other specimens collected in 2007 and 2009 to the genus Tretopleura in the family Uncinateridae. Three additional specimens do not fit into any known genera and are therefore listed as “Uncinateridae new genus new species.” All of the species in this family attach to hard substrates at depths of 685-1850 m.
Commensal crabs and ophiuroids are typically observed on the *Tetrapyleura* colonies, which can reach over a meter in height. *Tetrapyleura* sp. 1B and sp. 2 are relatively common and are therefore considered structure forming.

3.0 Order Lyssacinosida

Lyssacinosidans are relatively common in this region of which all have been assigned to one of two families: Euplectellidae and Rossellidae.

3.1 Family Euplectellidae

Euplectellids are the most diverse family of hexactinellids in Hawai‘i with 18 potential species having been identified from specimens and video images. Thirteen genera have been identified to date and include one in the lophophytoic subfamily Euplectellinae, four in the pedunculate subfamily Bolosominae and 8 in the vase-like and tube-like subfamily Corbitellinae. While *Dictyocalyx gracilis* was reported to have been collected near Hawai‘i (Tabachnick 2002), the 2 specimens of this genus actually collected in Hawai‘i are not the same and are believed to be a new species. Euplectellids are found from 330 m to over 4,000 m, with those in the genus *Regadrella* being observed in the shallowest depths while pedunculate euplectellids only appearing at depths below 500 m. All species attach to hard substrates and several have been observed in aggregations. Some species in both the Bolosominae and Corbitellinae can grow to relatively large sizes (Fig. 6d). Most euplectellids are inhabited by commensals such as ophiuroids and crustaceans. In some species with small or covered primary oscula, early colonization leads to commensal shrimp becoming “trapped for life” inside their atrial cavities (Baba 1983). For the purpose of this report, several species of euplectellids found in the genera *Bolosoma*, *Saccocalyx*, and *Regadrella*, and *Walteria* are considered structure forming in this region.

3.2 Family Rossellidae

Until CAPSTONE, rossellids were represented in Hawai‘i by 9 species, 7 of which have been placed into two genera: *Bathydorus* and *Caulophacus*. The two species of *Bathydorus* are vase-like, with the specimen of *Bathydorus* near *laevis* being a huge caldron sized sponge while the specimen of *Bathydorus* sp. was not. These two species, along with other similar looking vase sponges identified from video as only rossellids, have been recorded at depths of 350-1760 m. The five species of *Caulophacus* are pedunculate with small bodies supported above the substrate by a relatively long stalk. Both pedunculate and non-pedunculate rossellids can be found in small aggregations but none are considered structure forming in this region. CAPSTONE collections of rossellids around Hawai‘i included members in additional genera of both pedunculate and non-pedunculate species. The most noteworthy of these was a specimen from an extremely large colony of an undescribed genus in the subfamily Lanuginellinae. While this colony had numerous associated fauna, the species is rare and therefore is therefore not considered to be structure forming at this time.
Figure 7. Maps of the Hawaiian Archipelago and Johnston Atoll showing the locations where deepwater octocorals (purple, upper left), scleractinians (orange, upper right), antipatharians (green, lower left), and sponges (blue, lower right) have been found. For additional detail see maps in Appendix. The yellow line indicates the monument boundaries and the red line is the EEZ boundary. The two are the same around Johnston Atoll.
II.3. Coral Growth, Biology and Reproduction

The Western Pacific Fishery Management Council placed a moratorium (2007) on the harvesting of gold coral (*K. haumeae*) (Fig. 8) for the precious coral fishery until a validation study of conflicting growth estimates could be conducted. Gold coral colonies that were measured and marked up to 9 years earlier were revisited and re-measured (Parrish and Roark 2009). The measured change in growth was statistically indistinguishable from zero, indicating that gold coral growth is much slower than the annual growth estimate derived from basal stem ring-counts previously relied on for the fishery. The duration of the re-measurement period was too short to effectively evaluate the validity of longer lifespan estimates from radiocarbon dating that yielded a linear growth rate of 2.2 ± 0.2 mm yr⁻¹ but clearly indicated that gold coral growth was very slow. The main criticism of using radiocarbon measurements to determine the lifespan of *K. haumeae* and *Leiopathes* sp. (estimated at up to 2,742 years and 4,265 years, respectively) was that the corals might be feeding on old dead carbon thereby giving unrealistically old ages. By reproducing the radiocarbon bomb curve in a Hawaiian *K. haumeae* specimen (Roark et al. 2009) and a Gulf of Mexico *Leiopathes* sp. specimen (Prouty et al. 2011) these studies clearly demonstrate that these deep-sea corals are feeding on recently exported young fresh particulate organic carbon from surface waters clearly demonstrating the validity of the extreme longevity and slow radial growth for both species (see Prouty et al., this volume, on age, growth rates, and paleoclimate studies). U-Series dating of stony coral *Enallopsammia rostrata* specimens from 480 to 788 m water depth in the Line Islands indicate life spans ranging from 209 ±8 to 605 ±7 years, radial growth rates ranging from 0.012 to 0.073 mm yr⁻¹ and with linear growth rates ranging from 0.6 to 1.9 mm yr⁻¹ (Houlbrèque et al. 2010). These

**Figure 8.** The purple stoloniferan *Clavularia grandiflora* growing on a Kulamanamana *haumeae* colony. Photo credit: HURL.

**Figure 9.** The invasive *Carijoa riisei* growing on shallow water black coral. Photo credit: HURL.
results show E. rostrata is relatively slow growing deep-sea coral.

Recent reproductive studies on Hawaiian deep-sea corals includes work on the morphological structures of precious gold coral (K. haumaeae), pink coral (Pleurocorallium secundum), and red coral (Hemicorallium laauense) (Waller and Baco 2007). All 3 species appear to be gonochoric broadcast spawners. The reproductive biology of the shallow water black corals (including Antipathes grandis, Antipathes griggi, Cirrhipathes cf. anguina, Stichopathes echinulata, Stichopathes sp., Aphanipathes verticillata), and deepwater corals (Leiopathes sp. and Alternatipathes alternata [=Bathypathes alternata]) (Wagner et al. 2011c, Wagner et al. 2012) has also been examined.

Wagner et al. (2011b) found that 10 out of 14 Hawaiian black coral species collected between 10 and 396 m contained the symbiotic algae Symbiodinium and thus perhaps should not be considered strictly azooxanthellate. Histological examination of five species showed low densities of Symbiodinium-like cells inside gastrodermal tissues. The authors concluded that the Symbiodinium were unlikely to play a significant role in the nutrition of the black corals.

II.4. Species Associations with Deep-Sea Corals and Sponges

The 2007 report summarized information on species associations with deep-sea corals and highlighted concerns over the colonization of shallow water black coral by the parasitic octocoral Carijoa sp. (originally identified as Carijoa riisei; Fig. 9). Wagner et al. (this volume) discuss the improved understanding of this parasitic association. Many additional associations of invertebrate species with deep-sea corals and particularly with sponge communities (Fig. 10) have been documented. The exceptional imagery collected during the CAPSTONE cruises have expanded the number of observed associations and along with collected samples will be a future area of research focus.

II.5. Research Priorities

The priorities for future work in the region on both deep-sea corals and sponges remain largely the same as those identified for deep-sea corals in the 2007 report, and can be divided into: 1. Exploration and mapping, 2. Taxonomy and connectivity, 3. Biology, ecology and environmental parameters, and 4. Resilience of deep-sea coral communities. In 2014, NOAA brought together over 20 researchers and resource managers to identify and prioritize information needs to increase our understanding of deep-sea coral and sponge ecosystems in the U.S. Pacific Island Region. The workshop participants identified priority research questions and specific information needs and activities (Parrish et al. 2014). The results of the workshop informed NOAA’s Deep-Sea Coral and Sponge Fieldwork Initiative and the CAPSTONE expeditions, and are reflected in the priorities below:
Figure 10. Examples of invertebrates found associated with Hawaiian deep-sea corals (a-ophiuroid, b-crinoid, c-squat lobster, d-asteroid feeding on a bamboo coral; Photo credit: HLURL) and sponges (e-squat lobster, f-shrimp and ophiuroids, g-antipatharian growing out of sponge, h-ophiuroids; Photo credit: NOAA).
1. *Exploration and mapping*

Prior to 2015, there had been little or no exploration of the U.S. Pacific Islands Regions except for the Hawaiian Archipelago. There is a need to expand surveys to under sampled regions in the U.S. Pacific including the Marianas, American Samoa and the Pacific Remote Islands Marine National Monument. Exploring the rest of the U.S. Pacific is the highest priority for the region and represents a real challenge. Applying consistent taxonomy, and where possible, collecting genetic samples in order to evaluate the degree to which various assemblages are connected, will begin to elucidate biogeographic patterns at the Pacific basin scale. Even within the Hawaiian Archipelago, where research tools are available, most information on the distribution of deep-sea corals and sponges was restricted to depths shallower that 2000 m and little was known about the deep-sea fauna found below this depth.

2. *Taxonomy and connectivity*

Taxonomy using both traditional morphological methods and recently developed genetic methods continues to be a high priority for all deep-sea coral and sponge work because so many of the specimens are new to science. While gene flow in shallow water ecosystems is relatively well-understood, the gene flow in deep-sea coral ecosystems is poorly understood and their role in connectivity is an obvious emphasis for future work in the U.S. Pacific Islands region. CAPSTONE collected numerous samples of corals and sponges (including genetic sampling) that have already begun to identify new species (e.g., Cairns 2017), however, population-level studies were constrained by limited sample sizes.

3. *Biology, ecology, and environmental parameters*

Much of the basic biology and ecology of major structure-forming deep-sea corals and sponges in the region are poorly known, as are the environmental variables that govern where deep-sea coral and sponge communities colonize and develop into mature assemblages. Having information on the conditions needed to support these ecosystems is valuable, as this provides the parameters needed for planned modeling activities and contributes to the growing body of climate research. To date there are no published habitat suitability models for deep-sea sponges. The Pacific Islands, with its large protected areas in the form of marine national monuments, is an ideal place to look for environmental change using data loggers at established study sites.

4. *Resilience of deep-sea coral communities*

It is not known how long it takes for deep-sea coral or sponge individuals or communities to recover following disturbance. Deep-sea corals and probably many sponges can grow extremely slowly and are vulnerable to impacts from activities that disturb the seafloor. Additionally, ocean acidification may affect corals’ ability to grow and maintain their structures. There is a need to understand community development that considers overall natural recruitment, growth, and mortality over large spatial scales.
Opportunities for addressing these research priorities need to take into account the loss of research and monitoring assets in the region. In 2013 NOAA discontinued funding for the Hawai’i Undersea Research Laboratory, which operates the Pisces 4 and Pisces 5 submersibles, ROV, and support vessel. These have been the key and nearly exclusive assets for in situ explorations in the U.S. Pacific Islands Region. Loss of these assets will severely impact deep-sea coral and sponge work in Hawai’i and the U.S. Pacific Islands Region. The availability of other similar assets typically requires that highly competitive proposals based on hypothesis-driven research be submitted to funding entities. The success of CAPSTONE highlights the value of exploratory work, however it may be incredibly challenging to bring submersible and ROV assets here on a sustained basis in the future.

III. Update on Management of Deep-Sea Coral and Sponge Habitats

III.1. New Information on Impacts and Stressors

III.1.i - Precious coral fishery
Hawai’i has had the only significant black and precious coral fisheries in the U.S. There have been no reported commercial catch reports for precious coral since the 2007 report. Harvest of the precious coral (e.g., Corallium spp., Hemicorallium spp., Pleurocorallium spp, K. haumeaeae) has been dormant since 2000 although a permit was obtained in 2012 for harvesting in the Makapu’u bed using a small ROV system but is as yet unused. In 2011 sales reports of shallow water black coral were filed but cannot be described in detail because the number of participants is too small to report publicly due to confidentiality requirements. Robin Lee, long time black coral diver and key participant in the fishery passed away in 2012, and recently submitted landing logs indicate new participants have joined the fishery.

III.1.ii - Undersea cables
The laying of undersea cables in the channels of the Hawaiian Islands to deliver power from planned wind and solar farms on outer islands (e.g., Molokai, Lanai) is the region’s most immediate potential impact concern. Most of the known shallow-water black coral population is found in these channel waters and are the focus of harvesting by divers. Tracts of zooxanthellate scleractinian corals (e.g., Montipora capitata, Leptoseris hawaiiensis) also occur at the mesophotic depths between 30-150 m and are fragile, growing on the slopes and the submerged land bridge that connects the islands and could incur some damage if cables are laid on them. Azooxanthellate corals in the deeper channels between Oahu and Molokai are also at risk of damage from cables. However, at the moment, the state has taken the effort to survey potential cable routes and has already diverted proposed routes around known coral beds such as that off Makapu’u.

III.1.iii - Undersea mining
The interest in mining cobalt-manganese crust from the seafloor between 400-4000 m in the
U.S. Pacific was identified in the 2007 report and continues to be discussed as an option for the future. Although this is unlikely to occur in areas such as the Hawaiian Archipelago due to its young age and the fact that much of the archipelago has been designated as a marine national monument, other, older island groups in the U.S. Pacific may be more likely targets. However, Cretaceous seamounts (i.e., 60-120 ma) with presumed extensive Mn crusts do exist in the vicinity of the archipelago and could be targeted by the industry in the future. There is enough concern about the impacts of mining that the International Seabed Authority (ISA) funded data syntheses to provide the first ever comprehensive description of taxa present on cobalt-rich crusts (see Clark et al. (2011) and Schlacher et al. (2014)). Additional studies of this kind are clearly warranted, particularly in light of the fact that 3 exploratory leases have already been issued by the ISA on prospective Mn crust mining sites in the Western Pacific.

III.2. New or Planned Management Actions

III.2.i – Precious coral fishery
The only change in federal regulation for the precious coral fishery is a 5-year moratorium on the harvest of live gold coral due to its reported slow growth rate (Roark et al. 2006). A subsequent study (Parrish and Roark 2009) using mark and re-measurement techniques reported similar findings and the moratorium was extended until 2018. Other proposed actions relevant to the coral fishery included a proposal in 2009 to list the genera Corallium and Paracorallium under the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) Appendix 2 but this proposal did not pass.

III.2.ii – Designation of new Marine National Monuments
In January 2009, Presidential proclamations 8335-8337 designated waters off CNMI as the Marianas Trench Marine National Monument; Kingman Reef, Palmyra Atoll, Jarvis, Howland, Baker, Johnston and Wake Islands were designated the Pacific Remote Islands Marine National Monument; and Rose Atoll was made the Rose Atoll Marine National Monument under the Antiquities Act. These new Monuments added to the existing Papahānaumokuākea National Marine Monument (est. 2006) to form the largest network of marine monuments in the U.S. Their mandate is to protect the unique natural and cultural resources within the region through the advancement of scientific research, exploration and public education. Combined this area encompassed a total 800,076 km² with each marine national monument extending seaward 50 nm from mean low water the seabed. They are co-managed between the Department of Interior and the Department of Commerce in coordination with federal partners (e.g., Department of Defense) and the State/Territorial governments. No commercial fishing is allowed in any of the monuments, which precludes the expansion of the precious coral fishery into these areas.

In 2014, the boundaries of the Remote Pacific Islands National Marine Monument around Jarvis, Wake and Johnston Atoll were expanded
out to the 200 nautical mile U.S. EEZ by Presidential Proclamation 9173. The newly protected areas contain additional seamounts that have since been confirmed to include important deep-sea coral and sponge resources. The monument now encompasses an area of 1,057,494 km² (308,316 square nautical miles). These virtually unexplored areas were the target of mapping and ROV surveys by NOAA ship Okeanos Explorer under CAPSTONE.

The Papahānaumokuākea Marine National Monument management plan was finalized in 2008, and in 2010 the area was inscribed as a natural and cultural World Heritage Site. The Monument was expanded by Presidential Proclamation 9478 to 1,508,870 km² (582,578 square miles), making it the largest protected area - terrestrial or marine - on the planet.

III.3. New Priorities for Management

III.3.i - Alternative Energy

Hawaii’s push for alternative energy has prompted a number of feasibility studies including some initial surveys of potential cable-laying routes. Management groups involved in these plans are studying the potential impacts and examining the best alternatives. An example is the Hawaiian Islands National Humpback Whale Sanctuary, which spans the channel waters of the Main Hawaiian Islands, partnering with NOAA scientists and the University of Hawaii to spatially model data from their studies on mesophotic coral ecosystems in the Au’au channel between the islands of Maui and Lanai (Costa et al. 2012). The Bureau of Ocean Energy Management also supported modeling of shallow, mesophotic and deep-sea corals (Bauer et al. 2016) in order to inform potential future alternative energy development. There has also been an interagency meeting to look at potential impacts of implementing Ocean Thermal Energy Conversion (OTEC) using intake pipes laid down slope 800-1000 m to bring deep cold water to the surface for energy production.

III.3.ii - Ocean cage aquaculture

Limited offshore cage aquaculture of fishes has occurred on the leeward coast of a couple of the Main Hawaiian Islands and there is interest in expanding this activity, which could involve use of mooring anchors potentially at deeper depths. It is not known if this type of development would impact deep-sea coral communities significantly.

IV. Conclusions

In the first seven years since the 2007 report, deep-sea coral research focused on using available data from Hawaii to study the biology, reproduction and growth of select coral taxa – especially antipatharians. Notable advances included taxonomy, preliminary habitat suitability models for deepwater corals, and the first steps in the characterization of the sponge community. Hawaii’s deep-sea sponges are far less well studied than are the deep-sea corals. Much of the U.S. Pacific Islands has been recently designated as new Marine National Monuments and yet still little or no
information had been collected on the deep-sea coral and sponge communities in areas outside of the Hawaiian Archipelago. The monument designations will limit expansion of domestic commercial harvesting especially for precious coral resources that are protected as part of the seafloor. However, much of this area is remote making it difficult to monitor the degree of illegal fishing by foreign fleets. Other potential impacts include cable-deployment and development of oceanic cage aquaculture, and for the adjacent high seas region, deep-sea mining. Finally, the region’s ability to continue and expand studies of deep-sea corals in support of management using the submersible and ROV assets operated by the Hawai‘i Undersea Research Laboratory has been jeopardized if not ended as a result of budget cuts.

Beginning in 2015, NOAA’s Deep Sea Coral Research and Technology Program, in partnership with NOAA’s Office of Ocean Exploration and Research, National Marine Sanctuary Program, and NMFS, began a major three-year field research initiative, CAPSTONE, in the Pacific Islands region. This campaign conducted the first major biogeographic exploratory work on deep-sea coral and sponge ecosystems outside the Hawaiian Archipelago, as well as ecological studies off Hawai‘i, where the infrastructure and technical capacity exist to support this type of field work. The results will provide information on monument resources and increase scientific understanding of these unique deep-sea ecosystems.

Online Annex – Comprehensive list of deep-sea corals in the U.S. Pacific Islands region linked here:

V. Literature Cited

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Online Annex 1. Deep-sea Coral Taxa in the U.S. Pacific Islands Region: Depth and Geographic Distribution
Appendix – Distribution maps for the Hawaiian Archipelago and Johnston Atoll

Map 1. Locations of black corals (Order Antipatharia) recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017).
Map 2. Locations of branching stony corals (Order Scleractinia) recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017).
Map 3. Locations of non-gorgonian alcyonaceans (Order Alcyonacea) recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017).
Map 4. Locations of gorgonians (formerly Order Gorgonacea) recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017).
Map 5. Locations of sea pens (Order Pennatulacea) recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017).
Map 6. Locations of lace corals (Family Stylasteridae) recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017).
Map 7. Locations of sponges recorded in the National Deep-Sea Coral and Sponge Database (as of October 2017). Note: This does not include additional HURL records shown in Figure 6.