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State of Deep-Sea Coral and Sponge Ecosystems of the U.S. West Coast: 2015

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STATE OF DEEP-SEA CORAL AND SPONGE ECOSYSTEMS OF THE U.S. WEST COAST: 2015

M. Elizabeth Clarke[1], Curt E. Whitmire[2] and Mary M. Yoklavich[3]

[1]Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

[2]Northwest Fisheries Science Center
2032 SE OSU Drive
Newport, OR 97365

[3]Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA95060

I. Introduction

The U.S. Pacific coast marine region encompasses the continental margin off the coasts of Washington, Oregon and California, and accounts for about 7% (778,628 km^2) of the total area of the U.S. Exclusive Economic Zone (EEZ). The continental margin in this region is characterized by a relatively narrow (5-40 km) shelf and a steep continental slope, with the shelf break at approximately 200 meters water depth. This area is wholly within the California Current Large Marine Ecosystem (LME). The California Current LME is a transition ecosystem between subtropical and subarctic water masses and is characterized by seasonal upwelling. It encompasses portions of two marine biogeographic provinces – Oregon (cold-temperate) and California (warm-temperate [formerly San Diego]) – with a boundary between Point Conception and Los Angeles, CA (Allen & Smith 1988, McGowan 1971, Briggs & Bowen 2012). Relatively large estuaries border the area, including those associated with the Puget Sound, Columbia River, and San Francisco Bay. Fishing for salmon, groundfish, small coastal pelagics, highly migratory species, and invertebrates (most notably squid, crab, shrimp, and sea urchins) is significant throughout this region.

Rockfish sheltering in a glass sponge (*Aphrocallistes* sp.) near Grays Canyon off the coast of Washington.

Deep-sea corals and sponges are found throughout the area (Austin et al. 2007, Lee et al. 2007, Whitmire & Clarke 2007). Much of the information on the general zoogeography of corals in the region originated from taxonomic records collected from bottom trawl surveys over the past century. Sea pens, black corals, and gorgonians were recorded coastwide in the catch of bottom trawl surveys and by fishery observers monitoring bycatch during commercial fishing operations. Our understanding of the distribution of corals has been informed by visual surveys using underwater vehicles (e.g., submersibles, remotely operated vehicles [ROVs] and autonomous underwater vehicles [AUVs]).

Whitmire & Clarke (2007) reported 101 species of corals from six cnidarian orders from the West Coast region. They highlighted significant coral communities at Davidson Seamount (DeVogelaere et al. 2005), Monterey Canyon, Cordell Bank (Pirtle 2005), the Olympic Coast National Marine Sanctuary (Hyland et al. 2005, Brancato et al. 2007), and on numerous rocky banks off southern California (Yoklavich & Love 2005, Tissot et al. 2006, Love et al. 2007).

Major stressors on deep-sea coral communities off the Pacific Coast included oil and gas development in the Southern California Bight, deployment of pipelines and communication cables, and marine pollution. Fishing operations, particularly bottom trawling, were identified as the most immediate and widespread threat to these communities. The risk posed by fishing activities was reduced by fishery management measures (e.g., area closures such as marine protected areas (MPAs) and gear restrictions) taken before 2007. In June 2006, the Pacific Fishery Management Council (PFMC), in cooperation with NMFS, implemented a comprehensive plan to protect essential fish habitat (EFH) for west coast groundfish (PFMC 2005, 2006). This plan identified habitat areas of particular concern (HAPCs) that protect vulnerable biogenic habitats. The plan was developed in collaboration with non-governmental organizations, the fishing industry, and the National Marine Sanctuary Program, and addressed impacts from a broad range of human activities (fishing and non-fishing) and included procedures for review as new information became available.

As of 2007, MPAs were distributed along the length of the Pacific coast in both federal and state waters. Over 130,000 mi^2 (336,700 km^2) had been designated as MPAs fully protected from impacts from bottom trawls, with selected vulnerable habitats protected from all fishing gears that contact the bottom. Additional MPAs and fishery closures were designated by the individual states, including bottom trawl prohibitions for the entire portion of Washington state waters and most of California state waters. Furthermore, there are five national marine sanctuaries in the region, all of which prohibit activities that may be harmful to corals, including but not limited to 1) new oil, gas or mineral exploration, development and production, 2) discharge of materials or substances except fish parts, bait, water or other biodegradable effluents, and 3) alteration of the seabed except for normal fishing activities and anchoring.

In this report we highlight new scientific information on deep-sea corals uncovered since the 2007 report, and outline new management measures that help protect these organisms on the Pacific coast. We also include new information on deep-sea sponges, which were not previously addressed in the 2007 report.

II. Update on Scientific Information

II.1. New Research – Overview

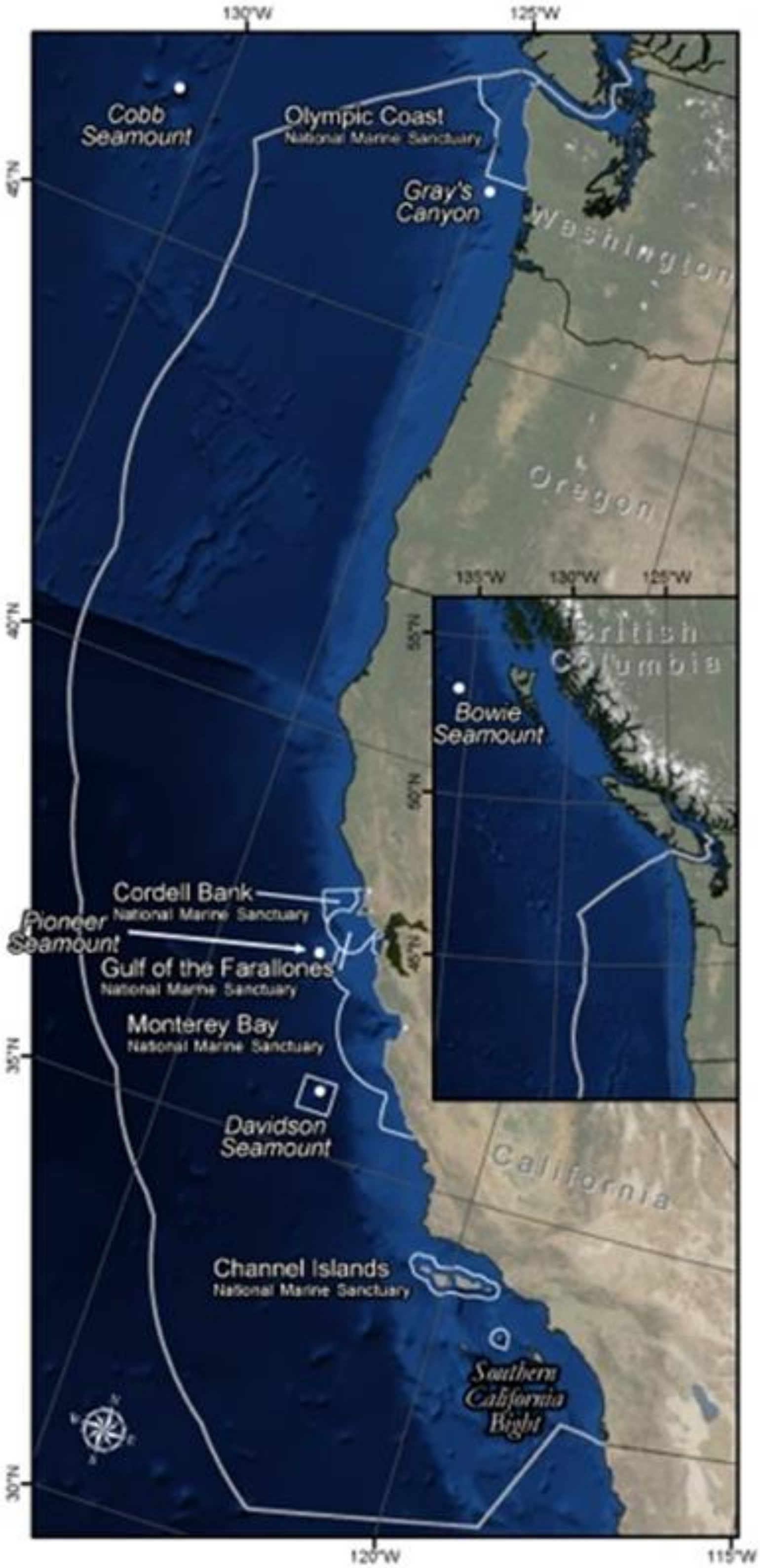
Several new studies on both deep-sea corals and sponges were initiated or completed since 2007 by researchers from NOAA and a variety of collaborative institutions. This includes research funded by NOAA's Deep Sea Coral Research and Technology Program (DSCRTP), other targeted studies conducted by academic and non-governmental institutions, and work aboard ships of opportunity, all of which has yielded valuable information about corals, sponges and their habitats. The DSCRTP also supported analysis of archived video or photographic surveys to assess the occurrence of deep-sea coral and sponge habitats. There also has been an expansion of regional bathymetric mapping of the seafloor (PFMC 2012), and of new methods to predict suitable habitats for corals. In addition, considerable attention has been given to the genetics of corals, which will assist in their identification and taxonomy. Opportunistic data collections continue, with coral and sponge specimens taken in the annual west coast groundfish bottom trawl survey and by observers monitoring the groundfish fishery.

New field research on deep-sea coral and sponge communities has been conducted coastwide, with many study sites located in and around the five national marine sanctuaries (Figure 1; Appendix Table A). Additional field expeditions, while not specifically targeting corals or sponges, also have provided information on these taxa.

II.1.i - NOAA's Deep Sea Coral Research and Technology Program

In 2010, NOAA's DSCRTP launched a research initiative on the U.S. West Coast to locate, study, and provide information for the conservation of deep-sea coral and sponge habitats. The initiative was developed in consultation with the PFMC and targeted information that could inform management. Field research was conducted at various sites in and around four national marine sanctuaries and in sponge habitats offshore of Grays Harbor, Washington as well as at seamounts in Canadian and international waters to further the understanding of biogenic habitats and associated fishes (Figure 1). These areas were chosen based on expected suitability for deep-sea coral or sponge habitats and their potential to inform sanctuary management plans and the PFMC's five year review of groundfish EFH. The field research, originally planned for three years (2010-2012), was extended to 2014 and has made substantial progress.

Figure 1. *General locations of surveys of deep-sea corals and sponges off the Pacific coast since 2007. See Appendix Table A for details of individual surveys.*



During this West Coast initiative, field research addressed one or more of the following specific goals:

1. Locate and characterize coral and sponge habitats, including the following:
    a. Collection of baseline data on abundance, size, condition, and distribution of deep-sea corals and sponges;
    b. Mapping of targeted seabed and collection of environmental data associated with coral and sponge habitats (e.g., depth, sea floor substratum types, seawater temperature, salinity, pH, and dissolved oxygen) to help understand habitat factors that may influence species distribution.
2. Quantify fish and invertebrate associations with corals and sponges to help understand their potential value as habitat.
3. Assess the condition of coral and sponge assemblages in relation to potential anthropogenic or environmental disturbances.
4. Collect specimens of deep-sea corals, sponges, and associated organisms to confirm taxonomic identifications, and for genetic and reproductive analyses.

Program-funded surveys were conducted using remotely operated vehicles (ROVs), human occupied vehicles (HOVs), and an autonomous underwater vehicle (AUV). Observations of corals and sponges are being incorporated into NOAA's National Database for Deep-Sea Corals and Sponges.

II.1.ii - Additional Field Research

Researchers at a number of institutions conducted studies that contribute to our knowledge of deep-sea corals off Washington, Oregon and California (Appendix Table A). Of particular significance are deeper water surveys by the Monterey Bay Aquarium Research Institute on a number of seamounts with rich deep-sea coral and sponge habitats. Additional field research has been conducted in the national marine sanctuaries (e.g., Etherington et al. 2011), by Oceana (Shester et al. 2012, Enticknap et al. 2013), as part of monitoring state MPAs (e.g., Yoklavich et al. 2010), and in association with other studies. Several graduate students at Washington State University summarized information on the spatial distribution and abundance of invertebrates and fishes that were quantified from archived videotape collected during visual surveys using ROVs or a submersible (e.g., Bright 2007, Graiff 2008, Bianchi 2011).

II.1.iii – Bottom Trawl Collections

The occurrence of deep-sea corals and sponges as catch in the NMFS West Coast Groundfish Bottom Trawl Survey remains the most comprehensive source of coastwide information on the general distribution of higher-level coral and sponge taxa. These surveys are conducted annually in "trawlable" habitats coastwide at depths from 55 to 1280 m. From 2001-12, sponges and pennatulids were the most abundant taxa observed in these surveys (Table 1), most likely because of the types of habitats (e.g., low relief) that are accessed by bottom trawls. Physical specimens were collected, with some sent to taxonomists for identification.

Table 1. *Summary of deep sea coral and sponge taxa recorded during bottom trawl tows as part of the West Coast Groundfish Bottom Trawl Survey (2001-2012). "#" denotes number of tows with recorded bycatch; "FREQ" denotes ratio of tows with catch to total tows recorded; "Weight" denotes catch weight (kg); "FREQ Rank" and "Weight Rank" columns denote the rank of taxon by either frequency of occurrence or catch weight, respectively. Taxa are ranked by highest catch weight within major taxonomic groups.*

	Taxon	Taxon Rank	#	FREQ	FREQ Rank	Weight (kg)	Weight Rank
	Porifera	Phylum	1,436	19.9%	1	11,035.01	1
	Hexactinosida	Order	512	7.1%	3	7,992.77	2
	Rossellinae	Subfamily	159	2.2%	8	1,328.24	3
	Suberites spp.	Genus	20	0.3%	19	1,073.27	4
	Hyalonema spp.	Genus	180	2.5%	7	561.63	5
	Hexactinellida	Class	17	0.2%	21	131.01	6
	Farrea spp.	Genus	11	0.2%	25	4.18	24
Porifera			**1,869**	**25.9%**		**22,126.11**	
	Pennatulacea	Order	926	12.8%	2	102.11	7
	Anthoptilum grandiflorum	Species	489	6.8%	4	97.89	8
	Halipteris spp.	Genus	211	2.9%	5	29.68	12
	Ptilosarcus gurneyi	Species	135	1.9%	10	21.09	14
	Umbellula spp.	Genus	141	2.0%	9	8.84	18
	Anthoptilum murrayi	Species	42	0.6%	15	3.00	25
	Anthoptilum spp.	Genus	5	0.1%	27	0.36	30
	Pennatula phosphorea	Species	15	0.2%	22	0.28	32
	Halipteris willemoesi	Species	5	0.1%	27	0.14	33
	Halipteris californica	Species	3	0.0%	28	0.05	34
Pennatulacea			**1,670**	**23.1%**		**263.44**	
	Gorgonacea	Order	197	2.7%	6	72.55	9
	Paragorgia spp.	Genus	26	0.4%	18	11.69	17
	Isidella spp.	Genus	12	0.2%	24	7.15	19
	Callogorgia kinoshitae	Species	29	0.4%	17	6.31	20
	Keratoisis spp.	Genus	5	0.1%	27	1.95	26
	Callogorgia spp.	Genus	5	0.1%	27	0.33	31
	Leptogorgia chilensis	Species	1	0.0%	30	0.04	35
	Swiftia pacifica	Species	2	0.0%	29	0.02	37
	Acanthogorgiidae	Family	1	0.0%	30	0.01	38
Gorgonacea			**253**	**3.5%**		**100.04**	
	Antipatharia	Order	126	1.7%	11	64.26	10
	Chrysopathes spp.	Genus	46	0.6%	13	44.45	11
	Bathypathes spp.	Genus	44	0.6%	14	1.37	27
	Lillipathes spp.	Genus	18	0.2%	20	1.01	28
Antipatharia			**217**	**3.0%**		**111.09**	
	Heteropolypus spp.	Species	104	1.4%	12	21.93	13
	Anthomastus spp.	Genus	39	0.5%	16	11.70	16
	Alcyonacea	Order	29	0.4%	17	6.11	21
	Nephtheidae	Family	1	0.0%	30	0.04	36
Alcyonacea			**168**	**2.3%**		**39.78**	
	Caryophylliidae	Family	7	0.1%	26	12.60	15
	Flabellidae	Family	13	0.2%	23	5.86	22
	Scleractinia	Order	7	0.1%	26	5.34	23
Scleractinia			**26**	**0.4%**		**23.80**	
Stylasteridae	Stylasteridae	Family	**5**	**0.1%**	27	**0.53**	29
ALL TAXA			**3,182**	**44.0%**		**22,664.78**	

With DSCRTP funding, these data have been summarized recently for the five-year review of Pacific Groundfish EFH being conducted by NMFS and PFMC (PFMC 2012). This analysis focused on changes in bycatch before and after implementation of EFH regulatory measures in June 2006. Although no significant difference in the total frequency of occurrence of corals and sponges is apparent, identification of species in the trawl surveys is improving and often samples are retained and sent to experts for taxonomic verification of species. Information collected by observers of the groundfish fishery provides only broad taxonomic resolution; however, these observers routinely collect specimens for species verification.

II.2. Taxonomy and Species Distributions

II.2.i - Corals

a. Taxonomy:

Whitmire and Clarke (2007) reported 101 species of corals from six cnidarian orders from the West Coast within the U.S. EEZ, including 18 species of stony corals (Class Anthozoa, Order Scleractinia) from seven families, seven species of black corals (Order Antipatharia) from three families, 36 species of gorgonians (Order Gorgonacea) from 10 families, eight species of true soft corals (Order Alcyonacea) from three families, 27 species of pennatulids (Order Pennatulacea) from eleven families, and five species of stylasterid corals (Class Hydrozoa, Order Anthoathecata, Family Stylasteridae). Since 2007, there have been several additions to the number of deep-sea coral species documented on the west coast including range extensions of certain species (Table 2). In addition, the relationships between species have been reviewed and several species have been synonymized.

With funding from DSCRTP, samples (vouchers) of deep-sea corals from the northeast Pacific Ocean have been identified to species using both morphology (form and structure) and DNA sequence bar codes. Coral samples have been collected during field research, research trawl surveys and by fishery observers. Genetic sequences for two mitochondrial genes – COI and MutS – are linked to voucher specimens to create a resource for researchers of deep-sea corals. Microsatellite loci also are being developed for the gorgonian *Primnoa pacifica* and a species of sea pen in order to analyze genetic patterns in populations of deep-sea octocorals. By creating a voucher collection for deep-sea corals and linking those vouchers to species-specific genetic sequences, taxonomic identifications can potentially be made using DNA sequences rather than sending individual specimens to the few morphological taxonomists. The genetic information also will be useful in the identification of corals collected from fishery observers and bottom trawl surveys, where poor condition of specimens makes morphological identifications difficult.

b. Coral Distribution:

Based on recent studies, an improved understanding of the distribution of coral species is emerging on the West Coast. With the exception of pennatulids, corals mostly occur on rocky substrata (e.g., boulders, pinnacles, rock outcrops). Region-wide, hard and mixed seabed types are relatively rare, representing only around 10% of the substrata from the shelf to depths of 3000 m (NMFS 2013). These seabed types are often associated with seamounts, banks, and canyons, which have been the focus of many of the recent studies.

Lundsten et al. (2009) described the abundance and distribution of benthic megafaunal invertebrates on Pioneer, Davidson, and Rodriquez seamounts off central and southern California. Coral diversity was relatively high with 23, 25, and 26 species identified, respectively on these seamounts. Davidson Seamount was the site for several detailed studies of community structure and endemicity (McClain et al. 2009, McClain et al. 2010). From these studies, there was little support for

Table 2. *New coral species and range extensions reported from the U.S. West Coast region since 2007.*

Order	Species	Reference
New species:		
Gorgonacea	*Chrysogorgia pinnata*	Cairns 2007
	Chrysogorgia monticola	Cairns 2007
	Calyptrophora bayeri	Cairns 2007
	Calyptrophora laevispinosa	Cairns 2007
	Narella bowersi	Cairns 2007
	Parastenella gymnogaster	Cairns 2007
	Parastenella pacifica	Cairns 2007
	Isidella tentaculum	Etnoyer 2008
	Sibogagorgia cauliflora	Herrera et al. 2010
	Leptogorgia filicrispa	Horvath 2011
Alcyonacea	*Gersemia juliepackardae*	Williams and Lundsten 2009
Synonymized species:		
Gorgonacea	*Euplexaura marki = Chromoplexaura marki*	Williams 2013
Alcyonacea	*Gersemia rubiformis = Alcyonium* sp.	Williams 2013
Range Extensions:		
Scleractinia	*Caryophyllia diomedeae*	Gonzalez-Romero et al. 2009
	Caryophyllia quadragenaria	Gonzalez-Romero et al. 2009
Gorgonacea	*Paragorgia arborea* (CA Province)	Yoklavich et al. 2011
	Paragorgia stephencairnsi (CA Province)	Yoklavich et al. 2011
	Parastenella ramosa (CA Province)	Yoklavich et al. 2011
	Swiftia pacifica (CA Province)	Yoklavich et al. 2011
	Eugorgia rubens (OR Province)	M. Yoklavich (unpubl.)
Pennatulacea	*Pennatula phosphorea* (CA Province)	Yoklavich et al. 2011
	Umbellula lindahli (OR Province)	M. Yoklavich (unpubl.)

seamount endemicity, but seamount communities may have unique structure that changes significantly with depth. The summit of Davidson Seamount (1299-1477 m) was characterized by the large bubblegum coral *Paragorgia arborea* and several hexactinellid sponge species (*Farrea occa*, *Heterochone calyx*, and *Chonelasma* sp.), while deeper zones (> 1600 m) were characterized by different corals (e.g., *Corallium* sp., *Chrysogorgia* spp., bamboo corals and black corals) and other abundant glass sponge species (McClain et al. 2010). Dense aggregations of large corals occurred on peaks and steep slopes, but were less abundant in valleys or on the flanks (Clague et al. 2010). Deep-sea coral records from Monterey Bay Aquarium Research Institute ROV surveys at San Juan and San Marco seamounts also revealed relatively high densities of gorgonian and antipatharian taxa that commonly reach large sizes (e.g., *Paragorgia* spp., certain isidid bamboo corals, and certain black corals).

In 2011 and 2012, two surveys were conducted on Canada's Bowie Seamount and on Cobb Seamount just outside the U.S. EEZ, by the Canadian Department of Fisheries and Oceans in collaboration with NMFS researchers. Information particularly on coral species occurring on Cobb Seamount was expanded during these cruises: 8 of the 11 species of soft corals (Alcyonacea) and all of the species of black corals (Antipatharia) were new records for Cobb Seamount (M. E. Clarke pers comm).

In addition to seamounts, the Southern California Bight has varied topography with rocky banks, island flanks and ridges, and submarine canyons. A survey on Farnsworth Bank on the seaward side of Catalina Island revealed that much of the rocky area is covered by the purple hydrocoral, *Stylaster californicus*, at depths to 66 m (Love et al. 2010). Bright (2007) analyzed video from surveys conducted with a manned submersible in 1995-2004 at depths of 97-314 meters at the "Footprint," a high-relief rocky bank south of Anacapa Island in the Channel Islands. Densities of corals > 20 cm in size were quantified. Gorgonians were relatively common (7/100 m^2) with a mean size of 30 cm. Black corals, predominantly *Antipathes dendrochristos*, also were relatively abundant (4/100 m^2). These densities were higher than reported by Tissot et al. (2006) for other banks in the region but much lower than more recent studies conducted in this area.

In 2010, deep-sea corals and sponges, along with fishes and seafloor habitats, were surveyed using the *Kraken II* ROV and the Seabed AUV at depths of 275-900 m on Piggy Bank near the Footprint Bank within the Channel Islands National Marine Sanctuary. At least 26 taxa each of corals and sponges were quantified (Yoklavich et al. 2011). This site comprised some of the highest densities of corals and sponges found in the West Coast region, ranging from 10-54 corals/100 m^2 and 22-97 sponges/100 m^2. The most abundant corals (depending on depth) included Christmas tree black coral (*A. dendrochristos*), mushroom soft coral (*Heteropolypus ritteri*), several species of Primnoidae and Plexauridae (*Swiftia* spp.), dense stands of *Lophelia pertusa* and cup corals (*Desmophyllum dianthus*), and the sea pen (*Halipteris californica*; only on soft sediment).

Visual surveys using a manned submersible in 2010 focused specifically on the biology and ecology of Christmas tree black corals on deep offshore banks within the Channel Islands National Marine Sanctuary (Yoklavich et al. 2013). This survey included habitats of high-relief rock boulders and outcrops and steep slopes of soft sediments and rock rubble at depths 110-475 m. The 272 Christmas tree corals observed during 11 dives were 5-200 cm in height, and most were healthy with little or no evidence of damage.

Over 23,500 deep-sea corals and 23,800 sponges also have been identified from archived video transects conducted from a manned submersible while surveying fishes on rocky banks off southern California from 1995 to 2008 (unpubl. data, M. Yoklavich, Fisheries Ecology Division, SWFSC, NMFS, NOAA). Various types of sea fans were among the most abundant corals, including gold corals (*Acanthogorgia* spp.), primnoids (*Plumarella longispina*), and plexaurids (*Swiftia* spp.). Cup corals and substantial colonies of *Lophelia pertusa* also were relatively abundant. Sponges from at least 18 taxa in a variety of shapes, sizes, and colors were observed. These data have been integrated into an existing geospatial database, which represents deep-sea corals and sponges in a diverse array of demersal habitats off southern California (M. Yoklavich, Fisheries Ecology Division, SWFSC, NMFS, NOAA).

A photographic database of 30,000+ images collected during ROV surveys 2003-2011 in the Southern California Bight recently has been reviewed (unpubl. data, P. Etnoyer & K. Stierhoff). Distinct depth-related patterns were observed in coral assemblage structure. Shallow depths (< 100 m) were dominated by *Leptogorgia chilensis*, *Stylaster californicus*, and *Eugorgia rubens*, while between 100 – 400 m *Plumarella* sp. *Lophelia pertusa*, *Acanthogorgia* sp., *Antipathes* sp., and *Paragorgia* sp. were the most abundant taxa.

Deep-sea corals also are associated with banks off Central California (e.g., Cordell Bank; Pirtle 2005, Etherington et al. 2011) and Oregon (e.g., Coquille Bank; Strom 2006, Stierhoff et al. 2011, Enticknap et al. 2013). At Coquille Bank, the most abundant gorgonian was the small red *Chromoplexaura marki* (Stierhoff et al. 2011, Williams 2013). At least one specimen was observed with catshark egg cases attached.

Deep-sea corals are often observed on hard substrata in canyons. Bianchi (2011) assessed invertebrate composition, habitat complexity, and ecological associations with structure-forming invertebrates and fishes in three submarine canyons: Astoria Canyon off northern Oregon, and Carmel and Ascension canyons off the central California coast. There were two distinct habitat assemblages associated with soft and hard substrata in all three canyons, and deep-sea corals were mostly small species at relatively low densities (0.4-5 per 100 m^2). In 2011, a survey was conducted using an AUV to assess the distribution of corals and sponges in Bodega Canyon, an area under consideration for possible expansion of the Cordell Bank National Marine Sanctuary.

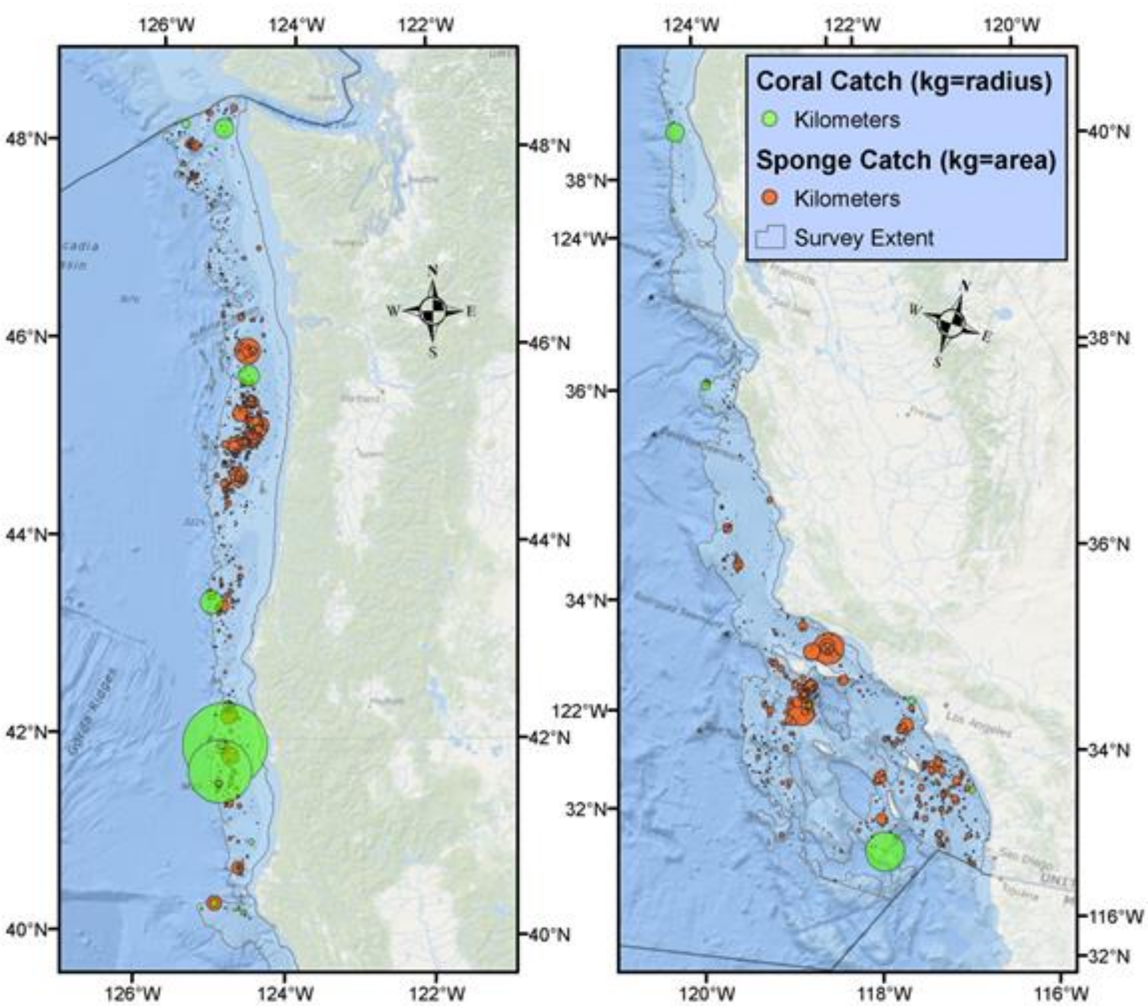
Much of this canyon had been categorized as hard substrata based on earlier multibeam sonar mapping. However, from the visual survey using the AUV, this area primarily was found to be mud draped rock with only occasional rocky outcrops and few small corals and sponges (Fruh et al. 2013).

Several studies have reported information on deep-sea coral and sponge habitats and demersal fishes within Monterey Bay National Marine Sanctuary, including Graiff (2008), Starr & Yoklavich (2008), Yoklavich & Starr (2010), Bianchi (2011), Knight (2011), Stierhoff et al. (2011), and Shester et al. (2012). Most of these studies were conducted in depths of 20-365 m using visual survey techniques from a manned submersible and ROVs. Scientists conducted baseline monitoring of seafloor communities in and out of eight newly designated MPAs on the central California in 2007 and 2008 (Yoklavich & Starr 2010). Direct observations were made of 134,000 fishes and 42,098 structure-forming invertebrates in 341,000 m^2 of seafloor habitats that included deep rocky banks and outcrops, canyons, cobble fields and mud flats. At least 16 taxa of corals and 14 taxa of sponges have been cataloged; abundant corals were *Stylaster californicus, Lophogorgia chilensis*, and *Heteropolypus ritteri*. *Lophelia pertusa* was relatively common in rocky steep areas. ROV surveys on Rittenberg Bank, Farallon Escarpment, and Fanny Shoals in the Gulf of the Farallones National Marine Sanctuary revealed twenty taxa of corals and sponges (GFNMS 2013).

Surveys of corals and sponges in Olympic Coast National Marine Sanctuary have received significant attention (Brancato et al. 2007; Bowlby et al. 2011a, 2011b). While the dominant corals in many areas were smaller species (e.g., *Swiftia* spp., *Calcigorgia beringi*, and *Stylaster* sp.), aggregations of larger species (*Paragorgia arborea* and *Primnoa pacifica*) also occurred in several locations.

The NMFS West Coast Groundfish Bottom Trawl Survey provides a broader view of deep-sea coral distributions at fishable depths (i.e., 55-1280 m) along the whole West Coast. In these surveys, most corals were identified to order. The largest catches of corals by weight occurred in 800-1200 m of water near the Oregon-California border (Figure 2). Taxa in these high-weight catches included gorgonian, black, and cup corals. This area also exhibited some areas of high bycatch of corals in the commercial trawl fishery as documented by the West Coast Groundfish Observer Program (PFMC 2012).

Figure 2. *Distribution of coral (green) and sponge (orange) catch weights (kg) for tows conducted as part of the Northwest Fisheries Science Center's annual West Coast Groundfish Bottom Trawl Survey (2001-2012). Symbol sizes are proportional to size of catch for all coral (excluding pennatulids) and sponge taxa recorded in the trawl net. Maximum sponge catches per tow within the time period were significantly higher than coral catches, so circle size is equal to radius (km) for corals and area (km²) for sponges. The survey extent (irregular polygon) is bounded by the exclusive economic zone to the north and south and by the 30- and 700-fm isobaths. Tows with no catch of either corals or sponges are not shown.*



c. Modeling Distribution and Abundance of Corals:

Modeling efforts relevant to the distribution and abundance of deep-sea corals on the West Coast are less than 10 years old, but the field is rapidly advancing. Five modeling efforts that incorporated either presence only or presence–absence data of various coral taxa and associated environmental factors off the west coast have been conducted recently. Bryan & Metaxis (2007) modeled habitat suitability for two gorgonian families (Primnoidae and

Paragorgiidae) in the Northeast Pacific from northern California to Alaska. Guinotte & Davies (2012) used presence-only data and a variety of environmental factors to develop predictive models of habitat suitability for several broad taxonomic groups of deep-sea corals for the entire West Coast region (see also Modeling Spotlight). Slope, temperature, salinity, and depth were important predictors for most taxa in their study. The majority of predicted suitable habitat for most taxa occurred within areas protected from bottom-trawling (e.g., 82% for black corals and 66% for calcaxonian gorgonians); however the majority of suitable habitat for holaxonian gorgonians (64%) was predicted to occur in unprotected areas. Both region-wide studies lacked high-resolution bathymetric and substratum data.

Deep-sea coral habitat modeling also has been conducted from data collected on Cordell Bank. Predictive models using presence-absence data and generalized linear models of *Stylaster* spp. and *Swiftia* spp. indicated that small-scale habitat features, including bathymetry, slope, and topographic position index, were important habitat predictors for both taxa (Etherington et al. 2011). Bathymetry and topographic position index had a positive influence, while slope had a negative influence on these taxa. Rugosity had a strong influence on the presence of *Stylaster* spp., which were associated with shallow, rocky habitats with high slope. Substratum type and aspect significantly contributed to the presence of *Swiftia* spp, which were predicted to be broadly distributed in deep water over a diversity of substratum types with low slope.

Krigsman et al. (2012) developed generalized linear models to predict the probability of occurrence of five commonly observed taxa (stony cup corals, hydroids, short and tall sea pens, and brittle stars) off southern California using presence-absence data from video transects in the Santa Barbara Channel. Predictive maps of probability of occurrence were produced using validated models and covariates of depth, location, and seafloor sediment types. Bottom habitat type was the strongest predictor of the occurrence of stony cup corals, which occurred predominantly on mixed sediment and rugose rock. As expected, sea pens were predicted to occur on unconsolidated sediments, but high probabilities of occurrence were predicted only in areas where bottom trawling was relatively low.

Most recently, models have been developed to predict the densities of the black coral (*A. dendrochristos*) using environmental factors such as depth, ocean currents, and productivity throughout the Southern California Bight (Huff et al. 2013). Predicted densities have been mapped in relation to the extensive system of MPAs throughout the Bight.

II.2.ii - Sponges

a. Taxonomy:

There have been few systematic studies of sponge taxa for the U.S. West Coast. Austin et al. (2007) produced a list of sponges for the northeast Pacific, and Lee et al. (2007) compiled current information on the sponges of California. Many of the species from the region were described from collections conducted in the late 1800s and early to mid-1900s.

From surveys off southern California, a new species of demosponge, *Cladorhiza pteron,* was collected from 1,442 m depth on San Juan Seamount, and also was seen at Rodriguez Seamount (Reiswig & Lee 2007). Several of 13 sponges collected during an ROV survey on Piggy Bank off southern California were new records for the northeastern Pacific and likely new species (pers. comm., W. Austin, Khoyatan Marine Laboratory, Sidney, BC; Yoklavich et al. 2011). In addition to new records and new species that have been reported since the 2007 report, several recently published taxonomic guides and compilations have improved the identification of sponges and corals on the West Coast and Alaska (Burton & Lundsten 2008, Stone et al. 2011).

b. Sponge Distribution:

Sponges occurred in about one quarter of all trawls by the NMFS West Coast Groundfish Bottom Trawl Survey (Table 1), though most could only be identified as "Porifera." Compared to corals, the focus on identifying sponges is very recent. The identified sponges were predominantly glass sponges (Class Hexactinellida) and demosponges in the genus *Suberites.* The highest weight of sponges per tow occurred in relatively discrete areas, especially off the coast of northern Oregon and around the northern Channel Islands, CA (Figure 2).

In general, taxonomic information on sponges is lacking, and species identification of sponges from visual surveys is even more difficult than for corals. Consequently, much of the distributional information is based on morphotypes (e.g., vase, shelf, foliose). Sponges have been reported from nearly all the surveys in rocky habitats off the West Coast that reported deep-sea corals. In many cases sponges were larger and more abundant than corals (other than sea pens). Bianchi (2011) reported higher densities and larger sizes for sponges than for corals in Astoria, Ascension and Carmel Canyons. Mean densities of sponges on southern California banks were reported to be 2.5 times higher than corals (Bright 2007). Sponges on Rittenburg Bank were particularly abundant, and occurred in larger sizes and densities than corals (GFNMS 2013). The most abundant sponges on Piggy Bank (Yoklavich et al. 2011) and other southern California banks (Yoklavich unpubl.) generally were mound, foliose, upright flat, vase, and barrel morphotypes.

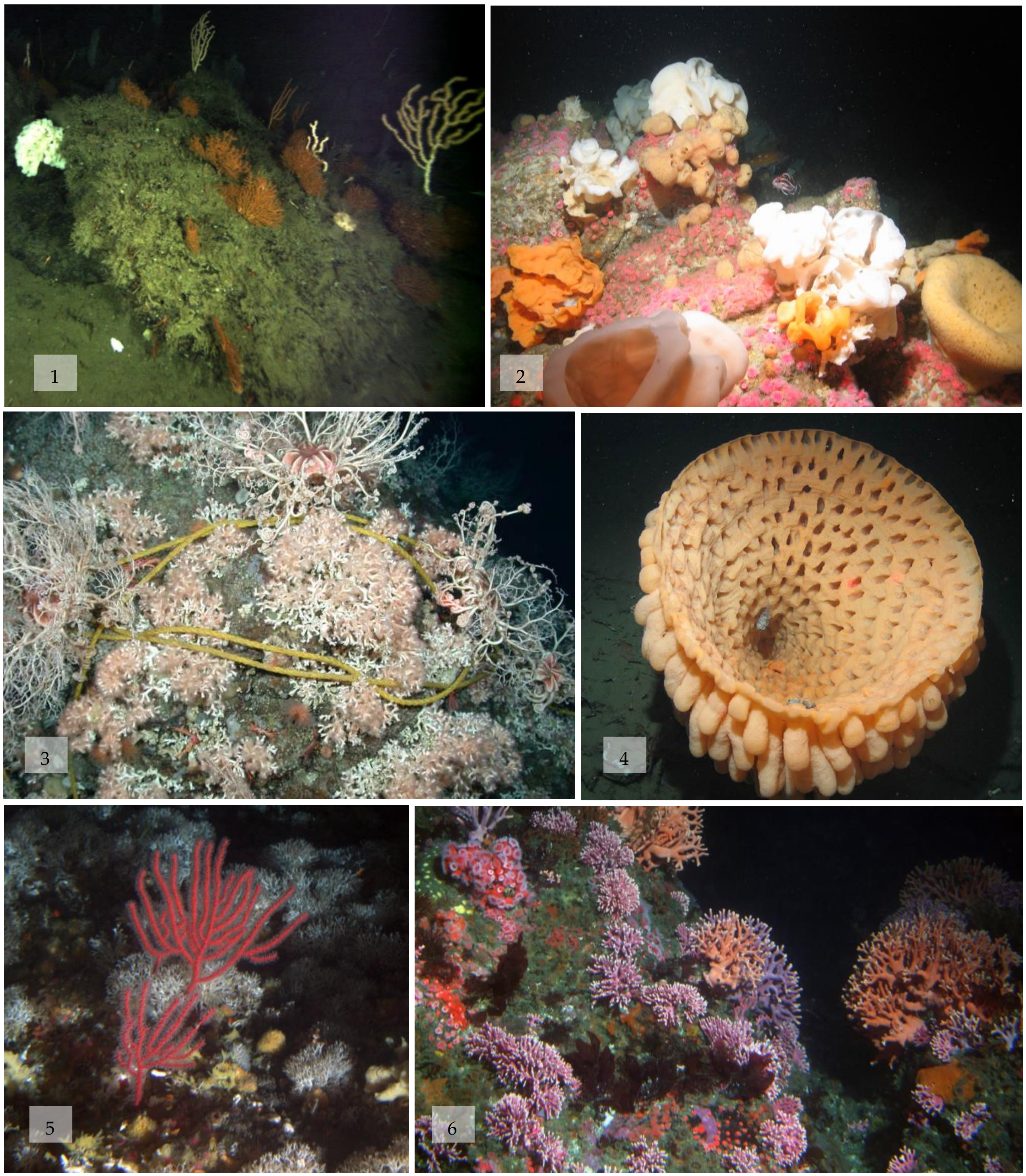
A unique habitat dominated by hexactinellid sponges has been discovered in the vicinity of methane seeps off Grays Harbor, Washington (Salmi et al. 2011). NMFS bottom trawl surveys in this area in 1983 and 1985 reported significant catches of sponges, up to 907 kg in a single ~ 1.5 km trawl haul. Glass sponges identified from this survey included *Aphrocallistes vastus*, *Hyalonema* sp., and rossellid sponges. In 2010 the distribution of the sponges and associated fishes was quantified during an AUV survey (Clarke & Fruh 2012). The seafloor was of low relief and much of it was covered with sediment. On five dives the densities of sponges ranged from 10 to 99 sponges per 100 m^2 and included the structure-forming glass sponges *Heterochone calyx*, *Aphrocallistes* sp., and a demosponge, *Poecillastra* sp. Many of the rockfishes in the area were associated with sponges, and a high percentage of the fishes either were touching or within one body length of these structure-forming sponges.

Sponge reefs have been described in several areas of British Columbia (Conway et al 2001). Similar to the area off Grays Harbor, *Heterochone calyx* and a species of *Aphrocallistes* are some of the most dominant species. However, the densities of sponges in the Grays Harbor area are much lower than found at the areas described as sponge reefs in British Columbia, Canada. In those areas, densities can typically be on the order of 2000 per 100 m^2 (Leys et al 2004) while off Grays Harbor the densities ranged up to 99 sponges per 100 m^2.

II.3 –Species Associations with Deep-Sea Corals and Sponges

While demersal fishes co-occur with various deep-sea corals and sponges, particularly in rocky areas, the extent and function of such relationships have yet to be fully described and quantified. Fishes occasionally have been seen resting inside, underneath, and beside corals and sponges during visual surveys conducted with manned submersibles, ROVs, and AUVs off the west coast (Brancato et al. 2007, Bianchi 2011, Clarke & Fruh 2012). Such associations, particularly of rockfishes (*Sebastes* spp.) with some of the same species of corals or sponges, have also been reported off British Columbia (Du Preez & Tunnicliffe 2011) and Alaska (Stone & Shotwell 2007, Rooper et al. 2007). However, there was little evidence of a functional relationship between fishes and structure-forming invertebrates that co-occurred in various habitats throughout southern California (Tissot et al. 2006). Bright (2007) documented the co-occurrence of several species of fishes with structure-forming invertebrates on the "Footprint" of the Channel Islands off southern California. In recent visual surveys conducted using an ROV and manned submersible on nearby seamounts in southern California, there were few instances of fishes associated with corals and sponges, and benthic invertebrates more commonly occurred on dead *Antipathes dendrochristos* (Christmas tree black corals) and *Heterochone calyx* (goblet sponges) than on living ones (Yoklavich et al. 2011, Yoklavich et al. 2013). Bianchi (2011) also reported few fishes in close proximity with structure-forming invertebrates (including corals and sponges) in submarine canyons off Washington and central California, with most fishes occurring ≥1 m away from the invertebrate. The extent of fish and invertebrate associations may depend on the densities of fishes and structure-forming invertebrates and on the local availability of rocky crevices in which fishes take shelter. Further research and critical evaluation are needed to clarify the role that corals and sponges serve as essential habitat for fishes in demersal communities off the West Coast.

Corals and sponges of the West Coast: 1) Deep-sea corals off Northern California at 750 m depth, including Swiftia *sp.,* Paragorgia *sp.,* Parastenella *sp., and a hexactinellid sponge. 2) Habitat dominated by deepwater sponges at Rittenburg Bank, Gulf of the Farallones National Marine Sanctuary. 3) Fishing gear line wrapped around* Lophelia pertusa *coral on Seamount 109 in the Channel Islands. 4)* Heterochone calyx *glass sponge from the Channel Islands National Marine Sanctuary. 5) Small colonies of* Swiftia *sp. and* Lophelia pertusa *on Piggy Bank off Southern California. 6) Stylasterid corals on rocky banks in the Channel Islands.*



II.4 – Mapping Potential Distribution of Deep-Sea Corals and Sponges

One of the impediments to identifying areas that are likely to have abundant populations of corals and sponges is a lack of high-resolution bathymetry, backscatter, and associated interpreted substratum types on the seafloor in deep water on a coastwide scale. A significant amount of new information on physical habitat has been collected off the Pacific Coast over the last decade, including at least 261 sources of seafloor imagery complied since the last regional habitat maps were published in 2005 (NMFS 2013). Some of this information has been used by NOAA's DSCRTP to target coral and sponge surveys. Most of the new information has been consolidated into Pacific coastwide comparative maps of bathymetry, acoustic coverage, seafloor substrata, and biogenic habitat observations in 2005 and 2011 for the EEZ off Washington, Oregon, and California in support of the PFMC 5-year review of EFH for Pacific coast groundfish (PFMC 2012). An online data catalog of this information is available: http://efh-catalog.coas.oregonstate.edu/overview/.

The Office of Ocean Exploration mapped the Mendocino Ridge and specific areas in and around the Gulf of the Farallones, Cordell Bank, and Monterey Bay national marine sanctuaries. A new ridge southwest of Santa Rosa Island in the Channel Islands National Marine Sanctuary was identified during these multibeam surveys conducted from the NOAA R/V *Okeanos Explorer*. The DSCRTP funded a research project to explore this newly charted ridge and to evaluate the depth stratification of deep-sea corals. Several studies supported by the DSCRTP have mapped various areas in preparation for targeted ROV or AUV surveys. Additional bathymetric mapping in the Olympic Coast and Gulf of the Farallones National Marine Sanctuaries was completed. Multibeam surveys were conducted in preparation for AUV surveys of a sponge area off Grays Harbor, Washington and off Oregon.

In addition to these federally supported efforts, all of the seafloor within California's state waters (to 3 miles offshore) and large portions of Oregon state waters have been mapped with high-resolution multibeam sonar. These data have been coupled with predictive models to map the occurrence of deep-sea corals.

II.5 - Research Priorities

Whitmire & Clarke (2007) identified a number of deep-sea coral research priorities for the region. In 2010, DSCRTP held a workshop (NOAA 2010) that supported and expanded on these research priorities for the West Coast (see below). While research since 2007 has made progress in many of these areas, most of the identified priorities remain.

1) *Identify deep-sea coral and sponge species, and map and characterize their distribution, abundance, densities, and diversity throughout the California Current LME.*
    - A great deal of new information is now available on coral presence, but

very few studies report abundances and densities in ways that can be compared across studies. Information on the identification of sponges at the species level is particularly weak.

- The lack of coastwide seabed mapping information at a spatial scale relevant to demersal communities (i.e., meter resolution) remains an impediment for predictive models of habitat suitability and of coral and sponge distribution and abundance. Improvements to seafloor maps also will yield efficient design of surveys to target areas with a high likelihood of containing abundant populations of corals and sponges. Additionally, much of the existing interpreted habitat mapping needs validation.

2) *Determine the ecological roles of deep-sea corals and sponges, especially the nature of associations between other invertebrates and fishes with deep-sea corals and sponges.*

- While co-occurrence of sponges and corals with some species of fishes and other invertebrates has been documented, the extent and nature of those associations has not been addressed. This is especially important from a management standpoint in relation to roles that structure-forming species might play as EFH for demersal fishes.

3) *Understand the basic biology of deep-sea corals, including taxonomy, age structure, growth, gender, population connectivity, and life histories.*

- There have been few new studies on the life history of west coast deep-sea corals. Flint et al. (2007) reported on the reproductive ecology of a deepwater solitary scleractinian coral. Andrews et al. (2009) and Hill et al. (2011) reported on growth and age of bamboo corals (Family: Isididae) from seamounts off California. Estimates of bamboo coral ages ranged from 98 ± 9 years (Andrews et al. 2009) to over 300 years (Hill et al. 2011).

- As in most other areas, information on the biology of deep-sea sponges lags far behind that of deep-sea corals.

4) *Develop models to predict distribution and abundance of deep-sea corals and sponges.*

- There is a particular need to incorporate bottom-substratum information into region-wide models and to model corals at the species level (rather than broad groupings of species).

- To date there have been no models of deep-sea sponge distributions off the west coast.

- Better understanding of abiotic and biotic habitat requirements will not only improve habitat-suitability modeling, but will result in models that better predict impacts of changing ocean conditions due to acidification and climate change.

5) *Understand anthropogenic and natural impacts on deep-sea coral ecosystems.*

   - Develop baseline indices of health and condition of corals and sponges at individual and community levels.
   - Better quantify bycatch of corals and sponges in commercial fisheries.

6) *Further synthesize and understand existing information on deep-sea corals and sponges.*

   - Bottom trawl surveys and fisheries bycatch provide valuable information on corals and sponges, but identification of these taxa is slow and inadequate. This will improve as progress is made in developing methods of genetic identification.

7) *Understand deep-sea corals' ability to recover from a variety of stressors.*

   - The impacts and recovery rates of corals and sponges from various stressors are largely theoretical because it is difficult to conduct controlled experiments with these fragile deep-sea organisms. As methodologies improve, particularly relevant to climate change and ocean acidification, we are hopeful that experimental studies will offer valuable insight.

8) *Utilize deep-sea corals to discern past climate conditions.*

   - There have been gains in determining paleoclimate information from tropical corals but information from deep-sea corals has been slow in coming.

9) *Evaluate the efficacy of existing management measures.*

   - Recent analysis suggests a majority of coral occurrences on the continental shelf and upper slope are outside existing conservation areas that are meant to protect seafloor habitats from interactions with certain bottom-contact fishing gears (NMFS 2013). In contrast, MPAs on the lower slope appear to protect a large majority of known coral (excluding pennatulaceans) and sponge habitats from adverse impacts of bottom trawling. We need to evaluate the overall efficacy of all management measures meant to protect deep coral and sponge ecosystems.

10) *Improve tools and methods for studying deep-sea corals (e.g., new technologies; new applications for existing technologies; and develop best practices for research).*

   - DNA analysis has become a standard tool to assist in species identification and collaborations between observer, survey and research programs are helping to increase the number of samples of corals and sponges available for analysis.

III. Update on Management of Deep-Sea Corals and Sponges

III.1. New Information on Impacts and Stressors

III.1.i - Fishing

Fishing activities were highlighted in the 2007 report as one of the most significant potential stressors to deep-sea coral and sponge communities, and impacts from bottom-contact gears, particularly bottom trawls and longlines, remain the most significant documented threat. Recent and ongoing activities by management agencies have focused on minimizing these impacts; however, quantifying these impacts is difficult. Bycatch and in situ evidence of fishing gears entangling corals and sponges (e.g., Brancato et al. 2007, Bowlby et al. 2011a, 2011b) continue to be the most direct evidence of adverse fishing interactions. As observer coverage increases and as fishery observers identify corals and sponges more consistently, bycatch data could be a reliable indicator of trends in fishing impacts.

There have been few in situ studies off the West Coast that relate observations of trawling to deep-sea coral or sponge habitats. Graiff (2008) analyzed the megafaunal invertebrate communities at three sites on the continental shelf and upper slope off central California, and examined the potential effects of fishing. It was difficult to discern fishing impacts from environmental effects on distribution of invertebrates in part because of the fairly course resolution of fishing effort information. Hixon & Tissot (2007) compared benthic communities in trawled and untrawled mud habitat off Oregon. Sea pens (*Stylatula* spp.) dominated untrawled bottoms, but were nearly absent on trawled bottoms. Hannah et al (2010) also found that densities of sea pens (*Halipteris* spp.) were significantly lower in areas off Oregon that were heavily-trawled for shrimp, compared to lightly-trawled areas. To more clearly quantify impacts, controlled in situ experimentation may be necessary.

Deep-sea corals and sponges are recorded as bycatch in both the commercial trawl fishery and fixed gear fisheries (as documented by the West Coast Groundfish Observer Program). Taxonomic identification of commercial bycatch is usually limited to "sea pens and sea whips" (i.e., pennatulaceans), "other coral," and "sponge." These observations document ongoing interactions between commercial fishing gear and deep-sea corals and sponges.

Since June 2006, observers of the bottom trawl fishery have recorded a doubling of encounters with sponges and pennatulaceans, while the frequency of occurrence of other corals remained unchanged (Table 3, PFMC 2012). Also, sponge bycatch appears to have increased almost 5-fold while bycatch of corals had decreased 4-fold. While these trends in bycatch may seem peculiar, they likely highlight one of the issues in examining observer data over longer time frames. Taxonomic identification of these organisms is challenging for non-experts, and training has enhanced their ability only in recent years to more accurately distinguish corals from sponges. Other possible explanations of these bycatch patterns are changes in fishing patterns due to spatial management of the trawl fishery and better recording of bycatch due to increased interest in conservation of these organisms.

Fixed bottom-contact fishing gears, such as bottom-set longlines and gill nets can also impact coral and sponge habitats, though the area contacted is likely to be much smaller than for bottom trawls. Surveys in the Olympic Coast National Marine Sanctuary have documented impacts to biogenic habitats from bottom longline fishing gear (Brancato et al. 2007, Bowlby et al. 2011a, 2011b). For fixed gear fisheries, corals and sponges are recorded in the catch infrequently by the West Coast Groundfish Observer Program (PFMC 2012), so it is difficult to examine trends in bycatch. The transition to full observer coverage with implementation of catch shares in the groundfish fishery should someday afford a more meaningful analysis of bycatch trends. Summaries and maps of bycatch of corals and sponges are available on the Consolidated GIS Data Catalog and Online Registry for the 5-Year Review of Pacific Coast Groundfish EFH: http://efh-catalog.coas.oregonstate.edu/overview/.

For the five-year review of Pacific Groundfish EFH conducted by NMFS and the PFMC, data were compiled on fishing effort in three major

Table 3. *(modified from PFMC 2012) Summary of coral and sponge bycatch for observed tows using bottom trawls as part of the West Coast Groundfish Observer Program, comparing two time periods: "Before" (3 Jan 2002 – 11 Jun 2006) and "After" (12 Jun 2006 – 31 Dec 2010) implementation of Amendment 19 regulations. "#" denotes number of hauls; "FREQ" denotes ratio of hauls with positive catch of taxon to total hauls observed; "Weight" denotes catch (kg); "CPUE" denotes catch per unit effort (kg/km). Haul counts represent only those hauls where corals or sponges were present in the catch. Pennatulaceans are recorded separately from other corals, as they are relatively easy to distinguish and generally occur in different habitats. Annual Observer Program coverage of the limited-entry bottom trawl sector can be found online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observer/sector_products.cfm.*

	BEFORE				AFTER			
TAXON	**#**	**FREQ**	**Weight**	**CPUE**	**#**	**FREQ**	**Weight**	**CPUE**
coral	319	2.0%	4,223	2.2E-02	335	1.8%	997	4.1E-03
sea pen	198	1.3%	105	5.5E-04	474	2.5%	66	2.7E-04
sponge	469	3.0%	4,547	2.4E-02	1,444	7.6%	20,585	8.5E-02
Combined	903	5.7%	8,875	4.7E-02	2,003	10.5%	21,648	8.9E-02

gear sectors: bottom trawl, midwater trawl and fixed gears (see PFMC 2012). The intensity and extent of fishing effort for each gear type was mapped for two time periods bracketing implementation of EFH regulatory measures in June 2006. Mapping of bottom trawl intensity showed discrete areas where fishing effort either increased or decreased after June 2006, but in general effort appears to have moved from the continental shelf to deeper slope habitats. This shift in effort to deeper waters was most likely caused not by EFH regulations but by the rockfish conservation area, a time-area closure designed to reduce bycatch of overfished groundfish. In fact, the analysis showed that EFH conservation areas did not significantly displace bottom trawling primarily because little (<5% per year) bottom trawling occurred within these areas for the 4.5 years prior to implementation (NMFS 2013). In addition to the trawl restrictions in the rockfish conservation area, a footrope size restriction in late 2000 likely altered behavior of the bottom trawl fleet away from high-relief rocky habitats (Hannah 2003, Bellman et al. 2005). It is these types of habitats that many of the EFH closures were designed to protect.

Midwater, or pelagic, trawls do occasionally contact the seafloor, but observers have recorded very little bycatch of corals or sponges since records began in 2000. In fact, corals and sponges have been recorded in only 0.4% of tows between 2000 and 2010, totaling only 38.4 kg of bycatch over that time frame (PFMC 2012).

For fixed gears (e.g., longlines, pots, other hook-and-line), the annual proportion of effort within areas now closed to bottom trawls has fluctuated between 4 and 18% (NMFS 2013). This and the fact that observer coverage of many fixed gear sectors was relatively low compared to the trawl sector during this time period suggests it may be difficult to discern changes to fishing behavior due to implementation of EFH closures. Full observer coverage in the new catch shares program in the region may someday facilitate a more thorough analysis of how various regulatory measures may have altered fishing effort, and possible correlations in changes in bycatch rates of deep-sea corals and sponges.

III.1.ii– Other Stressors

In addition to fishing, stressors such as sedimentation caused by oil and gas exploration, development and deployment of gas pipelines and communication cables, mining, pollution, and climate change were identified in the 2007 report. These continue to be important when considering the health and sustainability of deep-sea corals and sponges; however, little new information exists on specific impacts. A moratorium on new leases for offshore drilling for petroleum has existed in both federal (since 1984) and California state waters (since 1969); however, drilling continues on existing leases. A number of new submarine telecommunication cables have been installed in the region since 2007; however, only one known study (Brancato & Bowlby 2005) and some other anecdotal evidence suggest little impact on deep-sea corals and sponges. Finally, wind and wave energy projects have been considered along the West Coast, with a pilot wave energy facility permitted off Reedsport, Oregon. This facility underwent an extensive review by both state and federal agencies to ensure little impact to sensitive habitats. In the end, the installation company abandoned the project for lack of funding. Other sites would also be nearshore and should warrant a similar review, as deployment and operational aspects of these projects can have significant impact on the seabed, and should be evaluated for their potential impact on deep-sea corals and sponges (Boehlert et al. 2013). Despite growing interest from the energy sector, a moratorium on new federal wave energy permits for Oregon was put in place in 2008.

Since 2007, the specific role of climate change in ocean acidification has become more evident. Ocean acidification is predicted to affect corals worldwide, but maybe more immediately in the North Pacific (Guinotte et al. 2006). In the California Current System, upwelling brings acidified water up along the continental shelf, reaching the surface at some locations (Feely et al. 2008). Aragonite saturation levels (ΩA) on the shelf may be among the lowest in the world (Manzello 2010), which is expected to impact calcification rates for many corals. There have, however, been no direct studies on the effects of acidification on west coast corals. Teck et al. (2010) surveyed 107 experts to quantitatively estimate the relative vulnerability of California Current ecosystems. For hard slope ecosystems, those most likely to support deep-sea corals and sponges, the stressors with the highest scores were ocean acidification and "demersal destructive fishing." A recent threat assessment for the Davidson Seamount Management Zone identified ocean acidification, sea temperature rise, and vessel traffic (especially oil tankers) as the highest level threats to the seamount's resources (NOAA 2012).

III.2. New or Planned Management Actions

Since 2007, a few management measures have been enacted to expand protection of areas where corals and sponges likely occur. The most significant action occurred in 2009, when the Monterey Bay National Marine Sanctuary was expanded to include Davidson Seamount off the coast of central California (15 CFR § 922.130). This undersea mountain, whose crest is approximately 1,250 m below the sea surface, is home to a diverse assemblage of dense, extensive deep-sea corals and sponges (Clague et al. 2010). The seamount was previously protected (in 2006) from fishing with bottom contact gear (or any other gear) below 3,000 feet (~ 1,000 m) by NMFS and the PFMC. Sanctuary designation provided additional protection against activities that might impact biological or non-biological sanctuary resources below 3,000 feet within the 2,006 km^2 Davidson Seamount Management Zone is prohibited without a permit. NOAA is also considering whether to expand the boundaries of Cordell Bank and Gulf of the Farallones national marine sanctuaries, which could include areas with significant coral and sponge resources.

The State of California, under the Marine Life Protection Act, has designated 94 MPAs in state waters with varying levels of protection, all of which comprise a network of protection along the entire California coast. These areas are enhancing the protection of corals and sponges in California State waters, and associated monitoring and research in these areas has added to our knowledge of the distribution of corals and sponges (Starr & Yoklavich 2008, Yoklavich et al. 2010).

As part of the PFMC 5-year review of Pacific coast groundfish EFH, a large amount of new data has been summarized and has greatly expanded our knowledge of the distribution of corals and sponges in the region (PFMC 2012, NMFS 2013). This review includes maps of the boundaries of current MPAs off the west coast. As part of this review, the Council received proposals from various sectors of the public to modify Pacific groundfish EFH. Most of these proposals include goals to protect deep-sea coral and sponge habitats.

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (P.L. 109-479) directed NOAA to implement a Deep-sea Coral Research and Technology Program and allowed the designation of deep coral zones. It also gives regional fishery management councils new discretionary authority to protect corals and minimize interactions with fishing gears. This program funded research that has added to the information on corals and sponges on the West Coast. That information combined with a variety of continuing research projects conducted by other institutions has enhanced our knowledge of these resources. In addition, NMFS recently has developed a Habitat Assessment Improvement Plan (HAIP) (NMFS 2010) that outlines research priorities and procedures to improve habitat assessments. Many research activities associated with the HAIP will provide information to aid in our understanding and protection of deep-sea corals and sponges.

IV. Conclusions

Since 2007 there has been significant progress in gathering and organizing information on seafloor habitats and species, which has advanced our understanding of deep-sea coral abundance and distribution off the U.S. west coast. Most recently, much of this has been catalyzed by NOAA's DSCRTP and data efforts associated with the PFMC 5-year review of Pacific coast groundfish 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), larger gorgonian species may occur in patches of high density. Since 2007, there has been increased interest in sea pens, which occur on soft sediments and therefore are much more widespread than other corals.

Information on deep-sea sponges is much more rudimentary than our understanding of corals, and the data on sponges in this chapter is cursory at best. Most sponges, when recorded at all, are often not identified below the Phylum level. As elsewhere in the world, deepwater species are primarily glass sponges (Class Hexactinellida) and demosponges (Class Demospongiae). Still, it appears that in many hard-bottom habitats in deeper waters, sponges are more abundant than corals. Some habitats are dominated by sponges, such as glass sponge grounds, while corals are generally absent. The abundance of sponge habitats is reflected in their predominant occurrence in catches from the NMFS West Coast Groundfish Bottom Trawl Survey and in bycatch in bottom trawl fisheries as recorded by the West Coast Groundfish Observer Program.

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 (Figure 2). Among other stressors, ocean acidification will be a major long-term concern for some corals, although studies of specific impacts to corals in the region are lacking.

Since 2007, there have been very significant conservation actions in state waters (e.g., new MPAs) where corals and sponges are present. With the exception of the expansion of Monterey Bay National Marine Sanctuary to include Davidson Seamount, there have not been major management actions in the EEZ since 2007 that serve to protect deep-sea coral and sponge ecosystems.

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VI. Literature Cited

Allen MJ, Smith GB (1988) Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 66, 151 p.

Andrews AH, Stone RP, Lundstrom CC (2009) Growth rate and age determination of bamboo corals from the northeastern Pacific Ocean using refined 210Pb dating. Mar. Ecol. Prog. Ser. 397: 173–185

Austin W, Ott B, McDaniel N, Romagosa P (2007) Sponges of the cold temperate Northeast Pacific. Accessed 12/2013 at: http://www.mareco.org/KML/Projects/NEsponges_content.asp

Belcik FP (1977) A distribution study of the octocorallia of Oregon. Publ. Seto Mar: Biol. Lab., XXIV (1/3), 49-52

Bellman MA, Heppell SA, Goldfinger C (2005) Evaluation of a US west coast groundfish habitat conservation regulation via analysis of spatial and temporal patterns of trawl fishing effort. Can. J. of Fish. and Aquat.Sci. 62: 2886–2900.

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. 68 pp.

Boehlert G, Braby C, Bull AS, Helix ME, Henkel S, Klarin P, Schroeder D, eds. (2013) Oregon Marine Renewable Energy Environmental Science Conference Proceedings. U.S. Department of the Interior, Bureau of Ocean Energy Management, Cooperative Agreement with Oregon State University M12AC00012. OCS Report BOEM 2013-0113. 134 pp.

Bowlby CE, Brancato MS, Bright J, Brenkman K, Boutillier J (2011a) A characterization of deep-sea coral and sponge communities on the continental shelf of northern Washington, Olympic Coast National Marine Sanctuary, using a remotely operated vehicle in 2008. A preliminary report to Pacific Fishery Management Council Essential Fish Habitat Review Committee, 56 p.

Bowlby CE, Brancato MS, Bright J, Brenkman K, Hyland J (2011b) A characterization of deep-sea coral and sponge communities on the continental shelf of northern Washington, Olympic Coast National Marine Sanctuary, using a remotely operated vehicle in 2006. A preliminary report to Pacific Fishery Management Council Essential Fish Habitat Review Committee, 76 p.

Brancato MS, Bowlby CE (2005) Survey of fishing gear and fiber optic cable impacts to benthic habitats in the Olympic Coast National Marine Sanctuary. Pages 629-630 in P.W. Barnes and J.P. Thomas, editors. Benthic habitats and the effects of fishing. American Fisheries Society Symposium 41, Bethesda, Maryland.

Brancato MS, Bowlby CE, Hyland J, Intelmann S, Brenkman K (2007) Observations of deep coral and sponge assemblages in Olympic Coast National Marine Sanctuary, Washington. Cruise Report: NOAA Ship McArthur II Cruise AR06-06/07. Marine Sanctuaries Conservation Series NMSP- 07-04. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program, Silver Spring, MD. 48 pp. http://sanctuaries.noaa.gov/science/conservation/bowlby.html

Bright J (2007) Abundance and distribution of structure-forming invertebrates and their association with fishes at the Channel Islands "Footprint" off the southern coast of California. M.S. Thesis, Washington State University, Vancouver, WA. 66 p.

Briggs JC, Bowen BW (2012) A realignment of marine biogeographic provinces with particular reference to fish distributions. J. Biogeogr. 39:12–30.

Bryan T, Metaxas A (2007) Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. Mar. Eco. Prog. Ser. 330: 113–126.

Burton E, Lundsten L (2008) Davidson Seamount taxonomic guide. Marine Sanctuaries Conservation Series ONMS-08-08. 145 pp.

Cairns SD (2007) Calcaxonian octocorals (Cnidaria; Anthozoa) from Eastern Pacific Seamounts. Proceedings of the California Academy of Sciences. 58, (25): 511–541.

Clague D, Lundsten L, Hein J, Paduan J, Davis A (2010) Mountain in the sea spotlight 6: Davidson Seamount. Oceanography 23(1):126-127.

Clarke ME, Fruh E (2012) A characterization of the sponge community in the region of Grays Canyon, WA from a survey using an autonomous underwater vehicle October 2010. A Report to NOAA's Deep-Sea Coral Research and Technology Program. 62 pp http://data.nodc.noaa.gov/coris/library/NOAA/CRCP/other/other_crcp_publications/DeepSeaCoralRT/Site-char-report-2010-Grays-Canyon.pdf

Conway K, Krautter M, Barriem JV, Neuweiler M (2001) Hexactinellid Sponge Reefs on the Canadian continental shelf: A unique "living fossil". Geoscience Canada 28: 71-78.

DeVogelaere AP, Burton EJ, Trejo T, King CE, Clague DA, Tamburri MN, Cailliet GM, Kochevar RE, Douros WJ (2005) Deep sea corals and resource protection at the Davidson Seamount, California, U.S.A. In: Freiwald A, Roberts JM (eds) Cold-water corals and ecosystems. Springer-Verlag, Berlin, Heidelberg, pp 1189-1198.

Du Preez C, Tunnicliffe V (2011) Shortspine thornyhead and rockfish (Scorpaenidae) distribution in response to substratum, biogenic structures and trawling. Mar. Ecol. Prog. Ser. 425: 217–231.

Enticknap B, Shester G, Gorny M, Kelley M (2013) Important ecological areas: seafloor habitat expedition off the southern Oregon coast. Oceana publication, Washington, DC.

Etherington LL, van der Leeden P, Graiff K, Roberts D, Nickel B (2011) Summary of deep sea coral patterns and habitat modeling results from Cordell Bank, CA. Technical Report. NOAA– Cordell Bank Marine Sanctuary. Olema, CA.

Etnoyer P (2008) A new species of *Isidella* bamboo coral (Octocorallia: Alcyonacea: Isididae) from northeast Pacific Seamounts. Proceedings of the Biological Society of Washington, 121(4): 541-553.

Feely RA, Sabine CL, Hernandez-Ayon JM, Ianson D, Hales B (2008) Evidence for upwelling of corrosive "acidified" water onto the continental shelf. Science. 320: 1490-1492.

Flint HR, Waller G, Tyler PA (2007) Reproduction in *Fungiacyathus marenzelleri* from the northeast Pacific Ocean. Marine Biology. 151: 843-849.

Fruh E, Clarke ME, Whitmire C (2013) A characterization of the coral and sponge community in Bodega Canyon off the coast of California from a survey using an autonomous underwater vehicle. A report to NOAA Deep-Sea Coral Research and Technology Program. 40 pp.

Gonzalez-Romero S, Reyes-Bonilla H, Cairns SD. 2009. Range extensions of three species of the family Caryophylliidae (Scleractinia) in the eastern Pacific Ocean. Marine Biodiversity Records, doi:10.1017/S1755267209001031. Vol. 2:1-2; e108.

Graiff KW (2008) The abundance and distribution of megafaunal marine invertebrates in relation to fishing intensity off central California. M.S. Thesis. Washington State University, Vancouver, WA. 60 pp.

Guinotte JM, Orr J, Cairns SD, Freiwald A, Morgan L, George R (2006) Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals? Frontiers in Ecology and Environment 4:141-146.

Guinotte JM, Davies AJ (2012) Predicted deep-sea coral habitat suitability for the U.S. West Coast. Final Report to NOAA Deep-Sea Coral Research and Technology Program, 85 pp.

Gulf of the Farallones National Marine Sanctuary (GFNMS) (2013) A proposal to consider options for new EFH HAPC(s) and conservation areas submitted by Gulf of the Farallones National Marine Sanctuary. 42 pp.

Hannah RW (2003) Spatial changes in trawl fishing effort in response to footrope diameter restrictions in the U.S. West Coast bottom trawl fishery. North American Journal of Fisheries Management 23:693–702.

Hannah RW, Jones SA, Miller W, Knight JS (2010) Effects of trawling for ocean shrimp (*Pandalus jordani*) on macroinvertebrate abundance and diversity at four sites near Nehalem Bank, Oregon. Fish. Bull. 108:30–38.

Herrera S, Baco A, Sanchez JA (2010) Molecular systematics of the bubblegum coral genera (Paragorgiidae, Octocorallia) and description of a new deep-sea species. Molecular Phylogenetics and Evolution. 55:123-135.

Hill TM, Spero HJ, Guilderson T, LaVigne M, Clague D, Macalello S, Jang N (2011) Temperature and vital effect controls on bamboo coral (*Isididae*) isotope geochemistry: A test of the "lines method", Geochem. Geophys. Geosyst., 12, Q04008, doi:10.1029/2010GC003443.

Hixon MA, Tissot BN (2007) Comparison of trawled vs. untrawled mud seafloor assemblages of fishes and macroinvertebrates at Coquille Bank, Oregon. J. Exp. Mar. Biol. Ecol. 344: 23-34.

Horvath E (2011) An unusual new sea fan from the northeastern Pacific Ocean (Cnidaria: Octocorallia: Gorgoniidae). Proc. of Biol. Soc. of Washington. 124.1:45-52

Huff DD, Yoklavich MM, Love MS, WattersDL, Chai F, Lindley ST (2013) Environmental factors that influence the distribution, size, and biotic relationships of the Christmas tree coral *Antipathes dendrochristos* in the Southern California Bight. Mar. Ecol. Prog. Ser. 494: 159-177.

Hyland J, Cooksey C, Bowlby E, Brancato MS, Intelmann S (2005) A pilot survey of deep water coral/sponge assemblages and their susceptibility to fishing/harvest impacts at the Olympic Coast National Marine Sanctuary. Cruise Report for NOAA Ship *McArthur II* Cruise AR-04-04: Leg 2. NOAA Technical Memorandum NOS NCCOS 15. NOAA/NOS Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC. 13 pp. http://www.coastalscience.noaa.gov/documents/ar0404leg2.pdf

Knight A (2011) The distribution of demersal fishes over heterogeneous seafloor habitats: an application of landscape ecology to video imagery collected in a central California State Marine Conservation Area. M.S. Thesis, California State University Monterey Bay. 56 pp.

Krigsman LM, Yoklavich MM, Dick EJ, Cochrane GR (2012) Models and maps: predicting the distribution of corals and other benthic macro-invertebrates in shelf habitats. Ecosphere 3:art3. http://dx.doi.org/10.1890/ES11-00295.1

Lee WL, Elvin DW, Reiswig HM (2007) The Sponges of California. A Guide and Key to the Marine Sponges of California. Vermont Information Systems. Shelburne, VT

Leys SP, Wilson K, Holeton C, Reiswig HM, Austin WC, Tunnicliffe V. (2004) Patterns of glass sponge (Porifera, Hexactinellida) distribution in coastal waters of British Columbia, Canada. Mar. Ecol. Prog. Ser. 283: 133–149.

Love MS, Yoklavich MM, Black BA, Andrews AH (2007) Age of black coral (*Antipathes dendrochristos*) colonies, with notes on associated invertebrate species. Bull. Mar. Sci. 80: 391-400.

Love MS, Lenarz B, Snook L (2010) A survey of the reef fishes, purple hydrocoral (*Stylaster californicus*), and marine debris of Farnsworth Bank, Santa Catalina Island. Bull. Mar. Sci. 86: 35–52.

Lundsten L, Barry PJ, Cailliet GM, Clague DA, DeVogelaere AP, Geller GB (2009) Benthic invertebrate communities on three seamounts off southern and central California, USA. Mar. Ecol. Prog. Ser. 374: 23–32.

Manzello DP (2010) Ocean acidification hot spots: Spatiotemporal dynamics of the seawater CO^2 system of eastern Pacific coral reefs. Limnology and Oceanography. 55: 239-248.

McClain CR, Lundsten L, Ream M, Barry J, DeVogelaere AP (2009) Endemicity, biogeography, composition, and community structure on a Northeast Pacific Seamount. PLoS ONE 4(1): e4141. doi:10.1371/journal.pone.0004141.

McClain CR, Lundsten L, Barry PJ, DeVogelaere AP (2010) Assemblage structure, but not diversity or density, change with depth on a northeast Pacific seamount. Marine Ecology 31(Suppl. 1, 1–12):14-25.

McGowan JA (1971) Oceanic biogeography of the Pacific. In: B. M. Funnell and W. R. Riedel (Eds), The Micropaleontology of Oceans, p. 3-74. Cambridge University Press, Cambridge, England.

National Marine Fisheries Service (NMFS) (2010) Marine fisheries habitat assessment improvement plan. Report of the National Marine Fisheries Service Habitat Assessment Improvement Plan Team. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-108, 115 p.

National Marine Fisheries Service (NMFS) (2013) Pacific Coast groundfish 5-Year review of essential fish habitat. Report to the Pacific

Fishery Management Council. Phase 2: Synthesis Report. http://www.pcouncil.org/wp-content/uploads/D6b_NMFS_SYNTH_ELECTRIC_ONLY_APR2013BB.pdf

National Oceanic and Atmospheric Administration (NOAA) (2010) NOAA Deep-Sea coral and sponge fcosystems exploration and research priorities workshop for the U.S. West Coast. http://data.nodc.noaa.gov/coris/library/NOAA/CRCP/other/other_crcp_publications/west_coast_deep_sea_coral_workshop_rpt.pdf

National Oceanic and Atmospheric Administration (NOAA) (2012) Monterey Bay National Marine Sanctuary: Davidson Seamount management zone threats Assessment. Monterey Bay National Marine Sanctuary Technical Report 2012-1. 39.pp.

Pacific Fishery Management Council (PFMC) (2005) Pacific coast groundfish fishery management plan: essential fish habitat designation and minimization of adverse impacts: Final environmental impact statement. Pacific Fishery Management Council, Portland, Oregon, USA.

Pacific Fishery Management Council (PFMC) (2006) Amendment 19 to the Pacific coast groundfish fishery management plan: Essential fish habitat designation and minimization of adverse impacts. Pacific Fishery Management Council, Portland, Oregon, USA.

Pacific Fishery Management Council (PFMC) (2012) Pacific Coast Groundfish 5-Year Review of Essential Fish Habitat. Report to the Pacific Fishery Management Council. Phase 1: New Information. http://www.pcouncil.org/groundfish/background/document-library/pacific-coast-groundfish-5-year-review-of-efh/

Pirtle JL (2005) Habitat-based assessment of structure-forming megafaunal invertebrates and fishes on Cordell Bank, California. M.S. Thesis Washington State University Vancouver. 64 pp.

Reiswig HM, Lee WL. 2007. A new species of *Cladorhiza* (Porifera: Cladorhizidae) from S. California (USA). *In:* Custódio M.R., G. Lôbo-Hajdu, E. Hajdu and G. Muricy G (eds). Porifera research: biodiversity, innovation and sustainability. Série Livros 28. Museu Nacional, Rio de Janeiro. 517-523.

Rooper CN, Boldt JL, Zimmermann M (2007) An assessment of juvenile Pacific Ocean perch (*Sebastes alutus*) habitat use in a deepwater nursery. Estuarine Coastal and Shelf Science 75: 371–380.

Salmi MS, Johnson HP, Leifer I, Keister JE (2011) Behavior of methane seep bubbles over a pockmark on the Cascadia continental margin. Geosphere 7(6):1273-1283.

Shester G, Donlou N, Gorny M (2012) Important ecological areas: seafloor habitat expedition, Monterey Bay, CA. Oceana publication, Washington, DC.

Starr R, Yoklavich MM (2008) Monitoring MPAs in deep water off central California: 2007 IMPACT submersible baseline survey. CA Sea Grant College Program Publ. No. T-067: 1-22.

Stierhoff KL, Etnoyer PJ, Murfin DW, Butler JL (2011) A survey of deep-water coral and sponge habitats along the West Coast of the US using a remotely operated vehicle. NOAA Technical Memorandum NOS NCCOS 138. NOAA Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC. 38 pp.

Stone RP, Lehnert H, Reiswig HM (2011) A guide to the deep-water sponges of the Aleutian Island Archipelago. NOAA Professional Paper NMFS 12, 187 pp.

Stone RP, Shotwell SK (2007) State of deep coral ecosystems in the Alaska region: Gulf of Alaska, Bering Sea, and Aleutian Islands, p. 65-108. In: Lumsden SE, Hourigan TF, Bruckner AW, Dorr G. (eds.) The state of deep coral ecosystems of the United States. NOAA Technical Memorandum CRCP-3. Silver Spring, MD.

Strom NA (2006) Structure-forming benthic invertebrates: Habitat distributions on the continental margin of Oregon and Washington. M.S. thesis, Oregon State University, 96 p.

Teck SJ, Halpern BS, Kappel CV, Micheli F, Selkoe KA, Crain CM, Martone R, Shearer C, Arvai J, Fischhoff B, Murray G, Neslo R, Cooke R (2010) Using expert judgment to estimate marine ecosystem vulnerability in the California Current. Ecological Applications. 5: 1402-1416.

Tissot BN, Yoklavich MM, Love MS, York K, Amend M (2006) Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral. Fish. Bull. 104:167-181.

Whitmire CE, Clarke ME (2007) State of deep coral ecosystems of the U .S. Pacific Coast: California to Washington. pp. 109-154. In: Lumsden SE, Hourigan TF, Bruckner AW, Dorr G. (eds.) The state of deep coral ecosystems of the United States. NOAA Technical Memorandum CRCP-3. Silver Spring MD. 365 pp.

Williams GC (2013) New taxa and revisionary systematics of alcyonacean octocorals from the Pacific coast of North America (Cnidaria, Anthozoa) ZooKeys. 283: 15–42

Williams GC, Lundsten L (2009) The nephtheid soft coral genus *Gersemia* Marenzeller, 1878, with the description of a new species from the northeast Pacific and a review of two additional species (Octocorallia: Alcyonacea). Zool. Med. Leiden 83: 1067-1081.

Yoklavich MM, Love MS (2005) Christmas tree corals: A new species discovered off Southern California. Current: J. of Mar. Educ. 21: 27-30.

Yoklavich MM, Starr R, Laidig T, Watters D, Tissot BN (2010) Monitoring MPAs in Deep Water off Central California: 2007-2008 IMPACT submersible baseline survey. final report to CA Ocean Protection Council. 49 pp.

Yoklavich MM, Laidig T, Krigsman L, Taylor A, Watters D, Love MS, Lundsten L, Negrete B (2011) A characterization of the coral and sponge community on Piggy Bank seamount in southern California from a survey using a remotely operated vehicle. A report to NOAA Deep-Sea Coral Research and Technology Program. 63p. http://swfsc.noaa.gov/HabitatEcology./

Yoklavich MM, Laidig T, Taylor A, Watters D, Krigsman L, Love MS (2013) A characterization of the Christmas tree coral (*Antipathes dendrochristos*) community on three seamounts in the Southern California Bight from a survey using a manned submersible. A report to NOAA Deep-Sea Coral Research and Technology Program. 82p. http://swfsc.noaa.gov/HabitatEcology.

Appendix

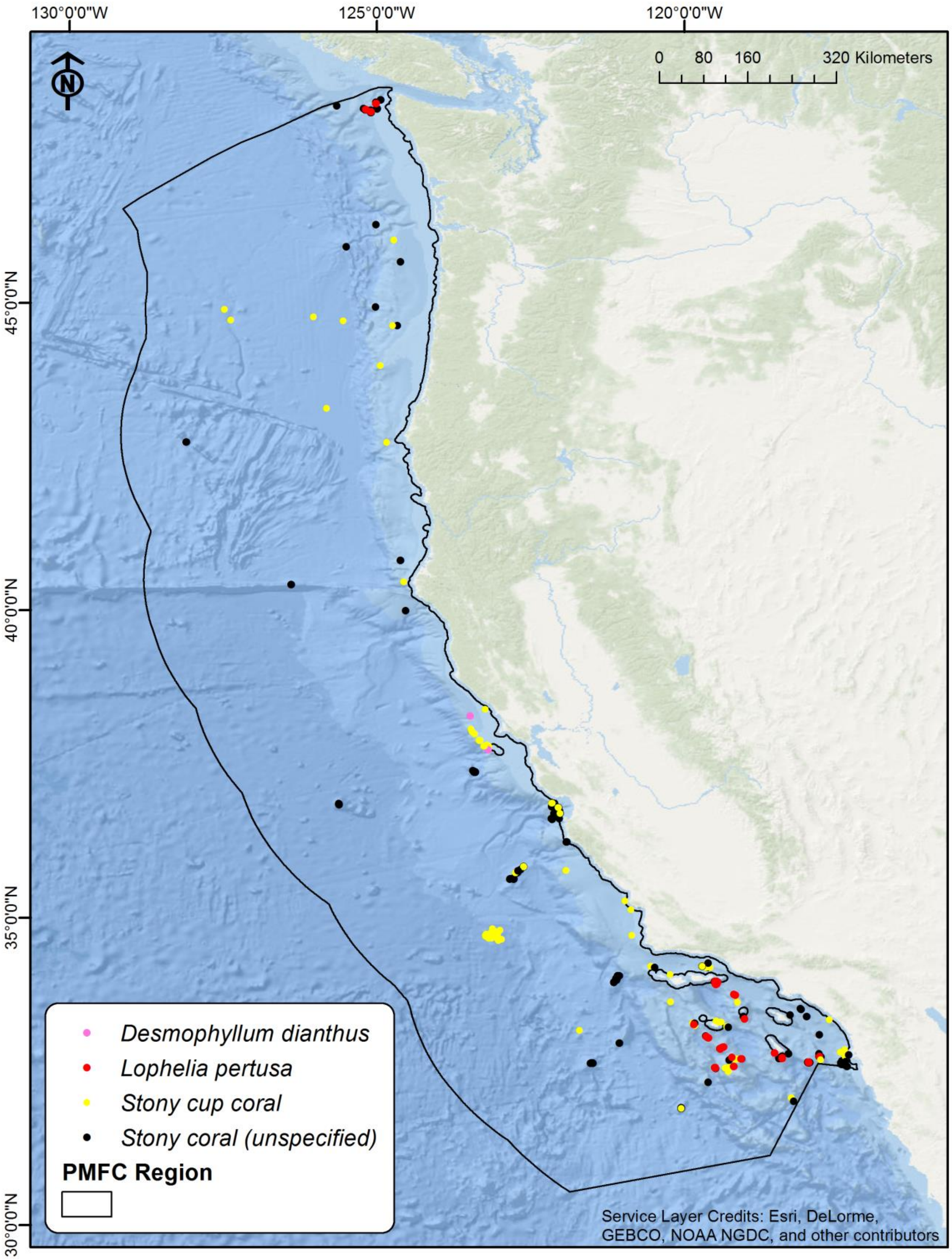
Table A. *Sites of major research expeditions (2007-2013) referenced in the chapter that included deep-sea coral or sponge research. (DSCRTP= Deep Sea Coral Research & Technology Program; MBARI = Monterey Bay Aquarium Research Institute; NCCOS = National Centers for Coastal Ocean Research; NMS = National Marine Sanctuary; SWFSC = Southwest Fisheries Science Center; DFO Canada = Department of Fisheries and Oceans, Canada; BOEM = Bureau of Ocean Energy Management; COPC = California Ocean Protection Council; CDFW = California Department of Fish and Wildlife; USGS = United States Geological Survey; NWFSC = Northwest Fisheries Science Center; UW = University of Washington)*

Location	Year	Vessel	Description	Program
Southern California Bight & Channel Islands NMS	2007 2008	NOAA Ship *David Starr Jordan*	ROV photo surveys for ESA-listed abalone (subsequently analyzed for deep-sea coral occurrence) on several rocky banks. PI: J. Butler	NOAA SWFSC
	2008	R/V *Velero IV*	Submersible video surveys for fishes and *Stylaster californicus* on Farnsworth Bank near Catalina Island. PI: M. Love	BOEM
	2010	NOAA Ship *McArthur II*	ROV and AUV surveys of Piggy Bank, Channel Islands NMS. PI: M. Yoklavich & M.E. Clarke	**NOAA DSCRTP**
	2010	R/V *Velero IV*	Submersible surveys of Christmas tree black coral habitats in Channel Islands NMS. PI: M. Yoklavich	**NOAA DSCRTP**
	2010 2011	CPFV *Outer Limits*	ROV photo surveys of several rocky banks. PI: J. Butler & P. Etnoyer	NOAA SWFSC, NCCOS
	2011	R/V *Velero IV*	Submersible surveys of fishes and invertebrates on rocky banks in Channel Island NMS. PI: M. Yoklavich	NOAA SWFSC
	2013	R/V *Shearwater*	ROV Surveys for deep-sea coral habitats in Channel Islands NMS. PI: S. Katz	**NOAA DSCRTP**
Pioneer & Davidson Seamounts	2007	R/V *Western Flyer*	ROV surveys of Pioneer and Davidson Seamounts. PI: D. Clague	MBARI
	2009	R/V *Western Flyer*	ROV surveys of Davidson Seamount. PI: J. Barry	MBARI
Monterey Bay NMS	2008	R/V *Point Lobos*	ROV surveys of Monterey Canyon. PI: C. McClain	MBARI
	2007 2008	R/V *Velero IV*	Submersible video surveys for fishes and invertebrates in and out of 8 offshore MPAs. PI: M. Yoklavich & R. Starr	COPC, CDFW
	2010	NOAA Ship *Bell M. Shimada*	ROV photo surveys of Sur Canyon. PI: J. Butler & P. Etnoyer	NOAA SWFSC, NCCOS
	2010	R/V *Derek M. Baylis*	ROV surveys at 17 sites in Monterey and Carmel Bays. PI: G. Shester	Oceana
	2013	R/V *Western Flyer*	ROV survey of Sur Ridge. PI: J. Barry & A. DeVogelaere	MBARI, NOAA MBNMS

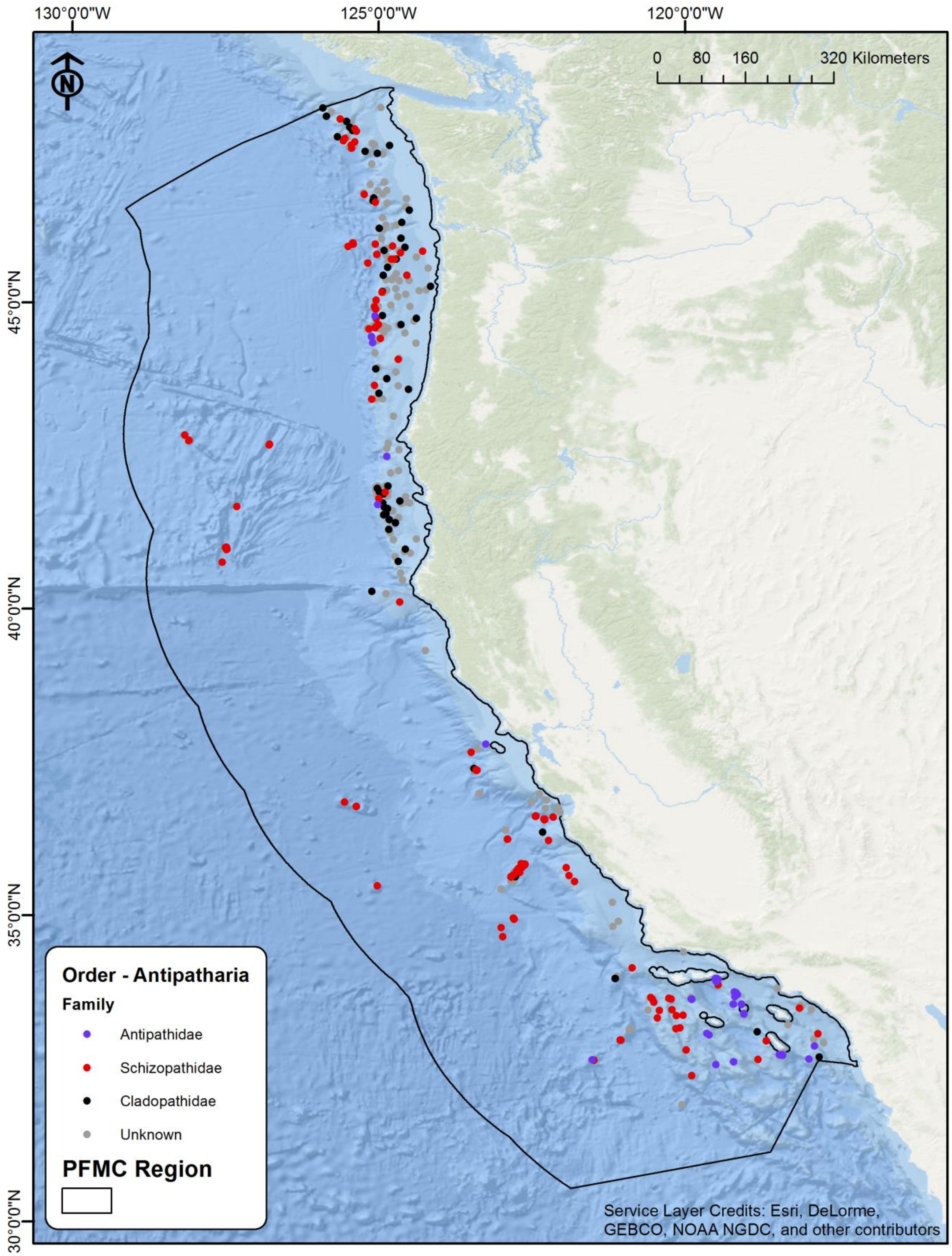
Table A. *continued*

Location	Year	Vessel	Description	Program
Gulf of the Farallones NMS	2009	NOAA Ship *Okeanos Explorer*	Multibeam mapping survey of Gulf of the Farallones NMS and potential sanctuary expansion area. PI: M. Malik	NOAA Ocean Exploration
	2011	R/V *Fulmar*	Multibeam survey of potential deep-sea coral habitats on Rittenburg Bank and Farallon Escarpment. PI: J. Roletto	**NOAA DSCRTP**
	2012	R/V *Fulmar*	ROV survey of Rittenburg Bank, Cochrane Bank and Farallon Escarpment. PI: J. Roletto	**NOAA DSCRTP**
Cordell Bank NMS	2007	R/V *Fulmar*	Camera sled video surveys of deepwater habitats. PI: D. Roberts	NOAA CBNMS
	2009	NOAA Ship *Okeanos Explorer*	Multibeam mapping survey of Cordell Bank NMS and potential sanctuary expansion area. PI: M. Malik	NOAA Ocean Exploration
	2010	NOAA Ship *McArthur II*	ROV surveys. PI: D. Howard	**NOAA DSCRTP**
	2011	R/V *Fulmar*	AUV survey for potential deep-sea coral habitats. PIs: M.E. Clarke & D. Howard	**NOAA DSCRTP**
California Coast	2007-2012	R/V *Lakota* & *Coral Sea*; R/V *Fulmar* & *Shearwater*	Camera sled video surveys of seafloor invertebrate communities in continental shelf habitats throughout California state waters. PI: G. Cochrane & L. Krigsman	USGS, SWFSC
Oregon Coast	2010	NOAA Ship *Bell M. Shimada*	ROV photo surveys of Coquille Bank. PI: J. Butler & P. Etnoyer	NOAA SWFSC, NCCOS
	2011	R/V *Miss Linda*	ROV surveys at Cape Arago, Coquille Reef and Bank, Orford Reef. PI: B. Enticknap	Oceana
	2013	R/V *Miss Linda*	ROV surveys at Stonewall Bank, Hecata Bank, Daisy Bank, Siletz Hotspot, Siletz Reef/Cascade Head. PI: B. Enticknap	Oceana
Grays Canyon	2007	R/V *Thomas G. Thompson*	Side-scan sonar and Van Veen grab surveys of glass sponge grounds. PI: P. Johnson	UW
	2009	R/V *Kvichak Defender VI*	ROV survey of glass sponge grounds and associated methane seeps and krill swarms. PI: P. Johnson	UW
	2010	R/V *Pacific Storm*	AUV surveys of glass sponge habitats. PI: M.E. Clarke	**NOAA DSCRTP**
Olympic Coast NMS	2008	CCGS *John P.Tully*	ROV surveys. PI: E. Bowlby	NOAA OCNMS, DFO Canada
	2008	NOAA Ship *Okeanos Explorer*	Multibeam mapping survey. PI: M. Malik	NOAA Ocean Exploration
	2010	NOAA Ship *McArthur II*	ROV and AUV surveys. PI: E. Bowlby	**NOAA DSCRTP**
	2010	NOAA Ship *Bell M. Shimada*	ROV photo surveys. PI: J. Butler & P. Etnoyer	NOAA SWFSC, NCCOS
	2011	R/V *Pacific Storm*	Multibeam survey of potential deep-sea coral habitats. PI: E. Bowlby	**NOAA DSCRTP**
Cobb Seamount	2012	CCGS *John P.Tully*	ROV and AUV surveys of corals and sponges. PI: M.E. Clarke & J. Curtis	**NOAA DSCRTP**, NOAA NWFSC, DFO Canada
Bowie Seamount	2011	CCGS *John P.Tully*	ROV and AUV surveys for corals and sponges. PI: M.E. Clarke & J. Boutillier	**NOAA DSCRTP**, NOAA NWFSC, DFO Canada

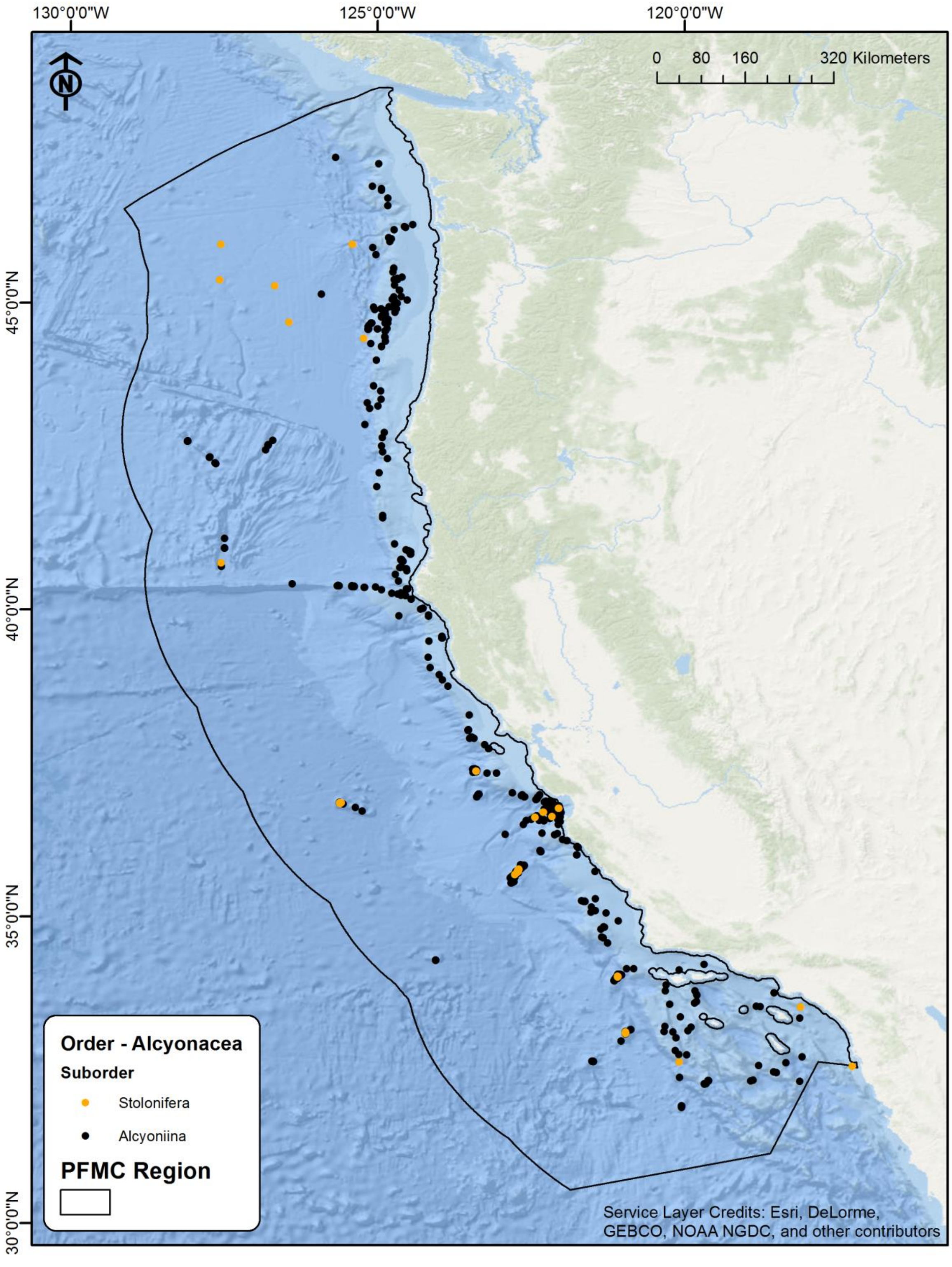
Map 1. *Locations of branching stony corals (Order Scleractinia) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



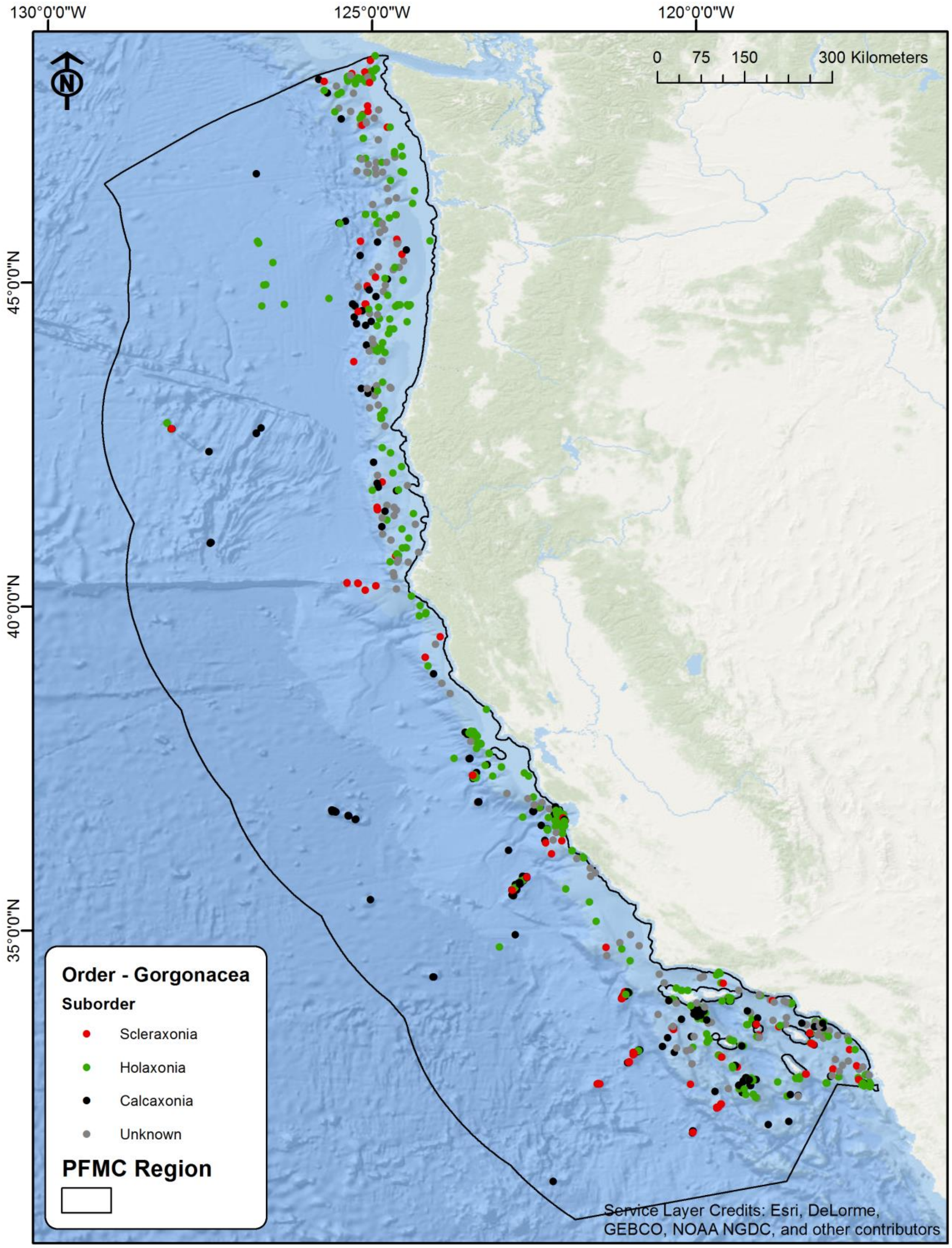
Map 2. *Locations of black corals (Order Antipatharia) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



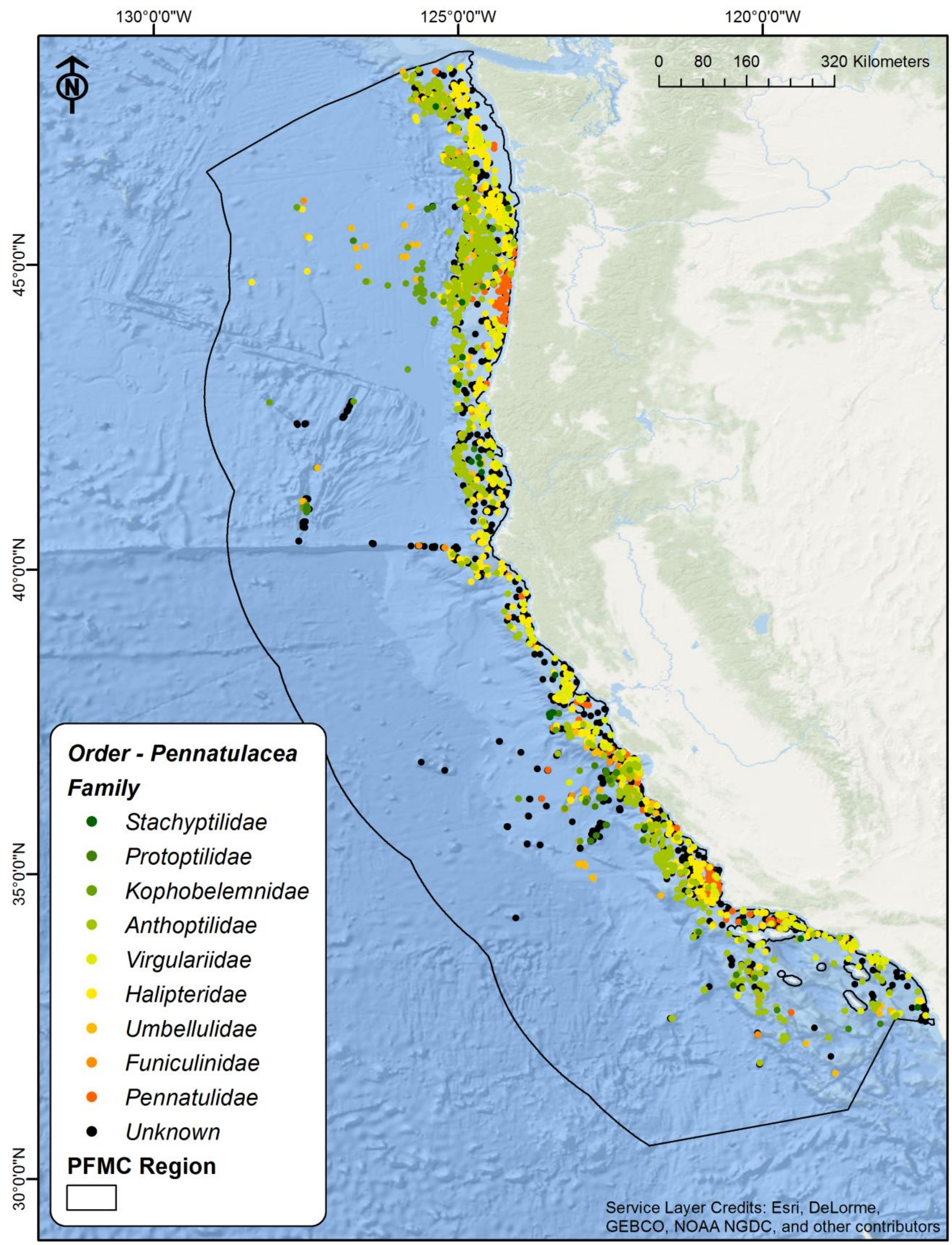
Map 3. *Locations of non-gorgonian alcyonacean (Order Alcyonacea) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



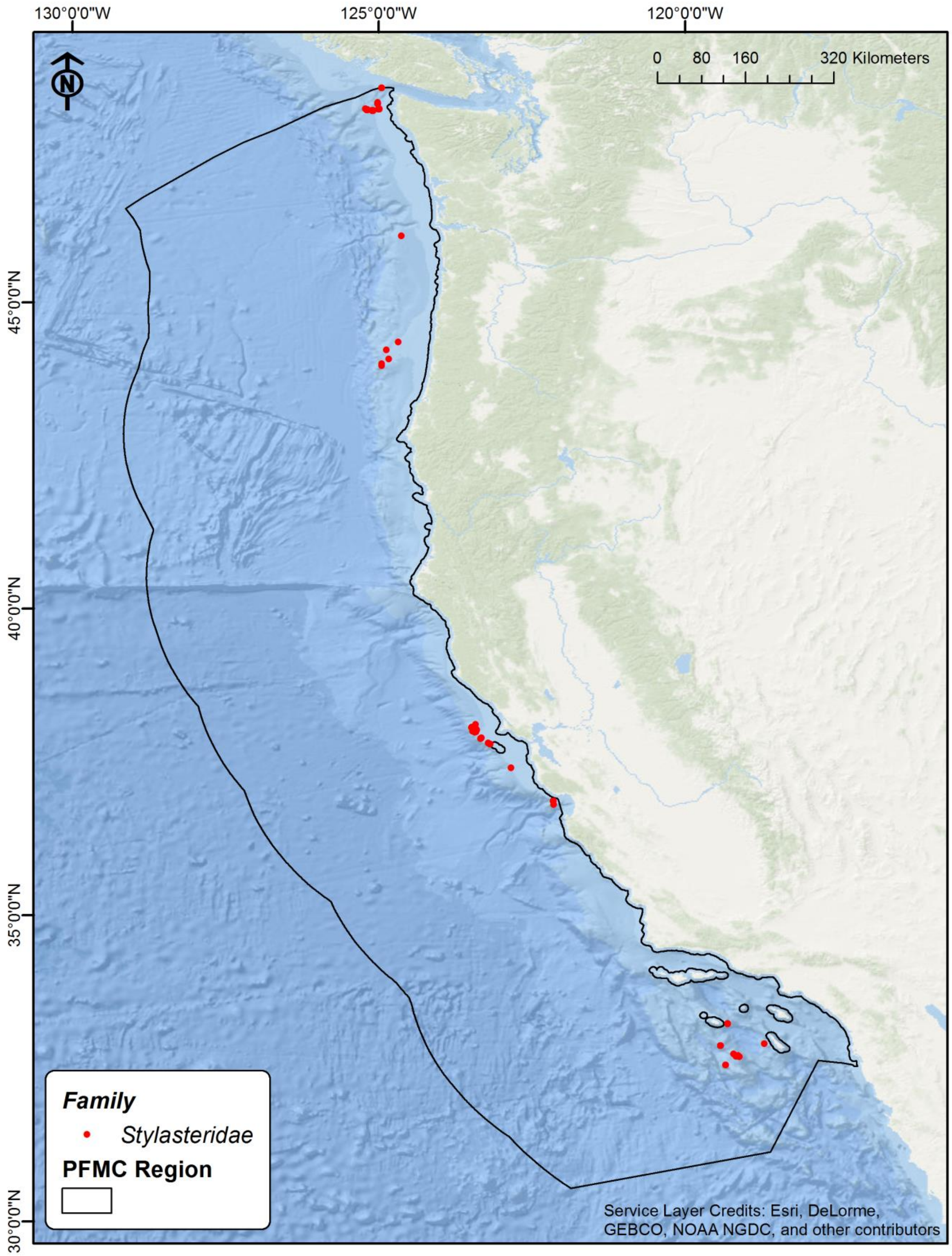
Map 4. *Locations of gorgonians (Order Gorgonacea)) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



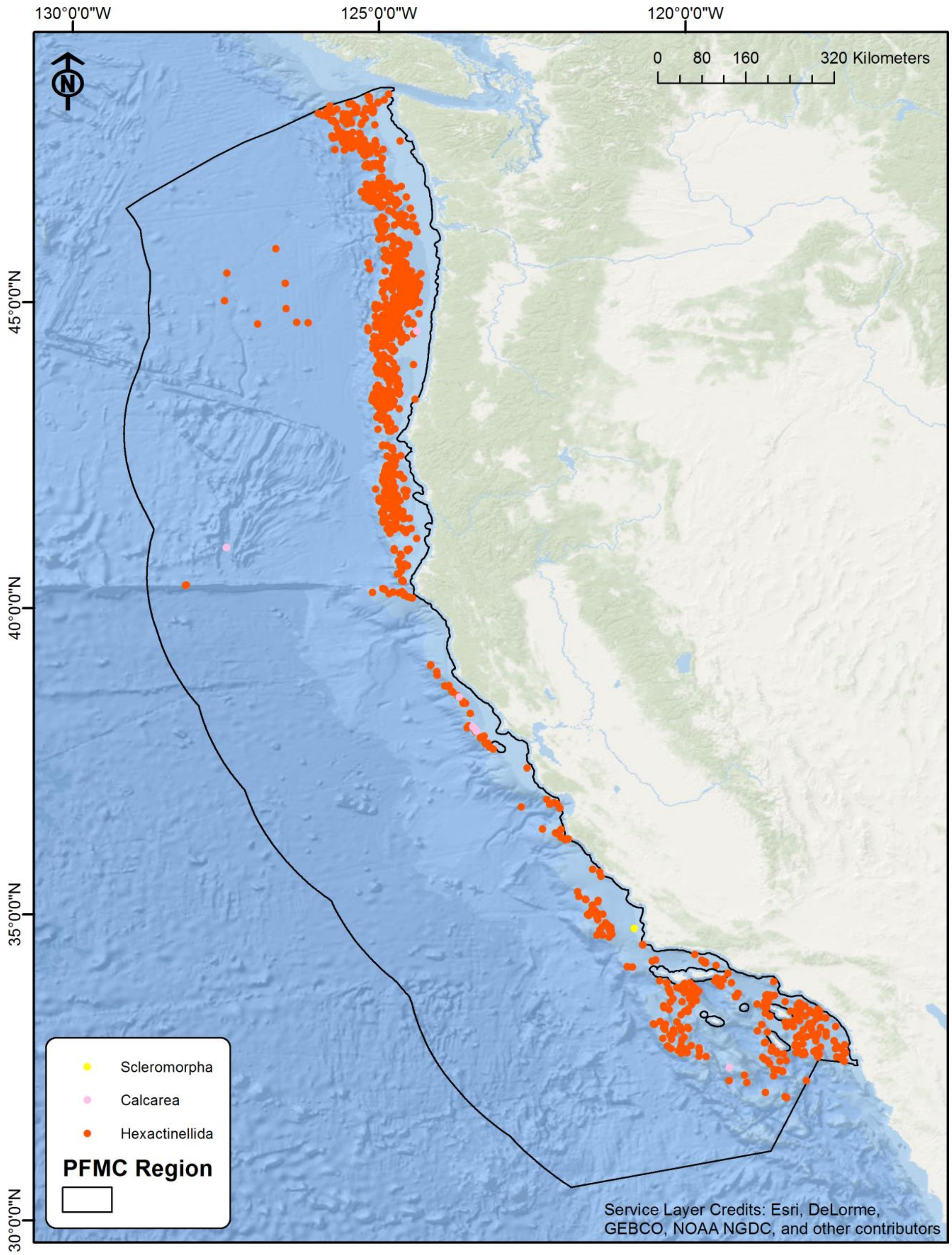
Map 5. *Locations of sea pens (Order Pennatulacea) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



Map 6. *Locations of lace corals (Family Stylasteridae) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



Map 7. *Locations of sponges (Classes Scleromorpha, Calcarea, Hexactinellida) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*



***Map 8.** Locations of sponges (Class Demospongiae and unspecified) recorded in the National Deep-Sea Coral and Sponge Database (as of 2/2015).*