NOAA Technical Memorandum NMFS

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A CHARACTERIZATION OF DEEP-SEA CORAL AND SPONGE COMMUNITIES IN AREAS OF HIGH BYCATCH IN BOTTOM TRAWLS OFF NORTHERN CALIFORNIA

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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At A Glance:

Using an autonomous underwater vehicle (AUV) and towed camera system (TCS), deep-sea corals, sponges, and seafloor habitats were visually surveyed for the first time in areas of longtime trawl fishing off northern California. During an 11-day cruise aboard the R/V *Point Sur* 8-18 September 2014, researchers completed 6 dives with the AUV and 9 deployments of the TCS, and spent over 42 hours underwater at depths of 586-1169 meters from the Oregon-California border to the Mendocino Ridge.

With perfect sea conditions and fair skies in an area of the coast that is otherwise notorious for foul weather and high swells, the researchers recorded over 60,000 images of corals, sponges, fishes and other marine life with digital, paired still cameras during daytime operations. Nearly 48,000 corals from at least 23 taxa were observed, including black corals, bamboo corals, and gorgonians, some of which may be hundreds if not thousands of years old. Sponges occurred on most of the dives, with a total of 5,200 individuals represented by 13 taxa. Relatively few fishes (mostly thornyheads) and marine debris were observed. The ship's echosounder was used to map the seafloor and sub-bottom geologic features each night; water conductivity, temperature, dissolved oxygen, and depth were measured at each station. These data will help us characterize seafloor habitat types associated with the corals and sponges.

Fishermen have long known that corals occur in this area off northern California, having retrieved parts of corals in their fishing nets along with the harvested fishes. Areas of relatively high numbers of corals also have been recorded in NMFS West Coast groundfish bottom trawl surveys. From the exploration of these sites with cameras, we have begun to determine the extent of these coral colonies for the first time. The highlight of the cruise was discovering forests of corals on rocky ridges adjacent to the trawl grounds. These areas of rough terrain likely have received less fishing pressure in recent years, with the elimination of large roller gear on the trawl nets. Further analyses of the images and resultant data from this cruise, as well as continuing these surveys, will improve our knowledge about deep-sea corals off northern California, increase our understanding of the influence of fishing on coral communities, and will inform decisions to protect and conserve these sensitive habitats.

INTRODUCTION AND SCIENTIFIC OBJECTIVES

Until recently, much of our understanding of the biology and ecology of deep-sea corals and sponges (DSC&S) on the Pacific coast came from chance collections in fisheries bycatch. Areas of high bycatch of DSC&S have been identified from analyses of West Coast groundfish bottom trawl surveys. Only anecdotal records of bycatch were kept from earlier surveys because invertebrates were not fully identified or quantified. The quantitative catch data from more recent surveys indicate that these bycatch events comprised large catches of bamboo and black corals in areas near the border of Oregon and California and on the Mendocino Ridge. These areas were identified in the State of the Deep Sea Coral Ecosystems of the United States (Whitmire and Clarke 2007) and in recent maps of coral bycatch. No exploration of these sites has occurred to determine the extent of these colonies.

The reduction of bycatch of DSC&S in federally managed fisheries is a high priority for NOAAs Deep-sea Coral Research and Technology Program (DSCRTP). With funding from DSCRTP, we conducted underwater visual surveys of seafloor communities using a towed camera system (TCS) and an autonomous underwater vehicle (AUV) in areas of high bycatch off northern California. The overall goals of this study were to assess the abundance, distribution, and habitats of corals and sponges, as well as associated fishes, and to provide this information to the Pacific Fishery Management Council's review of Pacific Groundfish Essential Fish Habitat (EFH). In particular, these data will be useful to interpret the results of recent predictive models of coral habitat suitability that have been developed to locate potential marine protected areas.

The specific objectives of our research were to:

1. collect baseline data on the distribution, abundance, size, and condition, of deep-sea coral and sponge communities in approximately 500 - 1200 m depth off northern California;
2. document environmental conditions of DSC&S habitats, including depth, seafloor substratum types, and seawater temperature, salinity, and dissolved oxygen to help understand factors that influence DSC&S distribution; and

3. conduct a geophysical survey using the ship's echosounder to improve our understanding of topographic features associated with coral and sponge communities;

This report provides a summary of the methods and results from these underwater surveys of DSC&S off northern California. This was a collaborative effort among investigators from NOAA National Marine Fisheries Service (Southwest Fisheries Science Center, Northwest Fisheries Science Center [NWFSC], Pacific Islands Fisheries Science Center [PIFSC], and Alaska Fisheries Science Center [AFSC]) and several universities including California State University (Humboldt State University and Moss Landing Marine Laboratories), University of California Santa Cruz, and Oregon State University.

STUDY SITE

We focused the visual surveys on areas of high trawl bycatch of corals (Figure 1), including rocky ridge tops and sedimentary ridge flanks. Specific dive locations were informed by maps of bathymetry at various levels of spatial resolution, which were developed in advance of the surveys by C. Goldfinger and the Oregon State University Seafloor Mapping Lab (OSU-SML).
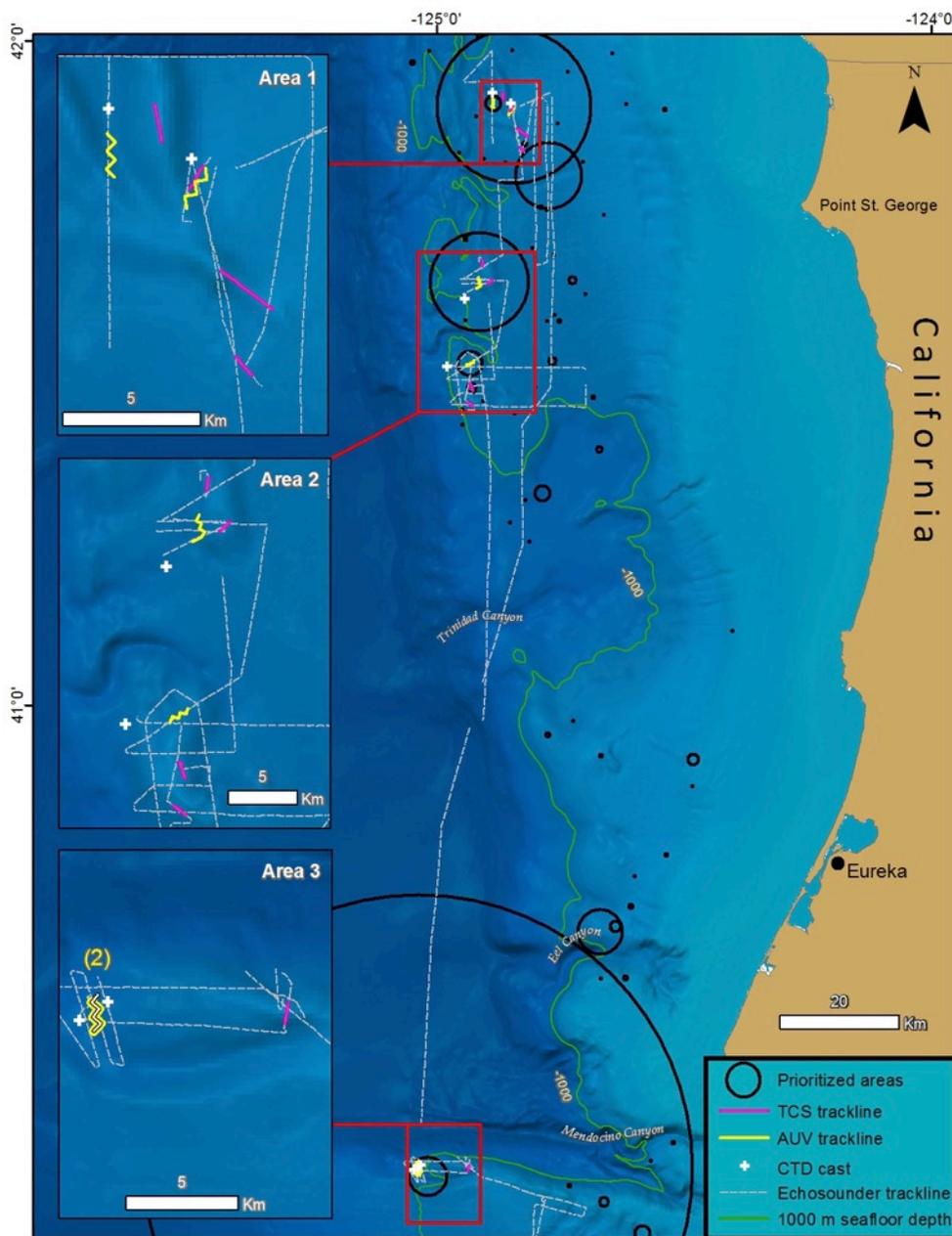

Figure 1. Study site of visual surveys off northern California in Area 1 north of Point St. George, Area 2 south of Point St. George, and Area 3 on Mendocino Ridge. Locations of dive track lines of the towed camera system (TCS) and the autonomous underwater vehicle (AUV), tracks of the geophysical survey using the R/V *Point Sur* echosounder, and the sites of CTD casts are indicated. Black circles are priority dive sites, based on the relative abundance of deep-sea corals as bycatch in bottom trawls.

FIELD SURVEY METHODS

Underwater visual surveys of corals, sponges, fishes, and associated seafloor habitats, were conducted using non-extractive transect methods with NMFS Alaska Fisheries Science Center's TCS and NMFS Pacific Islands and Northwest Fisheries Science Centers' SeaBED AUV (Figure 2). Surveys were conducted from the Moss Landing Marine Laboratories' R/V *Point Sur*, 08 September – 18 September 2014. The TCS was equipped with two Standard Definition (SD) stereo cameras, one color and one black and white, both directed forward. The AUV was equipped with high dynamic range, digital, color, 5 MP still photographic cameras arranged in a stereo pair directed downward and perpendicular to the seafloor and a third high dynamic range, digital, color, 4 MP still photographic camera directed forward at approximately 35°. Both survey vehicles had depth sensors. Digital still and hand-held video cameras were used to document topside activities during the cruise. Dive information (start and end time, location of dives, etc.) also was recorded in a logbook during the cruise.
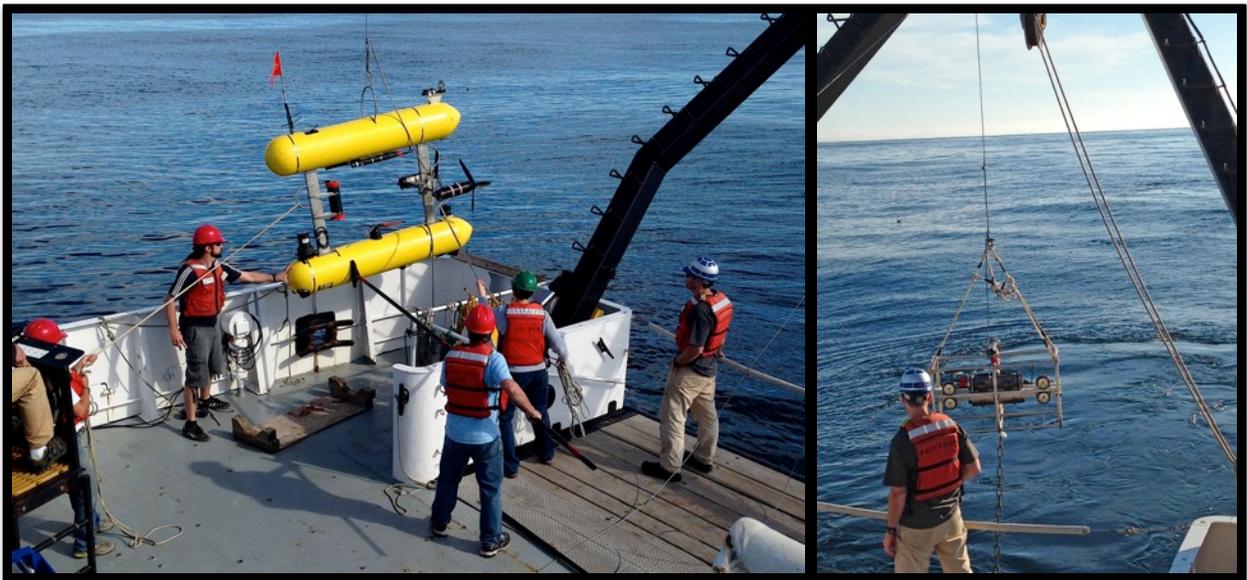

Figure 2. Left image: NMFS SeaBED autonomous underwater vehicle (AUV) being retrieved onto the back deck of the R/V *Point Sur* following a 5-hour mission to the seafloor off northern California. Right image: The NMFS towed camera system (TCS) is lowered to 700 meters and used to survey coral communities along the seafloor off northern California.

We used the ship's SeaBird SBE 911 Plus CTD profiler to collect data on temperature, conductivity (salinity), pressure (depth), and dissolved oxygen concentration from the surface to near the seafloor. One CTD cast was made in the vicinity of each AUV dive. Navigation data for the TCS were collected from the ship's GPS and smoothed and plotted in ArcGIS to determine the distance traveled for each dive. The AUV was programmed before each dive to follow a specified path. The AUV was tracked using USBL tracking software, and resultant navigation data was processed to determine the length and location of the AUV track lines. The vehicle operator communicated with the

AUV during dives using an acoustic modem. Ship CTD and navigation data were provided to the science team at the end of the cruise.

Visual surveys were conducted with both the TCS and AUV along quantitative strip transects during daylight hours. The TCS was lowered by a winch and tether to 0.5 m above the seafloor and towed at approximately 0.25 m/s (0.5 kt) for approximately 1 hour per dive. Four still images were collected per second from both cameras, yielding a continuous view of the seafloor to assist the winch operator in tending the TCS. Only one image per second was stored on TCS hard drive for later analysis. The AUV was deployed using the ship's crane. AUV surveys were conducted 3 m above the seafloor at a forward speed of 0.25-0.5 m/s (0.5-1.0 kt) for 4-6 hours per dive. Still images were collected from all cameras at a rate of approximately 1 image per 6 - 7.5 seconds, and stored on the AUVs internal hard drive for later analysis. Upon completion of the dive, the AUV surfaced and was recovered to the ship. At night, a geophysical survey of the seafloor was conducted throughout the mid-slope region of our study site (Figure 1). Sub-bottom seismic profiles were collected with the ship's Knudsen 3260 CHIRP system.

POST-DIVE DATA ANALYSES

Images from the TCS and AUV were analyzed and all corals, sponges, and fishes were counted. We used image-analysis software developed by AFSC to measure size (total length of fishes, and height and width of corals and sponges) and distance from the camera to each organism in the TCS images. Not all organisms could be measured. For accurate measurements, the entire organism needed to appear near the center two-

thirds of the image. Using the AFSC software, we also measured field of view for all images.

Seafloor habitats were classified by type of substratum, in order of decreasing particle size and vertical relief (as described in Greene et al. 1999): rock ridge (R), boulder (B), cobble (C), flat rock (F), and mud (M). A two-character code was used to quantify patches of uniform substratum type along each transect (as described in Yoklavich et al. 2000). Habitats were grouped into hard (R, B, C, and F in any combination), mixed (one of the hard substrata combined with M as either primary or secondary), and soft (the combination of MM). The area of each habitat group was estimated as the product of the transect width (average width of the field of view) and the length of each patch of habitat type, as determined from the geographic position at the beginning and end of each patch. Temperature, depth, salinity, and dissolved oxygen were derived from raw CTD data at one-second intervals. Data were plotted in R.

Corals, sponges, and fishes were identified to the lowest possible taxonomic level and enumerated from expert examination of digital images. Some sponges were classified by general morphology (i.e., upright flat, foliose, ball, branching, barrel, and vase) when taxonomic identification was difficult. Densities of corals, sponges, and fishes were estimated by dividing total number of each taxon by the area surveyed. Physical damage to DSC&S (i.e., broken or missing parts; knocked over or displaced), associations of DSC&S and fishes, and condition of the DSC&S were recorded from the TCS images. Fishes were considered to be associated with the DSC&S if they were less than one body length away or in direct contact with the DSC&S. Condition of each DSC&S was determined to be healthy (<10% of organism is dead), dying (10-50% is dead), or dead (>50% of organism dead). Frequency and type of derelict fishing gear and other marine debris also were documented in TCS images.

All data on navigation, habitat characteristics, DSC&S, and fishes were entered into a geo-referenced, relational database. The high-resolution data from the nighttime geophysical survey are still being processed by investigators at OSU-SML, and will not be included in this report. Those data will be merged with existing seismic, bathymetric, and core information to explore the relationships between geologic structure, sediment dispersal, slope stability, and the occurrence of DSC&S.

SUMMARY OF DIVES

We had outstanding sea conditions and weather throughout the cruise, including light fog and winds, low swells, and some sunny days. We were able to survey most of our planned sites, typically conducting two TCS dives per day (each about 1 hour on the seafloor) and 1 AUV dive per day (each about 5 hours on the seafloor). We used the TCS to survey the tops of rocky ridges at 586-798 m depth, and the AUV to survey deeper ridge flanks at 695-1169 m water depth (Table 1). About 32 hours of still photographic images were collected during 6 dives (two dives in each of the three areas) with the AUV, and 10 hours of still images were collected during 9 dives (4 dives each in Area 1 and 2; 1 dive in Area 3) with the TCS.

Table 1. Logistical information from dives using a towed camera system (TCS) and autonomous underwater vehicle (AUV) to survey deep-sea coral and sponge communities off northern California, 11-16 September 2014.

Date	Area	Dive #	Method	Start Time (local)	End Time (local)	Start Latitude (N)	Start Longitude (W)	Minimum Depth (m)	Maximum Depth (m)
11-Sep-14	3	3	AUV	12:31:00	17:10:00	40 19.290	124 59.260	1086	1169
12-Sep-14	1	0052	TCS	8:03:48	9:49:40	41 52.497	124 48.517	654	723
12-Sep-14	1	4	AUV	12:38:00	17:24:00	41 54.871	124 52.900	814	898
12-Sep-14	1	0053	TCS	18:23:02	19:40:01	41 55.668	124 51.642	596	646
13-Sep-14	1	0054	TCS	8:09:51	9:03:45	41 51.079	124 48.911	729	743
13-Sep-14	1	5	AUV	11:24:00	16:07:00	41 54.290	124 51.290	695	773
13-Sep-14	1	0055	TCS	18:09:12	18:54:27	41 54.604	124 51.127	704	772
14-Sep-14	2	0056	TCS	8:06:09	9:02:51	41 39.058	124 53.362	724	780
14-Sep-14	2	6	AUV	11:39:00	17:10:00	41 39.000	124 54.000	846	974
14-Sep-14	2	0057	TCS	18:40:51	19:45:32	41 40.511	124 53.890	720	759
15-Sep-14	2	0058	TCS	7:56:37	8:54:27	41 30.326	124 55.030	650	696
15-Sep-14	2	7	AUV	11:17:00	16:06:00	41 31.660	124 55.440	782	849
15-Sep-14	2	0059	TCS	17:58:33	18:56:59	41 28.529	124 55.380	586	618
16-Sep-14	3	0060	TCS	8:43:58	9:59:50	40 19.827	124 53.035	631	798
16-Sep-14	3	8	AUV	13:40:00	19:35:00	40 19.420	124 59.180	1094	1162

area 1=north of Point St. George
area 2= south of Point St. George
area 3= Mendocino Ridge

A total of 53,497 m^2 of seafloor habitat was classified during all 15 dives; 32,145 m^2 were surveyed with the TCS and 21,352 m^2 with the AUV. The TCS surveyed mostly hard (52%) and mixed (37%) rock habitats, while the AUV largely surveyed soft mud sediments (85%) and some mixed rock (12%).

We identified 23 taxa of corals, 13 taxa of sponges, and 18 taxa of fishes from the still photographic images collected from the TCS and AUV in our study areas (Table 2). A total of 47,954 corals were enumerated, including 34,196 corals in TCS images and 13,758 corals in AUV images. The most abundant corals included mushroom coral (*Heteropolypus ritteri* in the TCS survey), sea fans (*Swiftia* spp. and *Paragorgia* spp.), and black coral (*Antipathes* spp.). Sponges (total = 5,209) were much less abundant than corals in our survey, largely comprising unidentified barrel and ball sponges. A total of 9,162 fishes were observed in the TCS and AUV surveys, over 80% of which were unidentified thornyheads (*Sebastolobus* spp.).

Table 2. Total counts of deep-sea corals, sponges, and fishes observed from visual surveys conducted with a towed camera system (TCS) and autonomous underwater vehicle (AUV) off northern California, 11-16 September 2014.

Common Name	Scientific Name	TCS Count	AUV Count
Corals			
Mushroom coral	*Heteropolypus ritteri*	13,298	383
Sea fan (red with yellow polyps)	*Swiftia pacifica*	7,141	
Peppermint sea fan	*Paragorgia* spp.	4,729	754
Swiftia type (red w/unknown polyps)	Plexauridae	3,302	1,333
Black coral	*Antipathes* spp.	3,200	7,201
Soft coral	*Gersemia* spp.	1,841	1,005
Primnoid	*Parastenella ramosa*	508	235
Soft coral	*Clavularia* spp.	66	25
Unidentified corals	Hexacorallia/Octocorallia	38	50
Unidentified sea pens	*Funiculina* spp.	31	91
Bamboo coral	*Isidella* spp.	18	12
Bubblegum coral	*Paragorgia arborea*	8	
Unidentified lace corals	Stylasteridae	7	
Unidentified sea pens (thin)	Pennatulacea	5	57
Unidentified bamboo corals	Isididae	3	159
Black coral	*Bathypathes* spp.	1	4
Unidentified zoanthids	Zoantharia		7
Feather boa sea pen	*Anthoptilum* spp.		13
Primnoid (white)	Primnidae		10
Sea fan	*Swiftia* spp.		2,073
Sea pen	*Umbellula lindahli*		267
Bamboo coral	*Keratoisis* spp.		74
Bamboo coral	*Ledipisis* spp.		5
Total Corals		34,196	13,758

Sponges

Unidentified barrel sponges	Porifera	1,934	546
Lace (or cloud) foliose sponge	*Farrea occa*	372	223
Fingered goblet vase sponge	*Heterochone calyx*	165	
Unidentified vase sponge (white)	*Staurocalyptus* spp.	88	
Sponge ('lightbulb')	*Hexactinella* spp.	25	34
Unidentified vase sponges	Porifera	23	3
Unidentified sponges	Porifera	18	246
Unidentified vase sponge ('Picasso')	*Staurocalyptus* spp.	17	156
Unidentified foliose sponges	Porifera	13	
Unidentified shelf sponges	Porifera	3	
Unidentified puffball mound sponge	Porifera	2	
Unidentified ball sponges	Porifera		1,301
Unidentified sponges (green mound)	Porifera		40
Total Sponges		2,660	2,549

Fishes

Unidentified thornyheads	*Sebastolobus* spp.	2,991	4,449
Unidentified hagfishes	*Eptatretus* spp.	262	192
Deepsea sole	*Embassichthys bathybius*	141	163
Snakehead eelpout	*Lycenchelys crotalinus*	84	244
Dover sole	*Microstomus pacificus*	73	104
Unidentified eelpouts	Zoarcidae	9	92
Unidentified fishes	Osteichthyes	5	151
Roughtail skate	*Bathyraja trachura*	4	14
Skate eggcases	Rajidae	4	2
Sablefish	*Anoplopoma fimbria*	3	6
Unidentified poachers	Agonidae	2	1
Unidentified snailfishes	Liparidae	2	26
California slickhead	*Alepocephalus tenebrosus*	1	2
Unidentified catsharks	Scyliorhinidae	1	7
Shortspine thornyhead	*Sebastolobus alascanus*		52
Pacific grenadier	*Coryphaenoides acrolepis*		62
Twoline eelpout	*Bothrocara brunneum*		1
Pacific flatnose	*Antimora microlepis*		12
Total Fishes		3,582	5,580

Below we present summaries of the species composition and density of corals, sponges, and fishes and associated seafloor habitats observed in the AUV and TCS dives conducted in three areas of our study site off northern California: Area 1 north of Point St. George, Area 2 south of Point St. George, and Area 3 on Mendocino Ridge. Health and condition of the DSC&S are reported, along with incidence of marine debris in each area. We also present depth profiles of sea temperature, salinity, and dissolved oxygen in these areas.

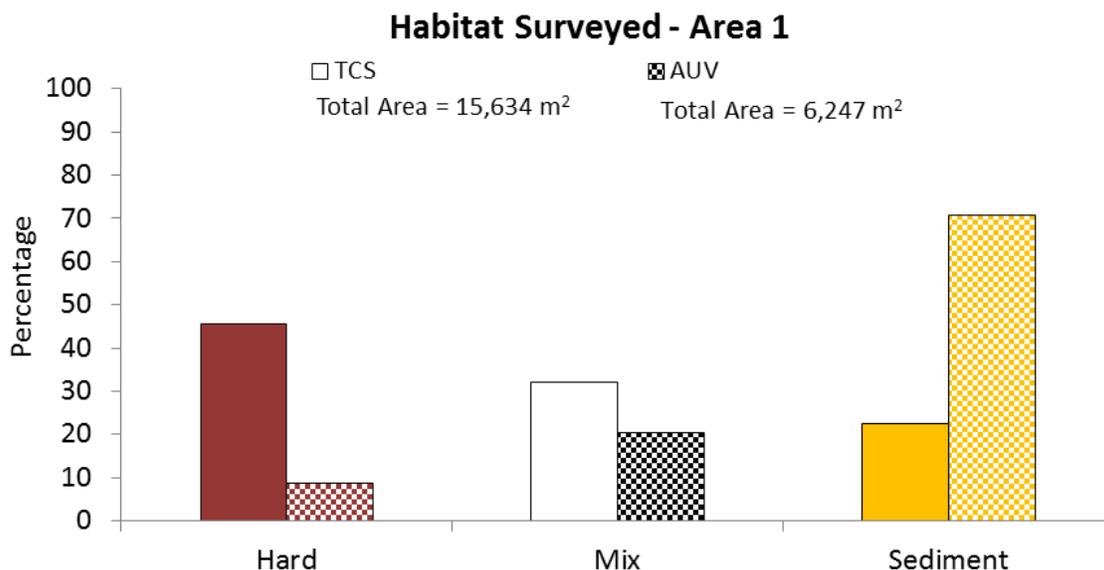## GENERAL LOCATION AND DIVE TRACKS: AREA 1
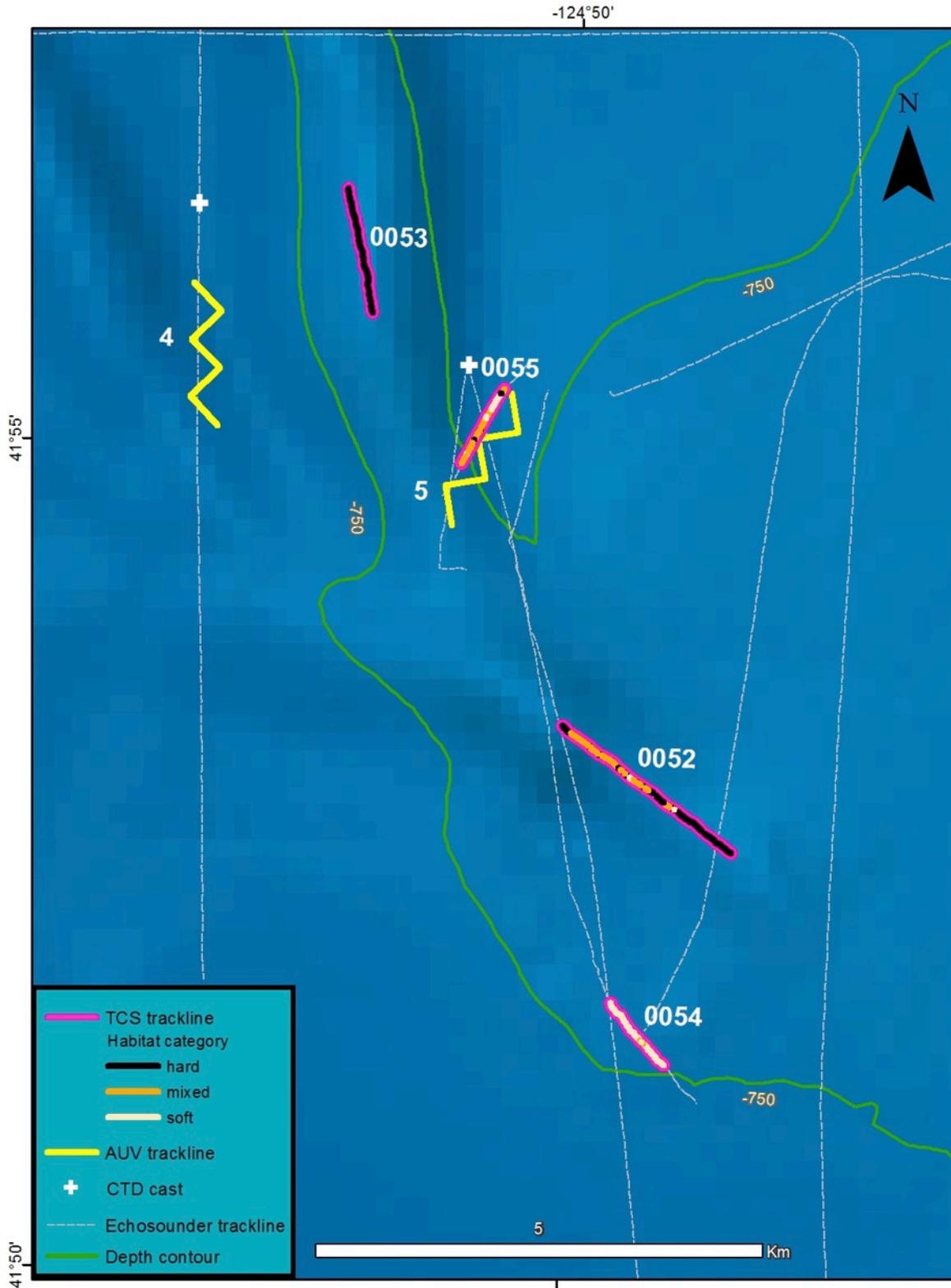
Area 1 study site north of Point St. George off northern California. Locations of dive numbers and tracks of the towed camera system (TCS) and the autonomous underwater vehicle (AUV), bottom types (hard, mixed, and soft) along TCS tracks, tracks of the geophysical survey using the R/V *Point Sur* echosounder, and the sites of CTD casts are indicated. Depth contours are in meters.

STATION OVERVIEW: AREA 1

Project	Northern California Coral and Sponge Trawl Bycatch Cruise
Chief Scientists	M. Yoklavich and E. Clarke
Contact Information	NMFS SWFSC mary.yoklavich@noaa.gov
	NMFS NWSFC liz.clarke@noaa.gov
Purpose	Survey deep coral and sponge communities in areas of high coral bycatch in northern California
Vessel	Moss Landing Marine Laboratories R/V *Point Sur*; NMFS NWFSC/PIFSC SeaBED autonomous underwater vehicle (AUV); NMFS AFSC towed camera system (TCS)
Science Observers	E. Clarke, E. Fruh, L. Krigsman, T. Laidig, M. Yoklavich
External Video Tapes	n/a
Internal Video Tapes	n/a
Digital Still Photos	TCS: 16,596; AUV: 7,944
Positioning System	Ship: GPS; TCS: Ship's GPS; AUV: USBL
CTD Sensors	Yes
O_2 Sensor	Yes
pH Sensor	No
Specimens collected	No
Other	Logbook, Access database
Report Analyst	L. Krigsman, T. Laidig, M. Yoklavich
Date Compiled	July 29, 2015

PHYSICAL ENVIRONMENT: AREA 1

Habitat Surveyed - Area 1

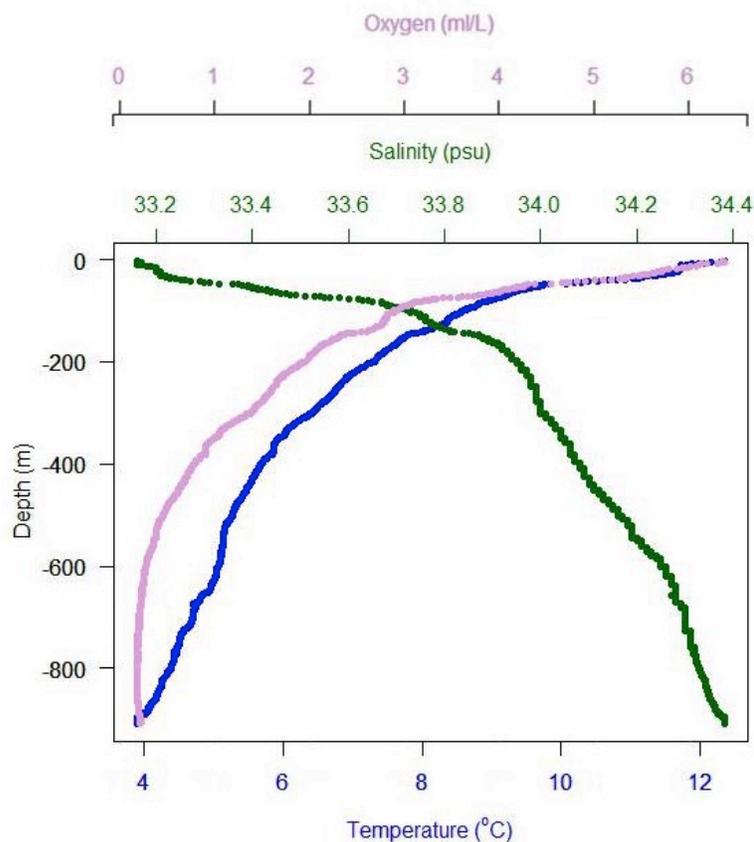□ TCS Total Area = 15,634 m^2　　　⊠ AUV Total Area = 6,247 m^2

A total of 15,634 m^2 of sea floor was surveyed during 4 dives using the towed camera system (TCS) deployed from the R/V *Point Sur* on 12-13 September 2014 in Area 1. The TCS dives were conducted along a series of ridges in water depths 596-772 m.
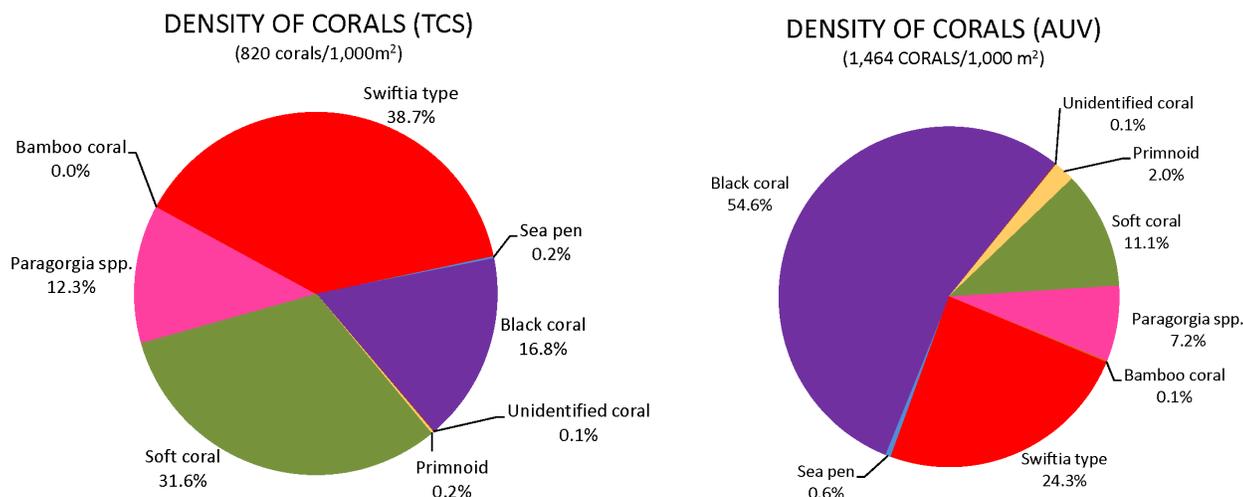
Habitat types classified from the TCS images comprised 46% Hard relatively high-relief rock features, 32% Mixed low-relief rock and mud, and 22% low-relief Sediment (mud).

The SeaBED autonomous underwater vehicle (AUV) surveyed 6,247 m^2 of sea floor during 2 dives on 12-13 September 2014 in Area 1. The AUV dives were conducted in deeper water (695-898 m) than the TCS dives, and comprised 9% Hard rocky habitats, 20% low-relief Mixed rocks and mud, and 71% low-relief Sediment (mud).

We collected data on depth, temperature, conductivity, and dissolved oxygen during descent of the ship's CTD. In Area 1, the CTD was deployed in two locations in association with the two AUV dives. Average temperature ranged from 12.4^{o}C at the sea surface to 4.2 ^{o}C at a maximum depth of 846 m. Salinity (as estimated from conductivity, temperature, and pressure) ranged from an average of 33.2 psu at the sea surface to 34.3 psu at maximum depth. Dissolved oxygen averaged 6.4 ml/L at the sea surface, and decreased to a minimum of 0.171 ml/L at 825 m.

BIOLOGICAL ENVIRONMENT: AREA 1 CORALS

DENSITY OF CORALS (TCS)
(820 corals/1,000m²)

Swiftia type 38.7%
Bamboo coral 0.0%
Paragorgia spp. 12.3%
Sea pen 0.2%
Black coral 16.8%
Soft coral 31.6%
Primnoid 0.2%
Unidentified coral 0.1%

DENSITY OF CORALS (AUV)
(1,464 CORALS/1,000 m²)

Unidentified coral 0.1%
Primnoid 2.0%
Black coral 54.6%
Soft coral 11.1%
Paragorgia spp. 7.2%
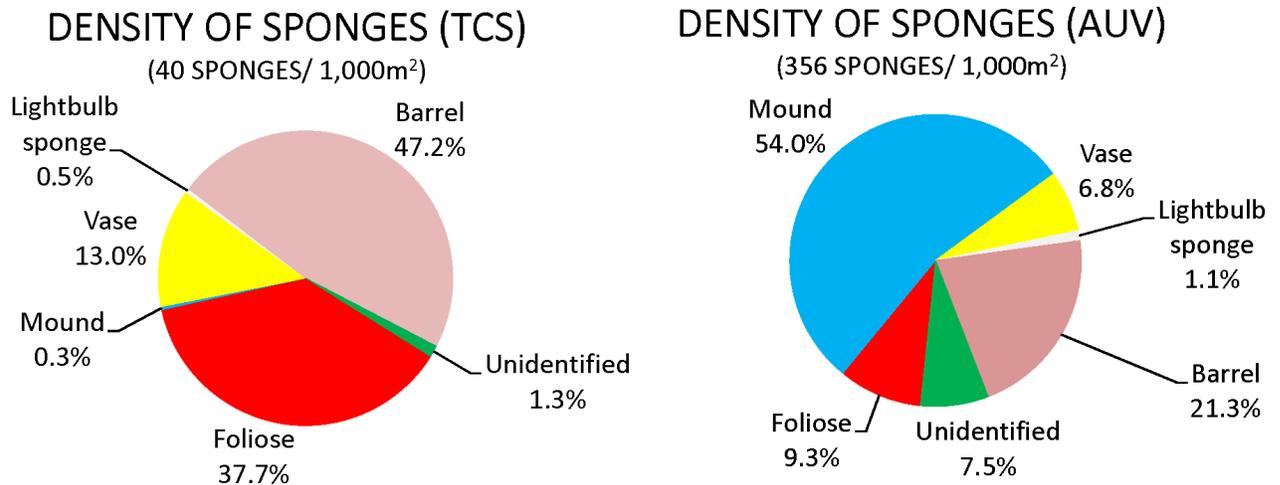Bamboo coral 0.1%
Swiftia type 24.3%
Sea pen 0.6%

Colors in pie diagrams match colors in table below.

A total of 12,821 individual corals, comprising at least 13 taxa, were enumerated from 4 dives conducted with the TCS in Area 1. We estimated an average density of 820 corals per 1,000 m² of sea floor. At least 1 species of the gorgonian *Swiftia* accounted for nearly 39% of the coral density in the TCS dives. Also abundant were 3 species of soft coral (32%; mostly *Heteropolypus ritteri*), 2 species of black coral (17%; mostly *Antipathes* spp.), and the fan-like peppermint coral (12%; *Paragorgia* spp.). Most of the corals occurred in the relatively common Hard and Mixed substrata (78% of seafloor habitats). Corals in the TCS survey ranged in width from 2 – 46 cm and in height from 2 - 89 cm.

	Scientific name	Common name	TCS Count	AUV Count
	Anthoptilum spp.	Feather boa sea pen	0	2
	Funiculina spp.	Unidentified sea pens	26	26
	Pennatulacea #1	Sea pen (thin)	5	16
	Umbellula lindahli	Sea pen	0	9
	Antipathes spp.	Black coral	2154	4991
	Bathypathes spp.	Black coral	1	1
	Hexacorallia/Octocorallia	Unidentified corals	12	11
	Parastenella ramosa	Primnoid	28	179
	Primnoidae	Primnoid (white)	0	3
	Clavularia spp.	Soft coral	14	23
	Gersemia spp.	Soft coral	754	695
	Heteropolypus ritteri	Mushroom coral	3284	302
	Paragorgia spp.	Peppermint coral	1577	658
	Isidella spp.	Bamboo coral	2	0
	Isididae spp.	Unidentified bamboo corals	0	12
	Plexauridae	Swiftia type w/unknown polyps	1229	845
	Swiftia pacifica	Sea fan (red with yellow polyps)	3735	0
	Swiftia spp.	Sea fan		1375
	Total:		12,821	9,148

A total of 9,148 individual corals, comprising at least 16 taxa, were enumerated from 2 dives conducted with the AUV in Area 1. We estimated an average density of 1,464 corals per 1,000 m^2 of sea floor. Over 50% of these corals were black coral (mostly *Antipathes* spp.). The gorgonian *Swiftia* (24%), 3 species of soft coral (11%; mostly *Gersemia* spp.), and the peppermint coral (7%; *Paragorgia* spp.) also were relatively abundant in these deeper AUV dives. Most of the corals occurred in the relatively uncommon Hard and Mixed substrata (29% of seafloor habitats).

BIOLOGICAL ENVIRONMENT: AREA 1 SPONGES

DENSITY OF SPONGES (TCS)
(40 SPONGES/ 1,000m^2)

Lightbulb sponge 0.5%
Barrel 47.2%
Vase 13.0%
Mound 0.3%
Unidentified 1.3%
Foliose 37.7%

DENSITY OF SPONGES (AUV)
(356 SPONGES/ 1,000m^2)

Mound 54.0%
Vase 6.8%
Lightbulb sponge 1.1%
Barrel 21.3%
Foliose 9.3%
Unidentified 7.5%

Colors in pie diagrams match colors in table below.

	Scientific name	Common name	TCS Count	AUV Count
	Porifera	Unidentified foliose sponges	13	0
	Farrea occa	Lace (or cloud) foliose sponge	224	207
	Porifera	Unidentified puffball mound sponges	2	0
	Porifera	Unidentified ball sponges	0	1199
	Porifera	Unidentified green mound sponges	0	2
	Staurocalyptus spp.	Picasso sponge	13	0
	Staurocalyptus spp.	Staurocalyptus like but white	69	150
	Porifera	Unidentified vase sponge	0	1
	Hexactinella spp.	Lightbulb sponge	3	25
	Porifera	Unidentified barrel sponges	297	474
	Porifera	Unidentified sponges	8	168
	Total:		629	2,226

A total of 629 individual sponges, comprising at least 8 taxa, were enumerated from 4 dives conducted with the TCS in Area 1. We estimated an average density of 40 sponges per 1,000 m^2 of sea floor. Nearly 50% of the sponges in the TCS dives were unidentified barrel sponges, followed by foliose (38%; mostly *Farrea occa*) and vase sponges (13%; *Staurocalyptus* spp.). The sponges typically occurred in the relatively

common Hard and Mixed substrata (78% of seafloor habitats). Sponges in the TCS survey ranged in width from 3 – 81 cm and in height from 3 – 50 cm.

Many more sponges occurred in deep water in the AUV dives. A total of 2,226 individual sponges, comprising at least 8 taxa, were enumerated from 2 AUV dives in Area 1. We estimated an average density of 356 sponges per 1,000 m^2 of sea floor. Over 50% of the sponges in the AUV dives were unidentified mound sponges, followed by barrel (21%), foliose (9%; *Farrea occa*), and vase sponges (7%; *Staurocalyptus* spp.). Most of the sponges occurred in the relatively uncommon Hard and Mixed substrata (29% of seafloor habitats).

BIOLOGICAL ENVIRONMENT: AREA 1 FISHES
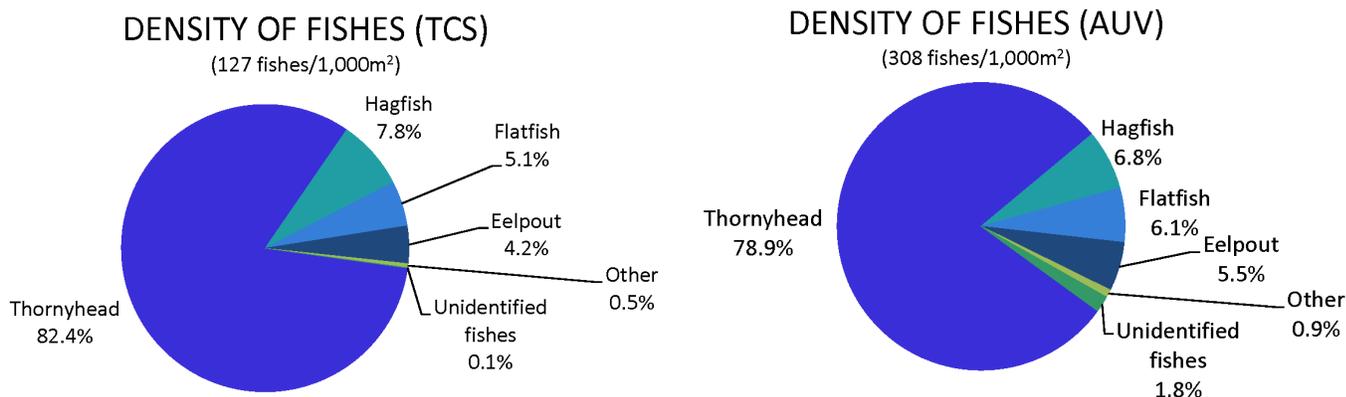
DENSITY OF FISHES (TCS)
(127 fishes/1,000m^2)

Hagfish 7.8%
Flatfish 5.1%
Eelpout 4.2%
Other 0.5%
Unidentified fishes 0.1%
Thornyhead 82.4%

DENSITY OF FISHES (AUV)
(308 fishes/1,000m^2)

Hagfish 6.8%
Flatfish 6.1%
Eelpout 5.5%
Other 0.9%
Unidentified fishes 1.8%
Thornyhead 78.9%

Colors in pie diagrams match colors in table below.

	Scientific name	Common name	TCS Count	AUV Count
	Sebastolobus spp.	Unidentified thornyheads	1640	1518
	Eptatretus spp.	Unidentified hagfishes	156	130
	Embassichthys bathybius	Deepsea sole	46	75
	Microstomus pacificus	Dover sole	55	42
	Lycenchelys crotalinus	Snakehead eelpout	82	97
	Zoarcidae	Unidentified eelpouts	2	9
	Bothrocara brunneum	Twoline eelpout	0	0
	Anoplopoma fimbria	Sablefish	1	1
	Bathyraja trachura	Roughtail skate	3	1
	Alepocephalus tenebrosus	California slickhead	1	0
	Liparidae	Unidentified snailfishes	1	8
	Scyliorhinidae	Unidentified catsharks	1	3
	Agonidae	Unidentified poachers	2	2
	Antimora microlepis	Pacific flatnose	0	0
	Coryphaenoides acrolepis	Pacific grenadier	0	4
	Rajidae	Skate eggcase	0	0
	Osteichthyes	Unidentified fishes	1	35
	Total:		1,991	1,923

Demersal fish assemblages surveyed with the TCS in 596-772 m and the AUV in 695-898 m were nearly identical in Area 1. A total of 3,914 fishes (1,991 in TCS survey and 1,923 in the AUV survey) comprised at least 13 taxa. We estimated an average density of 127 fishes per 1,000 m^2 of sea floor in the TCS surveys and 308 fishes per 1,000 m^2 in the AUV surveys. The assemblages were overwhelmingly dominated by unidentified thornyheads (*Sebastolobus* spp.). Hagfish (*Eptatretus* spp.), flatfishes (*Microstomus pacificus and Embassichthys bathybius*), and eelpouts (mostly *Lycenchelys crotalinus)* were modestly abundant in the TCS and AUV surveys. Fishes in the TCS survey ranged from 5 – 70 cm in total length.

Only 52 (0.4%; 48 corals and 4 sponges) of the 13,450 corals and sponges that were documented during the TCS dives in Area 1 were associated with fishes (one body or less away). Most associations were with black corals and lace foliose sponges. The 35 associated fishes included hagfishes (8%) and thornyheads (92%).

## ADDITIONAL COMMENTS: AREA 1

Three instances of marine debris were observed in TCS surveys in Area 1. A fish trap occurred on dive 0053 and 2 thick cables were observed on dive 0055.

Only 1 coral (*Swiftia pacifica)* and 2 sponges (*Farrea occa*) appeared to be damaged (i.e., had broken parts) in TCS surveys in Area 1. Twenty-four corals (mostly *Paragorgia* spp. and *Swiftia* type) and 4 sponges (mostly barrels) were knocked over or displaced. Most corals and sponges looked healthy; 60 corals (about 66% were black coral (*Antipathes* spp.) and *Swiftia pacifica*) and 11 sponges (mostly *Farrea occa*) appeared to be dying or dead.

IMAGE GALLERY: AREA 1
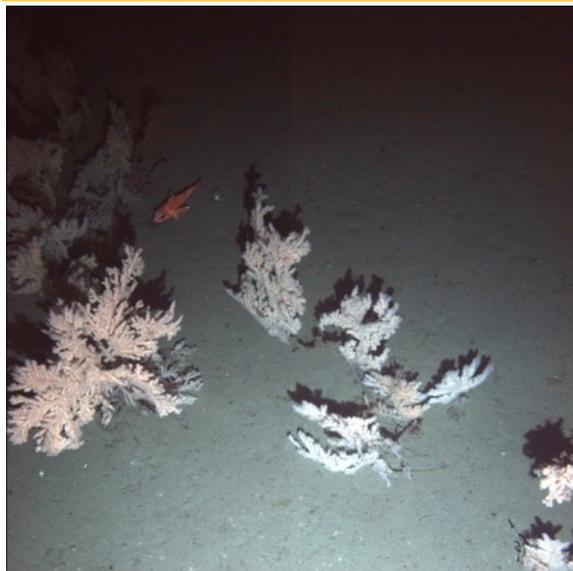
Black coral (*Antipathes* spp.) and a thornyhead (*Sebastolobus* spp.) at 850 m depth on AUV Dive 4.
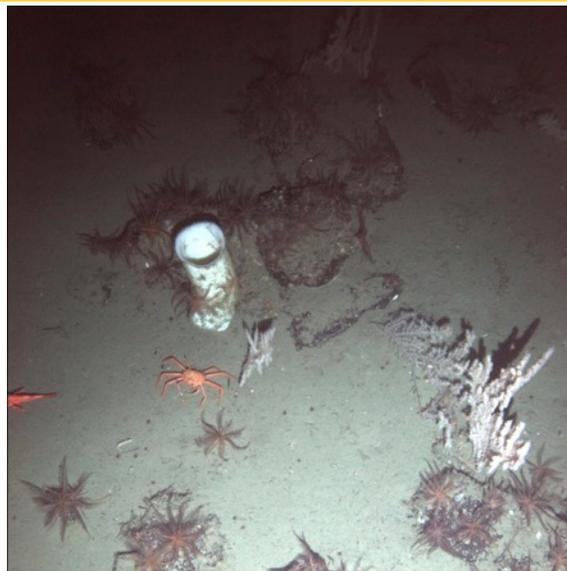
Barrel sponge, black coral (*Antipathes* spp.), tanner crab (*Chionoecetes tanneri*), feather star (*Florometra serratissima*), and thornyhead (*Sebastolobus* spp.) in mixed habitat at 830 m on AUV Dive 4.
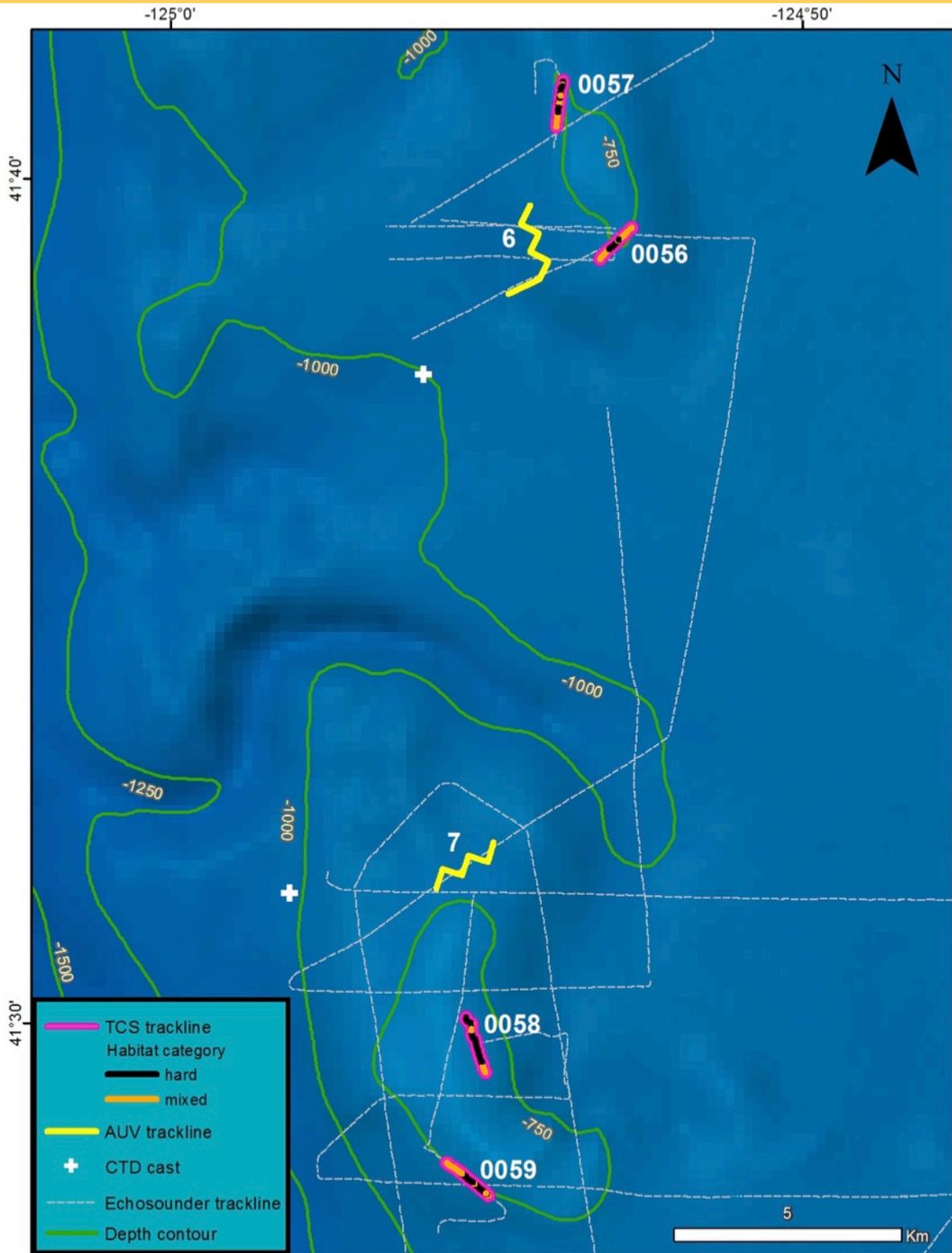

Black skate (*Bathyraja trachura*) and a thornyhead (*Sebastolobus* spp.) at 780 m depth on TCS Dive 0055.

The skeleton of a pinniped (likely a California sea lion, *Zalophus californianus*) and two white sea fans (*Paragorgia* spp.) on the seafloor at 611 m depth on TCS Dive 0053.
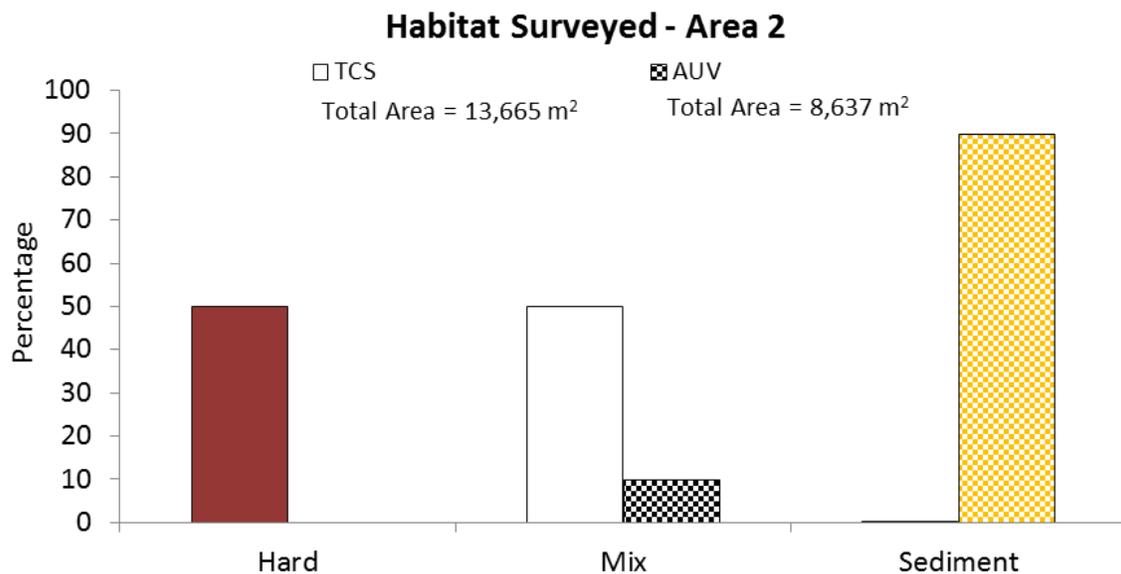
GENERAL LOCATION AND DIVE TRACKS: AREA 2

Area 2 study site south of Point St. George off northern California. Locations of dive numbers and tracks of the towed camera system (TCS) and the autonomous underwater vehicle (AUV), bottom types (hard, and mixed) along TCS tracks, tracks of the geophysical survey using the R/V *Point Sur* echosounder, and the sites of CTD casts are indicated. Depth contours are in meters.

STATION OVERVIEW: AREA 2	
Project	Northern California Coral and Sponge Trawl Bycatch Cruise
Chief Scientists	M. Yoklavich and E. Clarke
Contact Information	NMFS SWFSC mary.yoklavich@noaa.gov
	NMFS NWSFC liz.clarke@noaa.gov
Purpose	Survey deep coral and sponge communities in areas of high coral bycatch in northern California
Vessel	Moss Landing Marine Laboratories R/V *Point Sur*; NMFS NWFSC/PIFSC SeaBED autonomous underwater vehicle (AUV); NMFS AFSC towed camera system (TCS)
Science Observers	E. Clarke, E. Fruh, L. Krigsman, T. Laidig, M. Yoklavich
External Video Tapes	n/a
Internal Video Tapes	n/a
Digital Still Photos	TCS: 13,923; AUV: 10,938
Positioning System	Ship: GPS; TCS: Ship's GPS; AUV: USBL
CTD Sensors	Yes
O$_2$ Sensor	Yes
pH Sensor	No
Specimens collected	No
Other	Logbook, Access database
Report Analyst	L. Krigsman, T. Laidig, M. Yoklavich
Date Compiled	July 29, 2015

PHYSICAL ENVIRONMENT: AREA 2
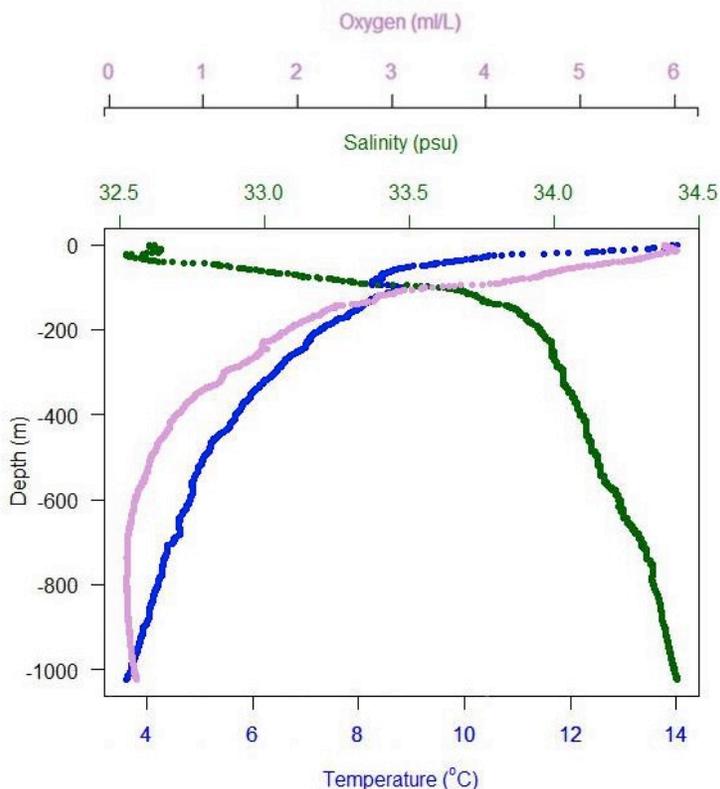

Habitat Surveyed - Area 2

A total of 13,665 m^2 of sea floor were surveyed during 4 dives using the towed camera system (TCS) deployed from the R/V *Point Sur* on 14-15 September 2014 in Area 2. The TCS dives were conducted along a series of ridges in water depths 586-780 m. Seafloor habitat types classified from the TCS images comprised 50% Hard relatively
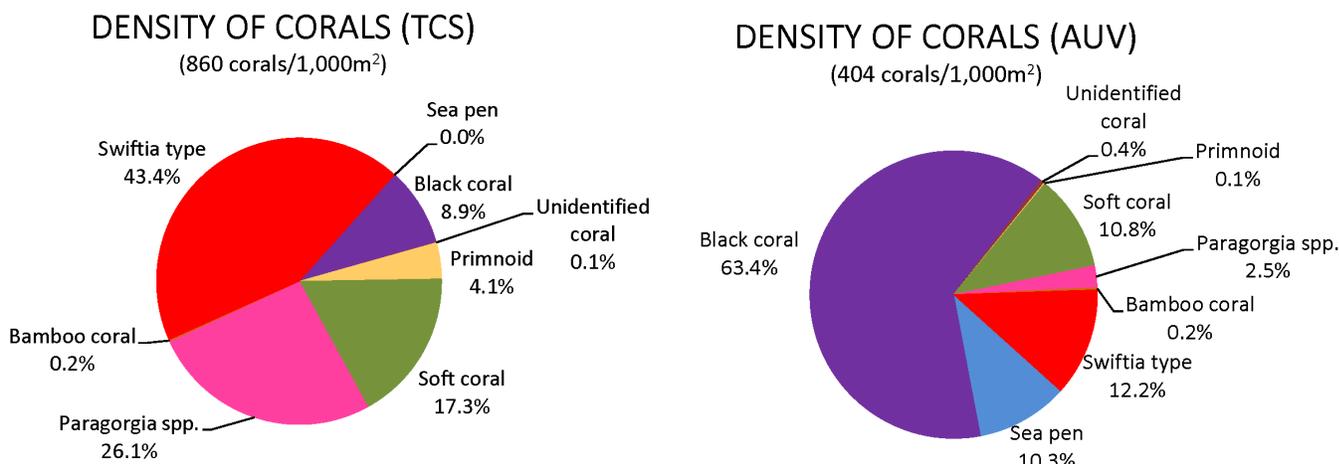
high-relief rock features and 50% Mixed low-relief rock. Low-relief, mud Sediment comprised <0.1% of the habitats surveyed with the TCS in Area 2.

The SeaBED autonomous underwater vehicle (AUV) surveyed 8,637 m^2 of sea floor during 2 dives on 14-15 September 2014 in Area 2. The AUV dives were conducted in deeper water (782-974 m) than the TCS dives. Habitats comprised 90% low-relief Sediment (mud) and 10% low-relief Mixed rocks and mud. Less than 0.2% of the AUV survey was in Hard rocky habitats in Area 2.

We collected data on depth, temperature, conductivity, and dissolved oxygen during descent of the ship's CTD. In Area 2, the CTD was deployed in two locations in association with the two AUV dives. Average temperature ranged from 14.0°C at the sea surface to 3.7°C at a maximum depth of 1,014 m. Salinity (as estimated from conductivity, temperature, and pressure) ranged from an average of 32.5 psu near the sea surface to 34.4 psu at maximum depth. On average, dissolved oxygen was 6.0 ml/L at the sea surface, decreased to a minimum 0.18 ml/L at 736 m, and then increased to 0.28 ml/L at 1,014 m depth.

BIOLOGICAL ENVIRONMENT: AREA 2 CORALS

DENSITY OF CORALS (TCS)
(860 corals/1,000m^2)

Sea pen 0.0%
Swiftia type 43.4%
Black coral 8.9%
Unidentified coral 0.1%
Primnoid 4.1%
Bamboo coral 0.2%
Soft coral 17.3%
Paragorgia spp. 26.1%

DENSITY OF CORALS (AUV)
(404 corals/1,000m^2)

Unidentified coral 0.4%
Primnoid 0.1%
Soft coral 10.8%
Paragorgia spp. 2.5%
Black coral 63.4%
Bamboo coral 0.2%
Swiftia type 12.2%
Sea pen 10.3%

Colors in pie diagrams match colors in table below.

A total of 11,752 individual corals, comprising at least 10 taxa, were enumerated from 4 dives conducted with the TCS in Area 2. We estimated an average density of 860 corals per 1,000 m^2 of sea floor. At least 1 species of the gorgonian *Swiftia* accounted for 43% of the coral density in the TCS dives. Also abundant were the fan-like peppermint coral (26%; *Paragorgia* spp.), 3 species of soft coral (17%), black coral (10%; *Antipathes* spp.), and a primnoid (4%; *Parastenella ramosa*). Most of the corals occurred in Hard and Mixed substrata (comprising 100% of seafloor habitats). Corals in the TCS survey in Area 2 ranged in width from 2 - 58 cm and in height from 3 – 68 cm.
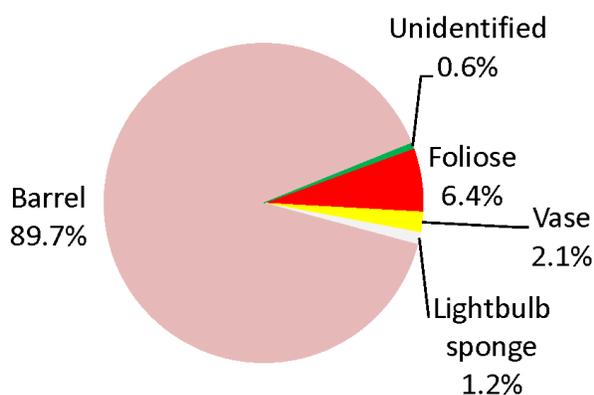
	Scientific name	Common name	TCS Count	AUV Count
	Anthoptilum spp.	Feather boa sea pen	0	11
	Funiculina spp.	Unidentified sea pens	5	59
	Pennatulacea #1	Sea pen (thin)	0	37
	Umbellula lindahli	Sea pen	0	254
	Antipathes spp.	Unidentified black corals	1046	2209
	Bathypathes spp.	Black coral	0	3
	Hexacorallia/Octocorallia	Unidentified corals	6	15
	Parastenella ramosa	Primnoid	479	1
	Primnoidae	Primnoid (white)	0	3
	Clavularia spp.	Soft coral	49	0
	Gersemia spp.	Soft coral	1077	307
	Heteropolypus ritteri	Mushroom coral	902	70
	Paragorgia spp.	Peppermint coral	3072	86
	Isididae	Unidentified bamboo corals	3	8
	Isidella spp.	Bamboo coral	16	0
	Plexauridae	Swiftia type w/unknown polyps	2050	343
	Swiftia pacifica	Sea fan (red with yellow polyps)	3047	0
	Swiftia spp.	Sea fan	0	83
	Total:		11,752	3,489

A total of 3,489 individual corals, comprising at least 13 taxa, were enumerated from 2 dives conducted with the AUV in Area 2. We estimated an average density of 404 corals per 1,000 m^2 of sea floor. Over 63% of these corals were black coral (mostly *Antipathes* spp.). The gorgonian *Swiftia* (12%), 2 species of soft coral (11%; mostly *Gersemia* spp.), and 4 species of sea pens (10%) also were relatively abundant in these deeper AUV dives. Many of the corals occurred in the relatively uncommon Mixed substrata (10% of seafloor habitats in the AUV survey), although the sea pens were observed in soft low-relief Sediment (90% of the survey habitats).
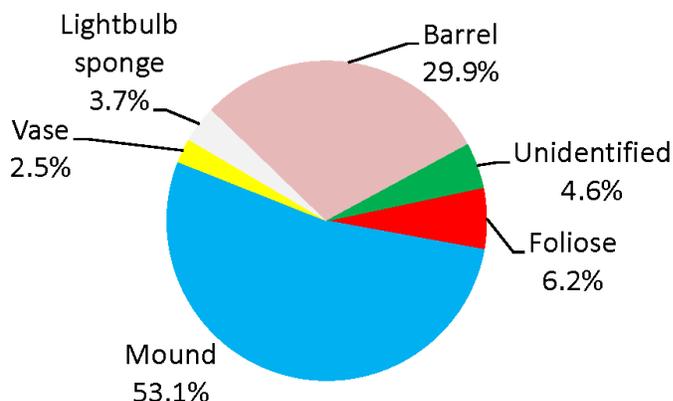
BIOLOGICAL ENVIRONMENT: AREA 2 SPONGES

DENSITY OF SPONGES (TCS)
(131 SPONGES/ 1,000m^2)

DENSITY OF SPONGES (AUV)
(28 SPONGES/ 1,000m^2)

Colors in pie diagrams match colors in table below.

	Scientific name	Common name	TCS Count	AUV Count
🟥	Porifera	Unidentified foliose sponges	0	0
🟥	*Farrea occa*	Lace (or cloud) foliose sponge	115	15
🟦	Porifera	Unidentified puffball mound sponges	0	0
🟦	Porifera	Unidentified ball sponges	0	91
🟦	Porifera	Unidentified green mound sponges	0	37
🟨	*Staurocalyptus* spp.	Picasso sponge	4	0
🟨	*Staurocalyptus* spp.	*Staurocalyptus* like but white	19	6
🟨	Porifera	Unidentified vase sponges	14	0
⬜	*Hexactinella* spp.	Lightbulb sponge	22	9
🟫	Porifera	Unidentified barrel sponges	1601	72
🟩	Porifera	Unidentified sponges	10	11
	Total:		1,785	241

A total of 1,785 individual sponges, comprising at least 6 taxa, were enumerated from 4 dives conducted with the TCS in Area 2. We estimated an average density of 131 sponges per 1,000 m^2 of sea floor. Nearly 90% of the sponges in the TCS dives were unidentified barrel sponges, followed by foliose (6%; mostly *Farrea occa*). The sponges typically occurred in the Hard and Mixed substrata, which together comprised 100% of seafloor habitats in the surveys. Sponges in the TCS surveys in Area 2 ranged in width from 4 - 46 cm and in height from 5 – 64 cm.

Fewer sponges occurred in deep water in the AUV dives in Area 2. A total of 241 individual sponges, comprising at least 6 taxa, were enumerated from 2 AUV dives in Area 2. We estimated an average density of 28 sponges per 1,000 m^2 of sea floor. Over 50% of the sponges in the AUV dives were unidentified mound sponges, followed by barrel (30%) and foliose (6%; *Farrea occa*). Most of the sponges occurred in the relatively uncommon Mixed substrata, which represented only 10% of seafloor habitats in the AUV surveys in Area 2.

BIOLOGICAL ENVIRONMENT: AREA 2 FISHES

DENSITY OF FISHES (TCS)
(104 fishes/1,000m^2)

DENSITY OF FISHES (AUV)
(309 fishes/1,000m^2)
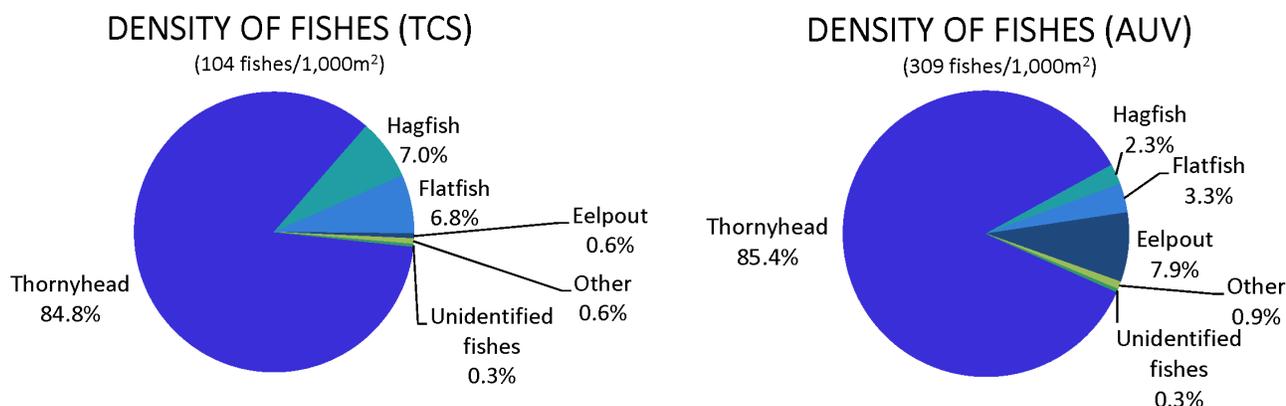
Colors in pie diagrams match colors in table below.

Demersal fish assemblages surveyed with the TCS in 586-780 m and the AUV in 782-974 m were nearly identical in Area 2. A total of 4,089 fishes (1,417 in TCS survey and 2,672 in the AUV survey) comprised at least 15 taxa. We estimated an average density of 104 fishes per 1,000 m^2 of sea floor in the TCS surveys, but much higher density (309 fishes per 1,000 m^2) in the AUV surveys. The assemblages were overwhelmingly dominated by unidentified thornyheads (*Sebastolobus* spp.). Hagfish (*Eptatretus* spp.), flatfishes (*Microstomus pacificus and Embassichthys bathybius*), and eelpouts (mostly *Lycenchelys crotalinus* in the AUV surveys) also were modestly abundant. Fishes in the TCS survey in Area 2 ranged from 5 – 58 cm in total length. In general, the fish assemblages surveyed in Area 1 and Area 2 were similar.

|	Scientific name	Common name	TCS Count	AUV Count
	Sebastolobus spp.	Unidentified thornyheads	1201	2281
	Eptatretus spp.	Unidentified hagfishes	99	62
	Embassichthys bathybius	Deepsea sole	79	57
	Microstomus pacificus	Dover sole	17	30
	Lycenchelys crotalinus	Snakehead eelpout	2	146
	Zoarcidae	Unidentified eelpouts	6	63
	Bothrocara brunneum	Twoline eelpout	0	1
	Anoplopoma fimbria	Sablefish	2	2
	Bathyraja trachura	Roughtail skate	0	6
	Alepocephalus tenebrosus	California slickhead	0	1
	Liparidae	Unidentified snailfishes	1	8
	Scyliorhinidae	Unidentified catsharks	0	2
	Agonidae	Unidentified poacher	0	0
	Antimora microlepis	Pacific flatnose	0	0
	Coryphaenoides acrolepis	Pacific grenadier	0	3
	Rajidae	Skate eggcases	6	1
	Osteichthyes	Unidentified fishes	4	9
	Total:		1,417	2,672

Only 26 of the 13,537 corals and sponges that were documented during TCS dives in Area 2 were associated with fishes (i.e., the fish was located less than one body length from the coral or sponge). The 25 associated fishes were thornyheads (81%), deepsea sole (7%), hagfish (5%), skate egg cases (5%), and Dover sole (2%).

ADDITIONAL COMMENTS: AREA 2

Marine debris was not observed in TCS surveys in Area 2.

In TCS surveys in Area 2, only 7 corals (*Paragorgia* spp.) were damaged (i.e., had broken parts). More corals and sponges were knocked over in Area 2 than in the other areas: 63 corals (73% *Paragorgia* spp. and 19% *Swiftia* type) and 17 sponges (all barrel sponges). Also, 187 corals (including 78 *Antipathes* spp., 58 *Swiftia* type, and 37 *Swiftia pacifica*) and 15 sponges (14 of which were *Farrea occa*) were classified as dead or dying in Area 2.

IMAGE GALLERY: AREA 2
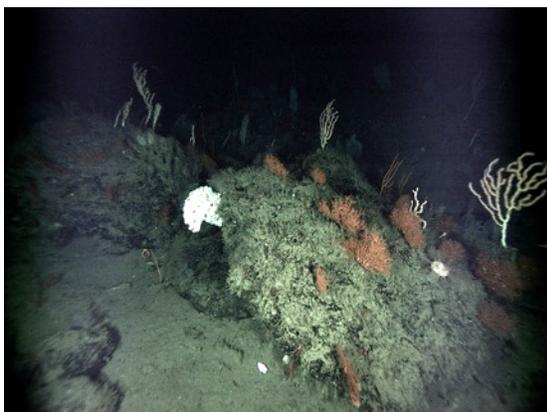
Bright white lightbulb sponge (*Hexactinella* spp.), red sea fan (two types: Plexauridae and *Swiftia* spp.), white sea fan (*Paragorgia* spp.), and mushroom coral (*Heteropolypus ritteri*) at 743 m on TCS Dive 0057.

Black coral (*Antipathes* spp.), lace foliose sponge (*Farrea occa*), primnoid (*Parastenella ramosa*), red sea fan (2 types: Plexauridae and *Swiftia* spp.), white sea fan (*Paragorgia* spp.), mushroom coral (*Heteropolypus ritteri*), and a large shortspine thornyhead (*Sebastolobus alascanus*) at 800 m depth on AUV Dive 7.

Black coral (*Antipathes* spp.), red sea fan (stick type, Plexauridae), and a pom pom anemone (*Liponema brevicornis*) at 830 m on AUV Dive 7.

Two white sea fans (*Paragorgia* spp.) and a large Pacific octopus (*Enteroctopus dofleini*) at 615 m depth on TCS Dive 0059.

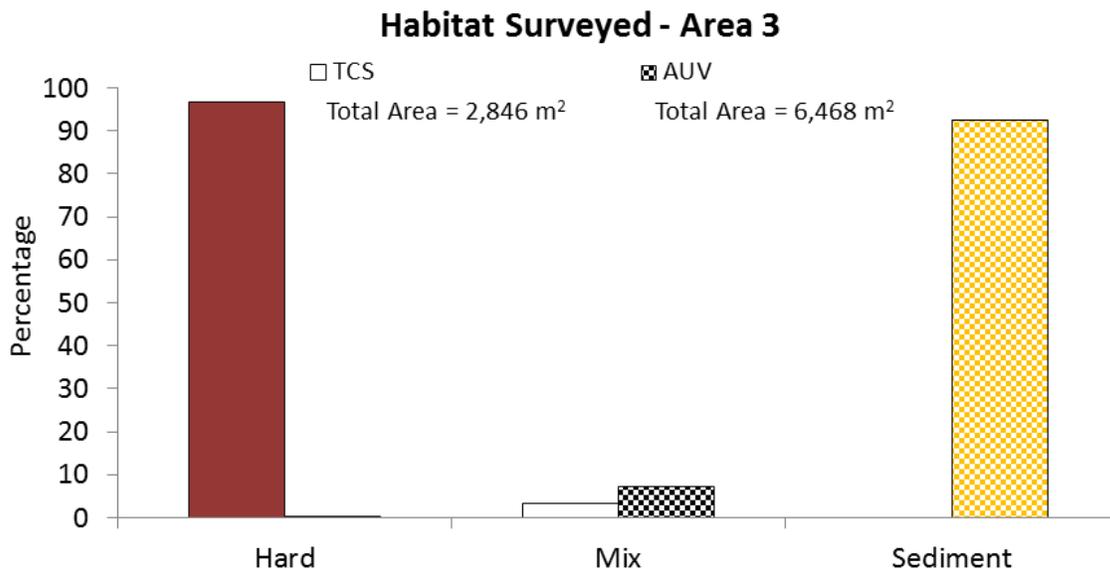## GENERAL LOCATION AND DIVE TRACKS: AREA 3
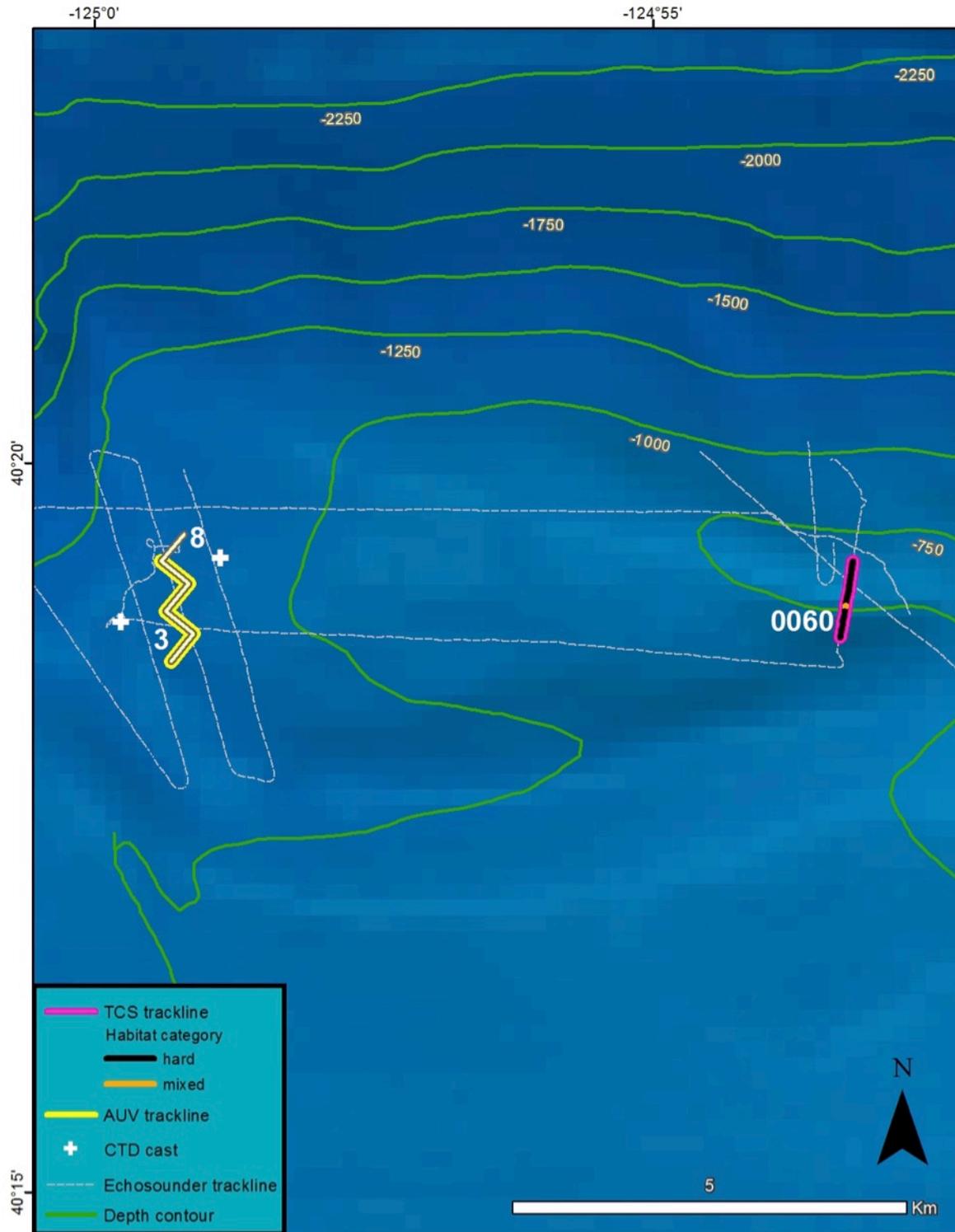
Area 3 study site on Mendocino Ridge off northern California. Locations of dive numbers and tracks of the towed camera system (TCS) and the autonomous underwater vehicle (AUV), bottom types (hard and mixed) along TCS track, tracks of the geophysical survey using the R/V *Point Sur* echosounder, and the site of CTD casts are indicated. Depth contours are in meters.

STATION OVERVIEW: AREA 3	
Project	Northern California Coral and Sponge Trawl Bycatch Cruise
Chief Scientists	M. Yoklavich and E. Clarke
Contact Information	NMFS SWFSC mary.yoklavich@noaa.gov
	NMFS NWSFC liz.clarke@noaa.gov
Purpose	Survey deep coral and sponge communities in areas of high coral bycatch in northern California
Vessel	Moss Landing Marine Laboratories R/V *Point Sur*; NMFS NWFSC/PIFSC SeaBED autonomous underwater vehicle (AUV); NMFS AFSC towed camera system (TCS)
Science Observers	E. Clarke, E. Fruh, L. Krigsman, T. Laidig, M. Yoklavich
External Video Tapes	n/a
Internal Video Tapes	n/a
Digital Still Photos	TCS: 4,460; AUV: 8,505
Positioning System	Ship: GPS; TCS: Ship's GPS; AUV: USBL
CTD Sensors	Yes
O$_2$ Sensor	Yes
pH Sensor	No
Specimens collected	No
Other	Logbook, Access database
Report Analyst	L. Krigsman, T. Laidig, M. Yoklavich
Date Compiled	July 29, 2015

PHYSICAL ENVIRONMENT: AREA 3

Habitat Surveyed - Area 3

□ TCS   ⊠ AUV
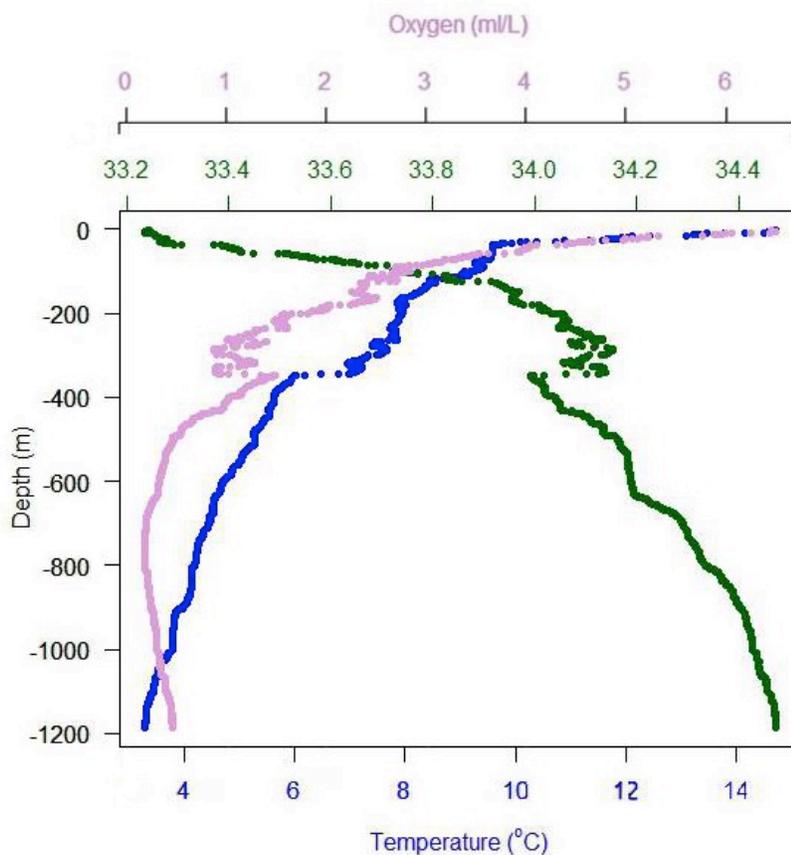Total Area = 2,846 m^2 Total Area = 6,468 m^2

A total of 2,846 m^2 of sea floor were surveyed during a single dive using the towed camera system (TCS) deployed from the R/V *Point Sur* on 16 September 2014 in Area 3. This dive was conducted along the south edge of the Mendocino Canyon in 631-798 m water depth. Seafloor habitat types classified from the TCS images were 97% Hard
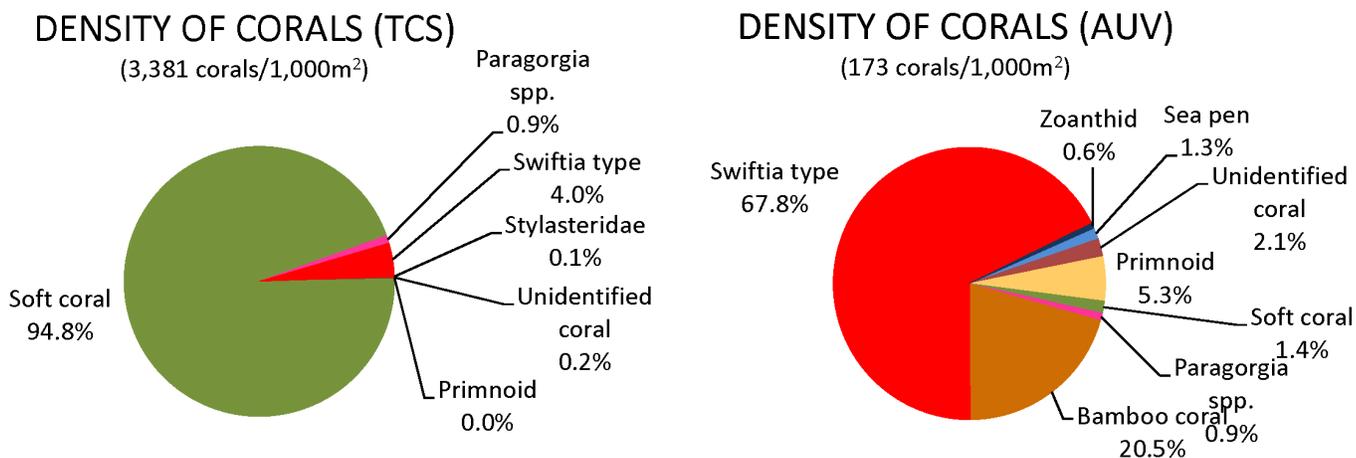
relatively high-relief rock and 3% Mixed low-relief rock and mud. Low-relief mud Sediment was not surveyed with the TCS in Area 3.

The SeaBED autonomous underwater vehicle (AUV) surveyed 6,468 m^2 of sea floor during 2 dives on 11 and 16 September 2014 in Area 3. The AUV dives were conducted on the south edge of the Mendocino Canyon in deeper water (1,086-1,169 m) than the TCS dives. Habitats surveyed with the AUV comprised 93% low-relief Sediment (mud) and 7% low-relief Mixed rocks and mud. Less than 0.5% Hard rocky habitats were surveyed with the AUV in Area 3.

We collected data on depth, temperature, conductivity, and dissolved oxygen during descent of the ship's SeaBird CTD. In Area 3, the CTD was deployed at two locations in association with the AUV dives. Average temperature ranged from 14.7°C at the sea surface to 3.2 °C at a maximum depth of 1,151 m. Salinity (as estimated from conductivity, temperature, and pressure) ranged from an average of 33.2 psu at the sea surface to 34.5 psu at maximum depth. On average, dissolved oxygen was 6.5 ml/L at the sea surface, decreased to a minimum of 0.17 ml/L at 780 m, and then increased to 0.45 ml/L at 1,151 m.

BIOLOGICAL ENVIRONMENT: AREA 3 CORALS

DENSITY OF CORALS (TCS)
(3,381 corals/1,000m^2)

Paragorgia spp. 0.9%
Swiftia type 4.0%
Stylasteridae 0.1%
Unidentified coral 0.2%
Soft coral 94.8%
Primnoid 0.0%

DENSITY OF CORALS (AUV)
(173 corals/1,000m^2)

Zoanthid 0.6%
Sea pen 1.3%
Unidentified coral 2.1%
Swiftia type 67.8%
Primnoid 5.3%
Soft coral 1.4%
Paragorgia spp. 0.9%
Bamboo coral 20.5%

Colors in pie diagrams match colors in table below.

A total of 9,623 individual corals, comprising at least 9 taxa, were enumerated from 1 dive conducted with the TCS in Area 3. We estimated an average density of 3,381 corals per 1,000 m^2 of sea floor, which was the greatest coral density at any of our study sites. The soft coral *Heteropolypus ritteri* dominated the assemblage (95% of all corals), followed by the gorgonian *Swiftia pacifica* (4% of coral density). Most (if not all) of the corals occurred in Hard and Mixed substrata (comprising 100% of seafloor habitats). Corals in the TCS survey in Area 3 ranged in width from 2 – 34 cm and in height from 2 – 54 cm.

A total of 1,121 individual corals, comprising at least 15 taxa, were enumerated from 2 dives conducted with the AUV in Area 3. We estimated an average density of 173 corals per 1,000 m^2 of sea floor. Nearly 68% of these corals were represented by the gorgonian *Swiftia*, followed by at least 3 species of bamboo corals (21%) and the primnoid *Parastenella ramosa* (5%). Many of the corals occurred in the relatively uncommon low-relief Mixed substratum (7% of seafloor habitats in the AUV survey) and rare high-relief rocky Hard substratum (0.5%); a few sea pens were observed in soft low-relief Sediment (93% of the survey habitats).

	Scientific name	Common name	TCS Count	AUV Count
	Pennatulacea #1	Sea pen (thin)	0	4
	Funiculina spp.	Unidentified sea pens	0	6
	Umbellula lindahli	Sea pen	0	4
	Antipathes spp.	Black coral	0	1
	Hexacorallia/Octocorallia	Unidentified corals	20	24
	Parastenella ramosa	Primnoid	1	55
	Primnoidae	Primnoid (white)	0	4
	Clavularia spp.	Soft coral	3	2
	Gersemia spp.	Soft coral	10	3
	Heteropolypus ritteri	Mushroom coral	9112	11
	Paragorgia spp.	Peppermint coral	80	10
	Paragorgia arborea	Bubblegum coral	8	0
	Isididae	Unidentified bamboo corals	0	139
	Isidella spp.	Bamboo coral	0	12
	Keratoisis spp.	Bamboo coral	0	74
	Ledipisis spp.	Bamboo coral	0	5
	Plexauridae	*Swiftia* type w/unknown polyps	23	145
	Swiftia pacifica	Sea fan (red with yellow polyps)	359	0
	Swiftia spp.	Sea fan	0	615
	Stylasteridae	Unidentified lace corals	7	0
	Zoantharia	Unidentified zoanthids	0	7
	Total:		9,623	1,121

BIOLOGICAL ENVIRONMENT: AREA 3 SPONGES

DENSITY OF SPONGES (TCS)
(86 SPONGES/ 1,000m^2)

Vase 70.7%
Barrel 14.6%
Unidentified shelf sponges 1.2%
Foliose 13.4%
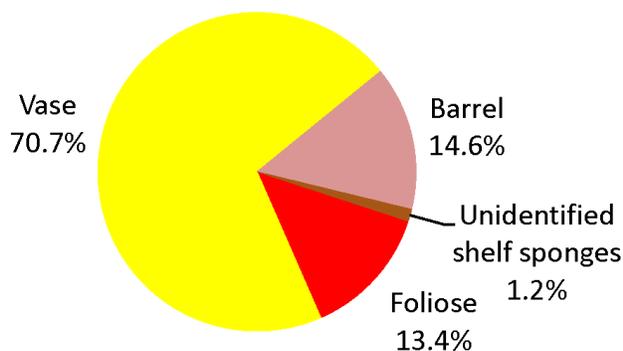
DENSITY OF SPONGES (AUV)
(13 SPONGES/ 1,000m^2)
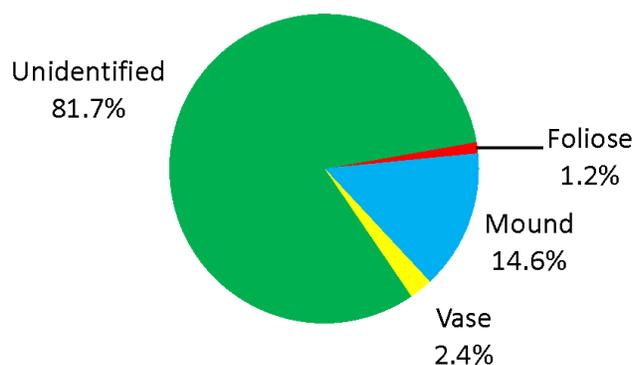
Unidentified 81.7%
Foliose 1.2%
Mound 14.6%
Vase 2.4%

Colors in pie diagrams match colors in table below.

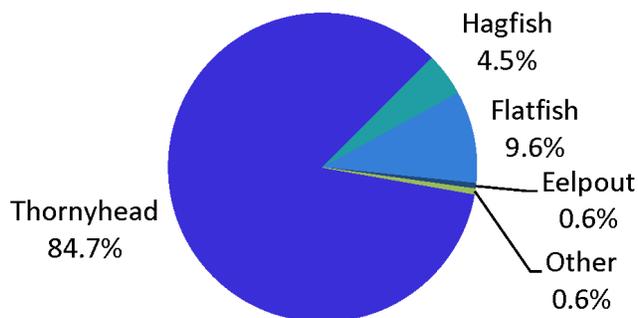|	Scientific name	Common name	TCS Count	AUV Count
🟥	Porifera	Unidentified foliose sponges	0	0
🟥	*Farrea occa*	Lace (or cloud) foliose sponges	33	1
🟦	Porifera	Unidentified puffball mound sponge	0	0
🟦	Porifera	Unidentified ball sponges	0	11
🟦	Porifera	Unidentified green mound sponge	0	1
🟨	*Staurocalyptus* spp.	Picasso sponge	0	0
🟨	*Staurocalyptus* spp.	*Staurocalyptus* like but white	0	0
🟨	Porifera	Unidentified vase sponges	9	2
🟨	*Heterochone calyx*	Fingered goblet vase sponge	165	0
⬜	*Hexactinella* spp.	Lightbulb sponge	0	0
🟫	Porifera	Unidentified barrel sponges	36	0
🟩	Porifera	Unidentified sponges	0	67
🟫	Porifera	Unidentified shelf sponges	3	0
	Total:		246	82

Very few sponges occurred in the TCS and AUV dives conducted on the Mendocino Ridge in Area 3. A total of 246 individual sponges, comprising only 4 taxa, were enumerated from a single TCS dive. We estimated an average density of 86 sponges per 1,000 m^2 of sea floor. The fingered goblet (*Heterochone calyx)* and other vase sponges were most abundant in the TCS (71%), followed by the lace foliose sponge (13%; *Farrea occa*) and unidentified barrel sponges (15%). Most (if not all) of the sponges occurred in Hard and Mixed substrata (comprising 100% of seafloor habitats). Sponges in the TCS dive in Area 3 were relatively small, ranging in width from 4 – 36 cm and in height from 4 – 35 cm.

Fewer sponges occurred in deep water in the 2 AUV dives in Area 3. A total of 82 individual sponges, comprising only 5 taxa, were enumerated from the AUV survey of Area 3. We estimated an average density of only 13 sponges per 1,000 m^2 of sea floor, which was dominated by unidentified sponges (82%) and unidentified mound sponges (15%). Most of the sponges occurred in the relatively uncommon low-relief Mixed substratum (7% of seafloor habitats) and rare high-relief rocky Hard substratum (0.5%) in the AUV surveys of Area 3.
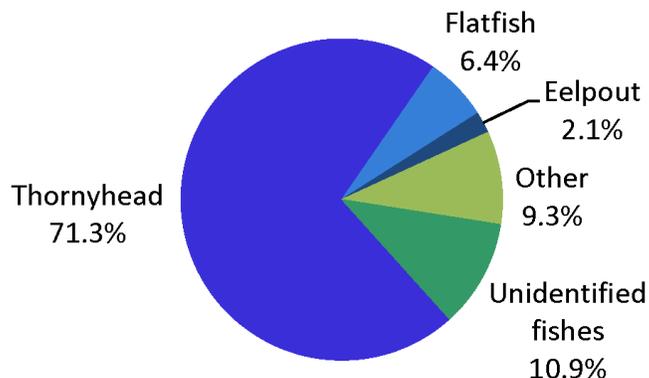
BIOLOGICAL ENVIRONMENT: AREA 3 FISHES

DENSITY OF FISHES (TCS)
(62 fishes/1,000m^2)

Hagfish 4.5%

Flatfish 9.6%

Eelpout 0.6%

Other 0.6%

Thornyhead 84.7%

DENSITY OF FISHES (AUV)
(152 fishes/1,000m^2)

Flatfish 6.4%

Eelpout 2.1%

Other 9.3%

Unidentified fishes 10.9%

Thornyhead 71.3%

Colors in pie diagrams match colors in table below.

	Scientific name	Common name	TCS Count	AUV Count
	Sebastolobus spp.	Unidentified thornyheads	150	702
	Eptatretus spp.	Unidentified hagfishes	8	0
	Embassichthys bathybius	Deepsea sole	16	31
	Microstomus pacificus	Dover sole	1	32
	Lycenchelys crotalinus	Snakehead eelpout	0	1
	Zoarcidae	Unidentified eelpouts	1	20
	Bothrocara brunneum	Twoline eelpout	0	0
	Anoplopoma fimbria	Sablefish	0	3
	Bathyraja trachura	Roughtail skate	1	7
	Alepocephalus tenebrosus	California slickhead	0	1
	Liparidae	Unidentified snailfishes	0	10
	Scyliorhinidae	Unidentified catsharks	0	2
	Agonidae	Unidentified poacher	0	1
	Antimora microlepis	Pacific flatnose	0	12
	Coryphaenoides acrolepis	Pacific grenadier	0	55
	Rajidae	Skate eggcase	0	1
	Osteichthyes	Unidentified fishes	0	107
	Total:		177	985

A total of 1,162 fishes were surveyed with the TCS (177 fishes) and the AUV (985 fishes) in Area 3. Only 62 fishes/1,000 m^2 were surveyed with the TCS in 631-798 m on the Mendocino Ridge, comprising the least diverse assemblage (only 6 taxa) in our entire study off northern California. Unidentified thornyheads (85%; *Sebastolobus* spp.),

Deepsea sole (10%; *Embassichthys bathybius*), and hagfishes (5%; *Eptatretus* spp.) were relatively abundant. Fishes in the TCS survey in Area 3 were relatively small, ranging from 5 – 45 cm in total length.

We estimated an average density of 152 fishes/1,000 m^2 of sea floor from the AUV surveys in 1,086-1,169 m water depth on the Mendocino Ridge (Area 3). This deeper assemblage was more diverse (at least 14 taxa) than that in the TCS survey, and comprised unidentified thornyheads (71%; *Sebastolobus* spp.), unidentified fishes (11%), flatfishes (6%; *Microstomus pacificus and Embassichthys bathybius*), and a variety of less abundant taxa.

Only 37 of the 9,869 corals and sponges that were documented from the TCS dives in Area 3 were associated with fishes (i.e., the fish was located less than one body length from the coral or sponge). The 26 associated fishes were thornyheads (69%), deepsea sole (27%), and Dover sole (4%).

ADDITIONAL COMMENTS: AREA 3

A single brown bottle was the only piece of marine debris observed during the TCS dive in Area 3.

No sponges or corals appeared to be damaged in the TCS survey in Area 3. Only 4 corals (*Paragorgia* spp.) were knocked over, and all sponges were upright. Most corals and sponges were healthy, with 4 sponges (*Farrea occa*) classified as dying.
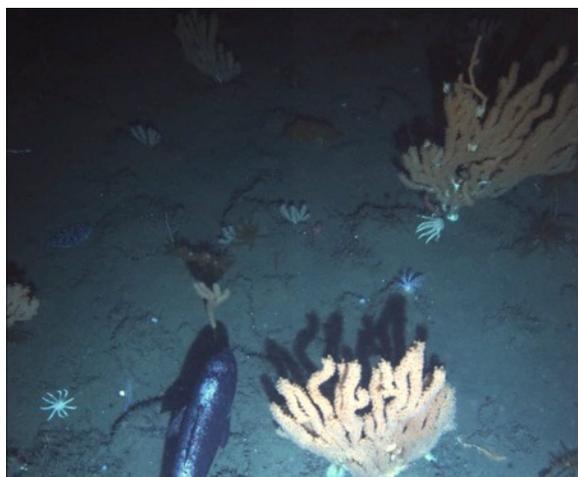
IMAGE GALLERY: AREA 3

Bamboo coral (*Isidella* spp.), red sea fan (*Swiftia* spp.), and tanner crab (*Chionoecetes tanneri*) at 1,110 m depth on AUV Dive 3.

Two types of bamboo coral (*Isidella* spp. and *Keratoisis* spp.) at 1,100 m depth on AUV Dive 3.

Bamboo corals (*Keratoisis* spp.) and a sablefish (*Anoplopoma fimbria*) at 1,110 m depth on AUV Dive 3.

A field of mushroom coral (*Heteropolypus ritteri*) at 708 m depth on TCS Dive 0060.

CONCLUSIONS

From this initial survey, we found that deep areas off Northern California support relatively high densities of corals, ranging from 173 to 3,381 corals/1000 m^2. By comparison, other recent surveys of corals off the U.S. west coast resulted in much lower densities (Table 3). Additionally, diversity of corals was higher in the surveys off Northern (23 taxa) and Southern California (26 taxa) compared to diversity off the coast of Washington and central California (2-10 taxa; Table 3). High diversity in these two locations could reflect the broad range in depth of these surveys.

Table 3. Density and diversity of sponges, corals, and fishes visually surveyed using a remotely operated vehicle, towed camera system, and autonomous underwater vehicle during recent studies funded by NOAAs Deep-sea Coral Research and Technology Program off the U.S. West Coast. Depth range of surveys and total area surveyed are indicated for each study.

Location (area surveyed)	Depth (m)	Sponge		Coral		Fish	
		Density (1000 m^{-2})	Diversity (# taxa)	Density (1000 m^{-2})	Diversity (# taxa)	Density (1000 m^{-2})	Diversity (# taxa)
Olympic Coast NMS, WA[1] (7,374 m^2)	100 - 138	598	12	33	2	-	10
Northern California[2] (53,497 m^2)	586 - 1,169	13 - 356	13	173 - 3,381	23	62 - 309	18
Gulf of Farallones NMS[3] (25,416 m^2)	71 - 453	29 - 184	12	26 - 60	10	49 - 165	46
Cordell Bank NMS[4] (1,754 m^2)	167 - 497	13	5	397	4	195	28
Piggy Bank, Southern CA[5] (21,237 m^2)	275 - 900	224 - 969	26	95 - 536	26	77 - 185	44

[1] Bowlby et al. 2011. [2] This study. [3] Etnoyer et al. 2014. [4] Graiff et al. 2011. [5] Yoklavich et al. 2011.

Density (13 to 356 sponges/1000 m^2) and diversity (13 taxa) of sponges at our study sites off Northern California were comparable to elsewhere along the coast, with the

exception of very few sponges in surveys at Cordell Bank and very high diversity and density of sponges on Piggy Bank in Southern California (Table 3).

Greater amounts of rocky sediment types, generally along ridge tops in relatively shallower water, were surveyed using the TCS compared with more soft mud sediments surveyed with the AUV along ridge flanks in deeper water. Consequently, habitat-specific densities of both corals and sponges will be much higher when considering just the relatively uncommon rocky Hard and Mixed substrata surveyed with the AUV.

Taxonomic composition of corals and sponges were similar in Area 1 and Area 2, with relatively large black corals dominating the deep AUV surveys in both areas. The taxonomic composition of corals and sponges in Area 3, the location of highest coral bycatch in trawl catches, differed from the other two areas. Relatively small corals dominated Area-3 assemblages in both the TCS dive at depths 631-798 m (*Heteropolypus ritteri*) and the AUV dives at depths 1,086-1,169 (*Swiftia* type corals). Relatively small sponges in low densities also occurred in the dives in Area 3.

Fish diversity was relatively low in all dives off northern California, with thornyheads (*Sebastolobus* spp.) dominating the assemblages. Fish densities were comparable to elsewhere along the coast (Table 3). As with other studies along the west coast (Yoklavich et al. 2011; Yoklavich et al. 2013), we found few instances of corals and sponges in close association with demersal fishes in our surveys off Northern California. That is, an average of only 0.3% of 36,856 corals and sponges documented during TCS dives were associated with fishes (fish less than 1 body length from the coral or sponge).

Very few corals and sponges appeared to be damaged or displaced (knocked over) in any of the TCS surveys at our study areas off Northern California (Table 4). The sea fans *Swiftia pacifica* and *Paragorgia* spp., among the most abundant corals in our surveys, were the only taxa with broken parts or knocked over. Barrel and lace foliose (*Farrea occa*) sponges were the most abundant sponges in our surveys and were the only sponge taxa damaged or displaced. Most corals and sponges looked healthy throughout our study area (Table 4), with an average of 1% of all corals (mostly *Swiftia spp.* and *Antipathes* spp.) and sponges (mostly lace foliose) classified as dead or dying in the TCS surveys. There was very little evidence of fishing (1 trap, 2 cables, no trawl tracks) or other marine debris (Table 4).

Examples of displaced and dead corals and sponges: (left image) fallen sea fan *Paragorgia* spp.; (middle image) dead black coral *Antipathes* spp. covered in hydroids; (right image) fallen white vase sponge *Staurocalyptus* spp.

Table 4. Number of damaged, displaced, and dead or dying corals and sponges observed in surveys conducted with the towed camera system (TCS) in study Area 1-3 off Northern California. Type and number of marine debris items also are included.

Area	Total Number	Damaged	Displaced	Dead/Dying	Debris
1	12,821 corals 629 sponges	1 coral 2 sponges	24 corals 4 sponges	60 corals 11 sponges	1 trap 2 cables
2	11,752 corals 1,785 sponges	7 corals 0 sponges	63 corals 17 sponges	187 corals 15 sponges	None
3	9,623 corals 246 sponges	0 corals 0 sponges	4 corals 0 sponges	0 corals 4 sponges	1 bottle

ACKNOWLEDGEMENTS

REFERENCES

Bowlby, C.E., M.S. Brancato, J. Bright, K. Brenkman, and J. Boutillier. 2011. A characterization of deep-sea coral and sponge communities on the continental shelf of Olympic Coast National Marine Sanctuary, Northern Washington, using a remotely operated vehicle. Final Report to NOAA Deep-sea Coral Research and Technology Program. 20 pp.

Etnoyer, P. J., G. Cochrane, E. Salgado, K. Graiff, J. Roletto, G. Williams, K. Reyna, and J. Hyland. 2014. Characterization of deep coral and sponge communities in the Gulf of Farallones National Marine Sanctuary: Rittenburg Bank, Cochrane Bank and the Farallon Escarpment. Technical Memorandum NOS NCCOS 190. NOAA National Centers for Coastal Ocean Science, Charleston, SC. 32 pp.

Graiff, K., D. Roberts, D. Howard, P. Etnoyer, G. Cochrane, J. Hyland, and J. Roletto. 2011. A characterization of deep-sea coral and sponge communities on the continental slope west of Cordell Bank, Northern California using a remotely operated vehicle. Final Report to NOAA Deep-sea Coral Research and Technology Program. 21 pp.

Greene, H.G., M.M. Yoklavich, R.M. Starr, V.M. O'Connell, W.W. Wakefield, D.E. Sullivan, J.E. McRea, Jr., and G.M. Cailliet. 1999. A classification scheme for deep seafloor habitats. Oceanologica Acta 22(6)663-678.

Whitmire, C.E. and M.E. Clarke. 2007. State of deep coral ecosystems of the U.S. Pacific Coast: California to Washington. Pp. 109-154. In: Lumsden, S.E., T.F. Hourigan, A.W. Bruckner, and G. Dorr (eds.) The state of deep coral ecosystems of the United States. NOAA Technical Memorandum CRCP-3, Silver Spring, MD. 365 pp.

Yoklavich, M., H. G. Greene, G. Cailliet, D. Sullivan, R. Lea, and M. Love. 2000. Habitat associations of deep-water rockfishes in a submarine canyon: an example of a natural refuge. Fishery Bulletin, U.S. 98:625-641.

Yoklavich, M., T. Laidig, L. Krigsman, A. Taylor, D. Watters, M. Love, L. Lundsten, and B. Negrete. 2011. A characterization of the coral and sponge community on Piggy Bank Seamount in Southern California from a survey using a remotely operated vehicle. Final Report to NOAA Deep-sea Coral Research and Technology Program. 63 pp.

Yoklavich, M., T. Laidig, A. Taylor, D. Watters, L. Krigsman, and M. Love. 2013. A characterization of the Christmas tree black 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 Prog. 82 p.