Benthic community characterization of the mid-water reefs of Cordell Bank

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Abstract

Scientists from Cordell Bank National Marine Sanctuary (CBNMS) completed visual surveys of mid-water depths as part of a long term plan to monitor benthic communities in the sanctuary in August 2017. The scientists used their Phantom HD2 Remotely Operated Vehicle (ROV) to conduct 10 quantitative dives at random locations over the mid-water reef areas on Cordell Bank in depths from 70-120 m and two quantitative dives at fixed locations on the shallower reefs less than 70 m that were identified for repeated sampling in future years. Densities of corals, sponges and fish and area of physical habitat types were enumerated from thirty five quantitative video transects (10 minutes each). Percent cover of invertebrates and algae was estimated from a total of 593 still images using Coral Point Count with Excel extensions (CPCe 4.1). A diversity of fish and invertebrates were quantified from the video and still images including at least 45 taxa of fish, at least 15 taxa of sponges, at least 5 taxa of corals, at least 33 taxa of other invertebrates and at least 3 taxa of red algae. A significant finding was a species of yellow gorgonian, newly described and named *Chromoplexaura cordellbankensis*. These data on habitat, fish and invertebrates build on the benthic data set collected from a 2014 ROV survey of the shallow water reefs (<70 m depth) of Cordell Bank (Graiff and Lipski, 2016) and allows a comparison to quantitatively assess any observed differences in depth strata. The mid water reefs surveyed in 2017 had a higher percentage (86%) of uncolonized habitat (bare rock or sand) compared to 13% in the shallow strata surveyed in 2014. A nonmetric multidimensional scaling (NMDS) ordination and similarity percentage (SIMPER) test illustrated a significant difference in average percent cover of invertebrate taxa on lines categorized by the depth strata. This difference was driven by high percent cover at depths <70 m of an unknown brown organic matter, encrusting sponges and *Corynactis californica,* while overall percent cover of these taxa were lower at the deeper sites. These data help in understanding the distinctive patterns in community composition, which is essential for monitoring and detecting changes in benthic communities over time.

Introduction

Cordell Bank National Marine Sanctuary (CBNMS) is a marine protected area managed by NOAA off the coast of Point Reyes in northern California. The sanctuary boundaries surround 1,286 square miles of offshore habitat composed of continental shelf, rocky reefs, continental slope, and submarine canyons. Characterization and monitoring of seafloor habitats to understand status and trends of marine resources is one of the sanctuary's management responsibilities.

Cordell Bank, the centerpiece of CBNMS, is an underwater feature composed almost entirely of granitic rock, located at the edge of the continental shelf. Benthic surveys have been completed at Cordell Bank using various technologies and approaches ranging from SCUBA in the late 1970s, human occupied submersibles in the 2000s and remotely operated vehicles (ROV) in the 2010s (Schmieder, 1991; Pirtle, 2005; Graiff and Lipski, 2016). In 2016 CBNMS staff developed a comprehensive benthic monitoring plan to conduct consistent and comparable surveys that would enable scientists and managers to monitor and detect changes in benthic communities over time (Lipski and Graiff, 2017). The plan outlines sampling techniques for four strata within the sanctuary that were identified by looking at depth contours and locality of seafloor features within CBNMS boundaries. The strata are 1) Cordell Bank, 2) the continental shelf, 3) the continental shelf/slope transition and 4) the deep slope including Bodega Canyon (Lipski, 2016). These four strata include a wide range of depths and numerous habitat types. Therefore, to adequately survey and characterize each strata at a fine-scale, it is necessary to design dive locations within a subset of depth ranges per strata for each survey expedition.

This survey in 2017, as well as a previous survey in 2014, focused on the Cordell Bank strata in two depth zones. Cordell Bank is a complex ecosystem with natural breaks in density and diversity of the benthic community structure relative to prominent habitat features like depth and geology. The shallow rocky reefs (above 70 meters) support a rich assemblage of benthic organisms, often exceeding 100 percent cover as animals are layered on top of one another, particularly at depths above 45 meters to the shallowest pinnacles at 35 meters (Graiff and Lipski, 2016). Deeper habitats (below 70 meters) are composed of mixed boulders, cobbles, sand and mud with a lower density of organisms. In addition to depth, other factors may influence community structure, such as the location on the bank, slope and complexity of rock or mixed habitats.

The first fine-scale benthic survey of the Cordell Bank strata targeted depths less than 70 meters (m) and was conducted in 2014 by sanctuary staff using a ROV (Graiff and Lipski, 2016). These depths included the shallowest parts of Cordell Bank and includes the areas of the highest invertebrate cover. In August 2017, CBNMS staff returned to Cordell Bank with the same ROV to conduct surveys at depths of 70-120 m. These depths were selected to cover the remaining extent of Cordell Bank. The goals of this survey were to 1) estimate densities of corals, sponges and fishes from quantitative video transects and 2) estimate percent cover of invertebrates and algae from still images using similar methods used in the 2014 survey and 3) comparative analysis of the 2014 and 2017 percent cover data sets to generate a more complete understanding of the spatial distribution of taxa on Cordell Bank in relation to depth and habitat variables. These surveys are the groundwork for monitoring Cordell Bank's complex ecosystem to detect changes in community composition over time.

Methods

Site Selection and Field Survey

Operations were conducted August 21- 28, 2017 onboard the NOAA R/V *Fulmar* using the CBNMS Phantom HD2 ROV. The ROV was outfitted with a 4k camera developed by Sub C Imaging (SubC Control Ltd, Canada) that is capable of capturing both high definition video in 4k and 16.6 megapixel digital still images. Data are saved internally to a non-removable 512 GB memory card. Video was recorded continuously and still images were manually triggered approximately every 30 seconds using the SubC software on a topside laptop and stored on the camera's storage card. At the end of each survey day, the camera was removed from the ROV and connected by USB to a hard drive to manually download and save video and still images via the SubC interface box. To help produce sharp still photos with even illumination the ROV was equipped with five Light Emitting Diodes (LED) with an output of 19,500 lumens along with a 4,800 lumen strobe lamp. During surveys the video camera angle was maintained at 35 degree tilt. Two parallel lasers spaced 20 cm apart were mounted on the center axis of the camera and were used for sizing objects viewed in video and images. A single green laser (that moved on the vertical axis) was used to help the ROV pilots maintain a consistent height off the bottom. In addition, a GoPro Hero3 camera in a custom submersible housing was mounted facing forward on the lower front lateral bar of the ROV frame to capture wide angle high-definition video imagery for education and outreach.

To study Cordell Bank at a fine-scale, multiple depth zones were targeted during survey design for stratified random transects as well as 'fixed sites' that had been historically sampled. The ROV dives consisted of a series of lines approximately 1 km in length that were randomly chosen from 92 points (coordinates) randomly generated in ArcGIS 10.1 within a grid of 1 km^2 cells overlaid between the 70 to 120 meter contours on Cordell Bank. The 1 km lines were drawn in the direction of 315 degrees (to the Northwest) in ArcGIS from the randomly selected points. In a few instances the random points were at the edge of the strata boundary (contour lines or grid box) so the 1 km line was drawn in the direction of 135 degrees (to the Southeast). Orienting the ROV lines from the Northwest to the Southeast was strategic for successful ship-ROV operations since the predominant weather conditions in the region are winds from the Northwest. ROV lines were also planned for sites in depths less than 70 m to be used as reference and repeatable lines (referred to as 'fixed-sites' in this paper) for comparison among years. Although the fixed sites are in the shallow strata the species community results will be reported in conjunction with the species community results from the ten random lines in the deeper strata. The fixed lines were drawn to overlap historic SCUBA, submersible and ROV surveys.

While on the survey line, the ROV pilots strived to maintain a consistent height and speed from the bottom; targeting about 1 meter off the bottom and at a speed of 0.5 to 1 knot. During the dive, the ROV position was tracked using an ORE Trackpoint II acoustic tracking system that provided bearing and range from the R/V *Fulmar* to the ROV. Trackpoint positions were integrated with the ship's GPS and relative to the planned transect lines using Hypack software (Hypack, Inc., Connecticut, USA). The ROV was also equipped with depth and altitude sensors from Impact Subsea (Impact Subsea Ltd., United Kingdom). The Subsea ISD 4000 (attitude and heading reference system (AHRS) and depth sensor) uses a triaxial gyroscope, accelerometer, and compass to determine the ROV's orientation relative to an absolute reference in real-time along with depth. The Subsea ISA 500 (altimeter and temperature) records temperature, distance from camera to seafloor, correlation factor, energy, heading, pitch, and roll. The ROV coordinates from Hypack were joined to the ISD 4000 and ISA 500 data being saved in .csv format on the computer running the Subsea software.

Data Processing and Image Analysis

ROV tracking was smoothed with a filter over a 20-point sampling window. Extraneous points and false loops in tracking data were removed by hand in an ArcGIS 10.5.1 editor session.

Digital video recorded for each line was subset into 10 minute transects that met specific criteria: the seafloor was in focus with clear visibility and the ROV moved at a consistent height and speed over bottom. These 10-minute segments were used for classifying substrate (habitat type), species identification and counts of corals, sponges and fishes. Substrate type was classified using a two-code classification scheme based on particle size and vertical relief as described in Stein et al (1992). Distinct changes in substratum types greater than or equal to 10 seconds in duration along the transect were recorded, thus establishing "habitat patches" that were then summarized into three classes: hard rock (e.g., rock ridge, boulder, cobble), mixed (hard substrata combined with sand), and soft sand sediment. Individual corals, sponges, and fishes were identified to the lowest taxonomic level and recorded by time to be linked to geographic position. Some sponges were classified by general morphology (e.g., flat, foliose, barrel, and vase) when taxonomic identification was difficult. The maximum size of corals and sponges (to the nearest 5 cm) was determined using the set of paired scaling lasers spaced 20 cm apart and color of individuals was recorded. Condition of each coral and sponge was determined to be healthy (< 10% of organism is dead), unhealthy (10–50% is dead), or dead (> 50% of organism dead). Densities of corals, sponges and fish were estimated by dividing the total number of each taxon by the area of each transect. Marine debris was also identified and georeferenced.

ROV transect area was estimated using methods as described in Stierhoff, et al (2016). Variables such as altitude (height of the camera above the seafloor), camera pitch (estimated from the pitch angle of the ROV, relative to the horizontal), optical properties of the camera (horizontal and vertical viewing angles), and smoothed ROV tracking data (distance between fixes) were incorporated into a script (using base functions in R (R Core Team, 2013) for the start and end times for each of the thirty-five 10 minute transects to compute area surveyed. Microsoft Access 2016 and JMP v14 were used to join the multiple biological datasets with transect navigation-area and estimate taxa densities.

Percent cover of benthic taxa were estimated from still images following methods used for analyzing ROV images collected in 2014 (Graiff and Lipski, 2016). Still images were first assessed for suitability for analysis based on the following criteria: sharp focus of substrate and image was composed of no less than 75% substrate to remove images that were primarily in the water column. All images suitable for benthic community analysis were imported into Coral Point Count with Excel extensions (CPCe 4.1; Kohler and Gill 2006). Although initially developed for assessing species coverage in warm-water coral reef ecosystems, we adapted the program's species and habitat codes to those characteristic of Cordell Bank. To robustly estimate benthic cover and low percent cover types, a total of 50 random points were displayed over each image and every organism or habitat underlying one of the randomly projected points was identified to the lowest practical taxon. Percent cover of all observed taxa was calculated and pooled for all the analyzed images within a line.

The analyzed images were assigned geospatial coordinates by joining the ROV position data with the common fields date and time. Average percent cover of taxa from each georeferenced image and the values from the habitat rasters (depth, slope, aspect, habitat, rugosity) were associated and extracted in ArcGIS 10.5.1. The raster data were coarsened from 3 m to 18 m resolution to provide a better match in resolution between the position data and the observation data. This is consistent with a predictive habitat model for *Stylaster* spp. and 'Swiftia' type gorgonians on Cordell Bank that used similar methods of extracting species observations from submersible video to the 18 m raster datasets (Etherington et al. 2011). The observations of *Stylaster* spp. and gorgonians documented during the image analysis were used to verify the predictive coral model.

A nonmetric multidimensional scaling (NMDS) ordination and similarity percentage (SIMPER) test analyzed the taxa with the most abundant percent cover categorized by the depth strata for each survey year (2014: <70 m and 2017: 70-120 m). The data matrix consisted of samples: lines and variables: percent cover, analyzed on the Bray-Curtis similarity matrix in PRIMER v7 (Clarke and Warwick, 2001).

NMDS is an ordination technique that assesses the similarity in the rank order of the data matrix to construct a visual configuration of the samples in a specified number of dimensions (in this case 2 dimensions). NMDS plots can be arbitrarily scaled, located, rotated, and inverted. The relative distances between points in the ordination are interpreted such that points closer together are more similar than points spaced farther apart. NMDS is an iterative procedure and will choose a configuration of points that minimizes the degree of distortion (measured as stress) between the similarity rankings and the corresponding distance rankings in the ordination plot. Habitat variables (depth, slope, aspect, rugosity) associated with each analyzed image were related to the resulting biological ordination and displayed as vectors to obtain a visualization of the similarities between habitat variables and taxa. SIMPER analysis breaks down the contribution of each taxon to the observed similarity (or dissimilarity) between samples. Therefore, identifying the species that are most important in creating the observed pattern of similarity in the NMDS ordination.

Results

Dive locations and substrate

Five sea days and two weather and equipment repair days occurred from August 21-28, 2017. ROV surveys were successfully completed on ten random lines and two fixed sites (Figure 1). Bottom depths ranged from 48-119 m. The depths of the random lines ranged from 63-119 m and the shallower fixed sites ranged from 48-79 m depth. Total area of all analyzed transects was 15,784 m^2 (Table 1).

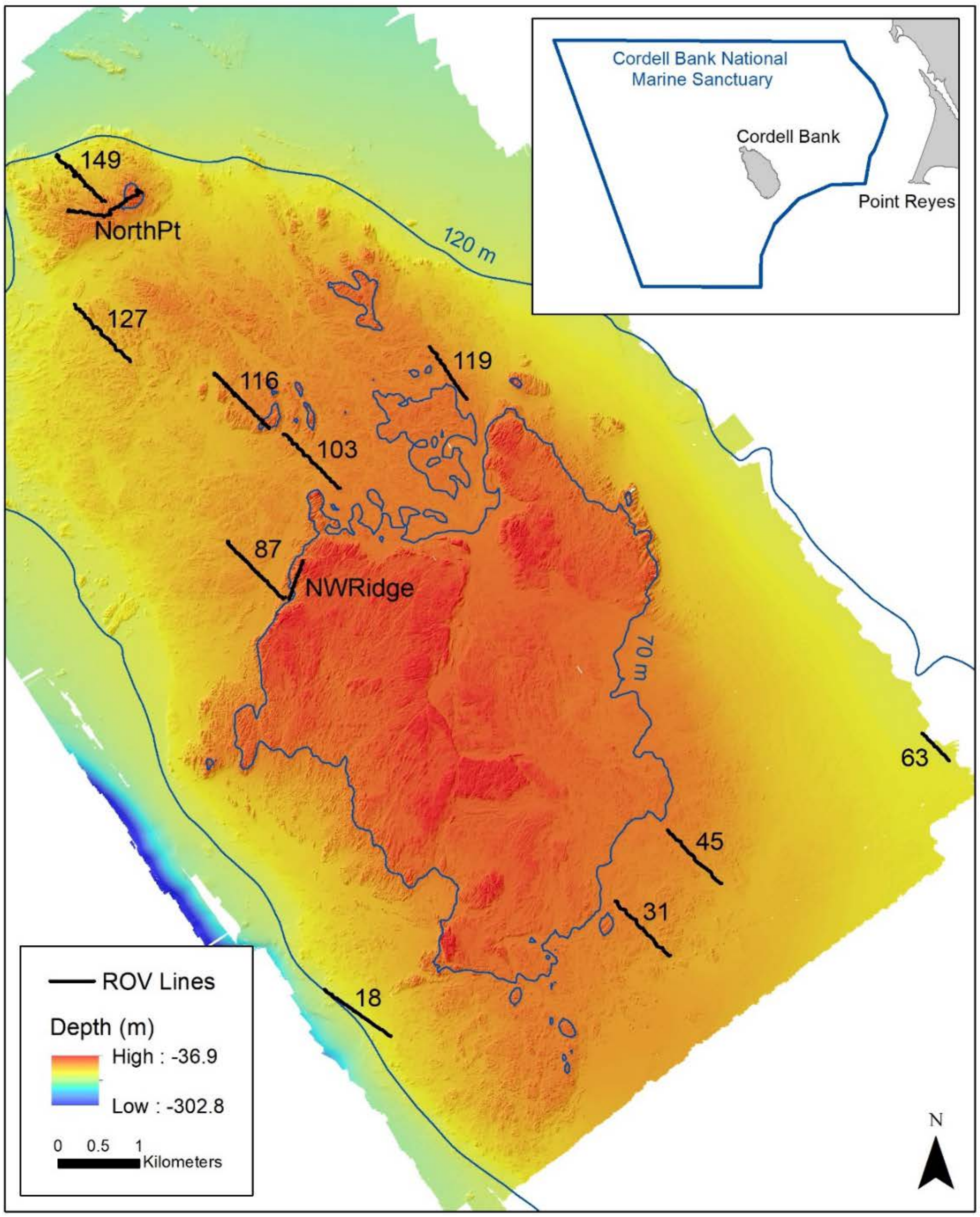

Figure 1. Locations of ROV lines on Cordell Bank. Line numbers correspond to Table 1. North Point and Northwest Ridge are the fixed sites.

Table 1. Line-transects surveyed by a ROV on Cordell Bank from August 21-28, 2017.

Date	Line-Transect	Area (m^2)	Percent of habitat			Average Depth (m)	Depth Min (m)	Depth Max (m)
			Soft	Mixed	Hard			
8/21/2017	45-1	468	0%	34%	66%	81	76	83
8/21/2017	31-1	848	16%	27%	57%	77	74	80
8/21/2017	31-2	431	0%	40%	60%	75	72	76
8/21/2017	31-3	561	3%	35%	63%	71	69	73
8/22/2017	116-1	695	13%	42%	46%	86	79	90
8/22/2017	116-2	526	0%	15%	85%	79	74	82
8/22/2017	116-3	266	0%	0%	100%	74	72	76
8/22/2017	116-4	426	0%	4%	96%	69	63	77
8/22/2017	103-1	338	4%	21%	75%	78	76	79
8/22/2017	103-2	375	0%	13%	87%	78	75	80
8/22/2017	103-3	332	0%	15%	85%	76	74	78
8/22/2017	127-1	332	9%	36%	56%	100	95	103
8/22/2017	127-2	914	0%	1%	99%	90	86	95
8/22/2017	127-3	527	0%	5%	95%	90	81	93
8/23/2017	149-1	620	0%	4%	96%	102	97	109
8/23/2017	149-2	557	0%	21%	79%	92	90	94
8/23/2017	149-3	435	0%	3%	97%	82	74	88
8/23/2017	North Point-1	426	0%	0%	100%	76	72	79
8/23/2017	North Point-2	262	0%	0%	100%	73	67	75
8/23/2017	North Point-3	388	0%	0%	100%	62	56	71
8/23/2017	119-1	762	0%	1%	99%	74	70	78
8/23/2017	119-2	486	0%	12%	88%	73	69	75
8/23/2017	119-3	600	0%	2%	98%	72	71	74
8/27/2017	87-1	365	0%	0%	100%	81	79	82
8/27/2017	87-2	241	0%	0%	100%	82	80	83
8/27/2017	87-3	337	0%	0%	100%	79	77	81
8/27/2017	87-4	830	75%	20%	4%	82	81	83
8/27/2017	NW Ridge-1	449	0%	19%	81%	69	62	76
8/27/2017	NW Ridge-2	390	0%	0%	100%	55	48	64
8/28/2017	18-1	230	74%	8%	18%	116	114	119
8/28/2017	18-2	228	36%	18%	46%	112	108	115
8/28/2017	18-3	174	100%	0%	0%	110	109	112
8/28/2017	18-4	312	6%	27%	67%	105	103	107
8/28/2017	63-1	272	100%	0%	0%	109	109	110
8/28/2017	63-2	382	100%	0%	0%	109	108	109

There were 14 different combinations of habitat types (primary and secondary habitat codes) from the video analysis that were further summarized into three categories: hard, mixed and soft habitats. The percent of total area for each habitat category was calculated per line. Habitat types classified as hard rock (rock-ridge, boulders, and cobbles) accounted for 70% of the total area sampled. Soft (sand) habitat accounted for 17% of the total area sampled. Mixed habitats (rock-ridge, boulders, cobbles and gravel mixed with sand) accounted for 13% of the total area sampled. The two fixed (shallowest) sites, North Point and Northwest Ridge, had the highest percent of hard rock habitats. The percentage of soft sand habitat was greatest on the deeper lines (Figure 2).

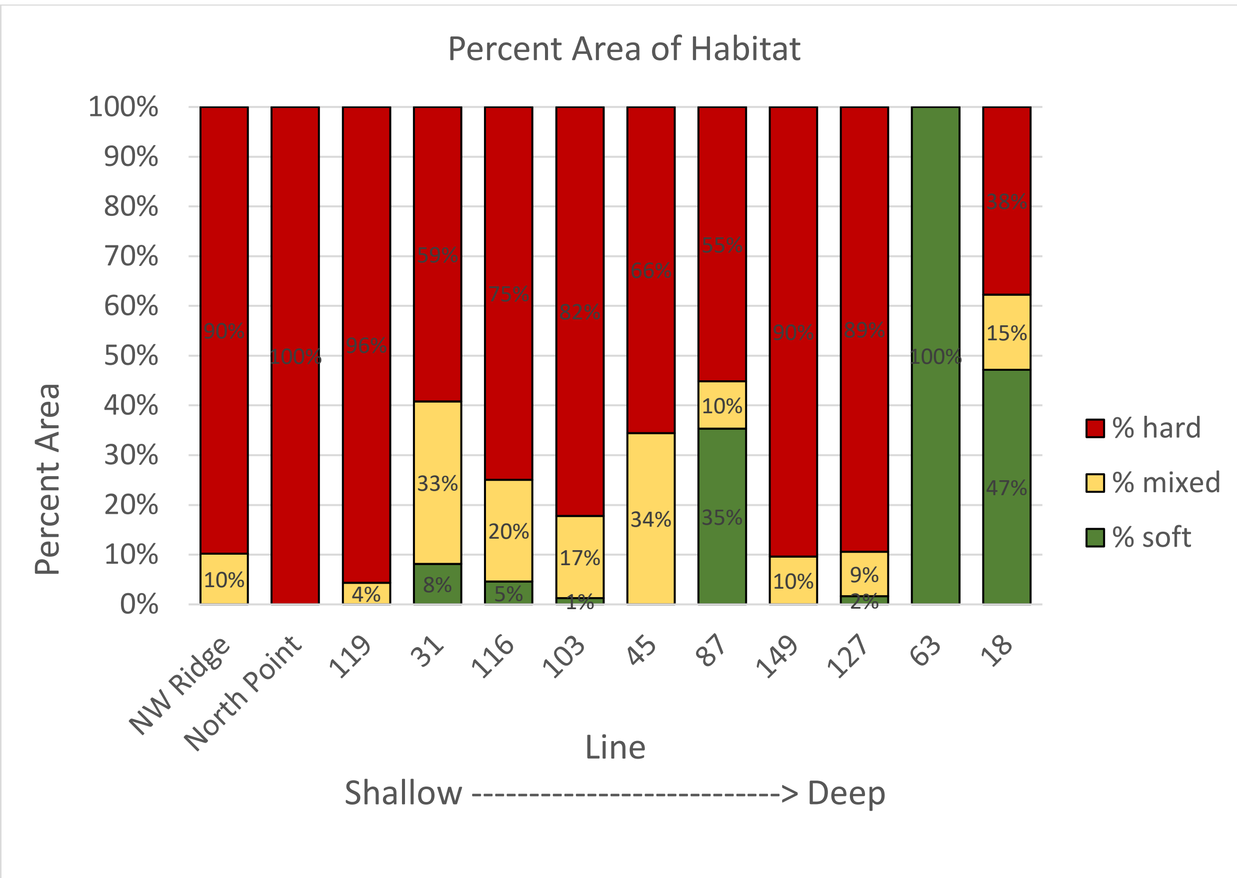

Figure 2. Percent of total habitat area surveyed per line summarized into three habitat categories: hard, mixed and soft. Lines are ordered on the x-axis from shallower to deeper depths from left to right.

Section 1: Species community results from video analysis

Corals

At least three taxa of corals were enumerated from the quantitative video transects. These included *Stylaster* spp. hydrocoral, *Chromoplexaura* spp. gorgonians, and *Halipteris* spp. sea whips (Image Gallery A). *Stylaster* spp. colonies were the densest on the shallow upper reefs at North Point and Northwest Ridge. *Chromoplexaura* spp. gorgonians displayed a more even distribution among the majority of lines between 70 and 120 meters. The majority of *Halipteris* spp. sea whips were observed on the sand bottom of line 63 (Table 2 and Figure 3).

A new observation for CBNMS was small yellow gorgonians, identified as a new species *Chromoplexaura cordellbankensis* (Williams and Breedy, 2019) observed among the red *Chromoplexaura marki* gorgonians that are more commonly observed on Cordell Bank.

Table 2. Densities of corals per 1000 m^2. Corresponding percentage of these densities per line is displayed in Figure 3. *denotes shallow sites

Line	Stylaster	Gorgonian	Sea Whip
18	0	66	1
31	2	168	0
45	4	190	0
63	0	0	23
87	0	455	0
103	0	159	0
116	641	499	0
119	12	623	0
127	17	412	0
149	134	386	0
NrthPt*	2441	12	0
NWRidge*	6949	0	0

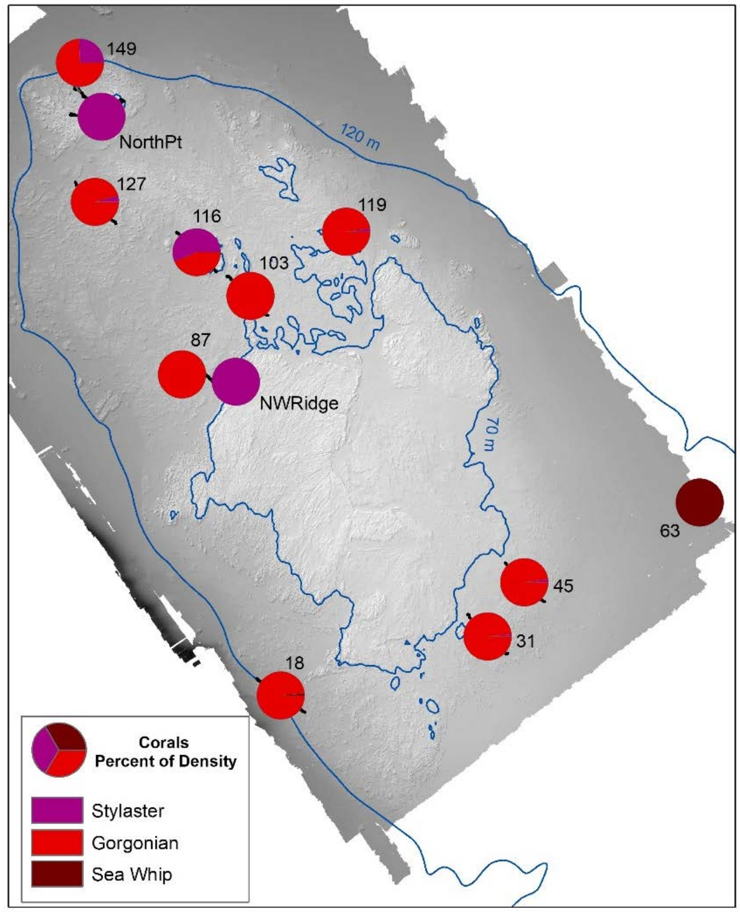

Figure 3. Percent of coral densities per line.

Of the 4,960 gorgonians enumerated on all transects, 82% (n=4,081) were red, 16% (n=771) were yellow and 2% (n=108) were other colors including brown, black and one observation of a white individual. The brown and black individuals were in conditions categorized as 'unhealthy' and the color appeared to be due to the exposed axes or colonization of epiphytes. Yet, only 4% (n=227) of all gorgonians were greater than 50% dead and 10% (n=483) were classified as 10-50% dying. Therefore, 86% of all gorgonians were recorded as being alive and healthy. The unhealthy or dead gorgonians were usually covered in amphipod tubes (n=120) and others had associated zoanthids (n=128) that colonize on dead or dying parts of the coral's skeleton. An unknown ovulid snail (possibly *Simnia* sp.) was observed on 510 gorgonians (10% of total gorgonians), in highest abundance on healthy corals (n=367) and lower abundance on dead or dying corals (n=143). Representative photos in Image Gallery B.

Gorgonian size (width and height) was variable for each color morph. Generally, the yellow *Chromoplexaura cordellbankensis* gorgonians were smaller than the red *Chromoplexaura marki* gorgonians. Half of all *C. cordellbankensis* (51%, n=395) were single stalked and only 5 cm or less in height. Single stalked individuals measured at 10 cm tall accounted for 15% of total observations (n=115) and 13% (n=101) of the total observations were small, branched individuals measured at 5 cm wide and 5 cm tall. The largest *C. cordellbankensis* was 25 cm wide and 30 cm tall. *Chromoplexaura marki* had a greater range of sizes, with 38 different width and height combinations recorded. The greatest frequency of *C. marki* were single stalked and 5 cm tall (18% of total, n=751). About 8% (n=330) were 5 cm wide and 15 cm tall, 7% (n=274) were 10 cm wide and 15 cm tall, 7% (n=272) were 15 cm wide and 20 cm tall and 4% (n=170) were 20 cm wide and 20 cm tall. The largest red gorgonian observed on transects was measured at 30 cm wide and 35 cm tall.

To determine if there were size patterns for *Stylaster* based on depth, percent of total *Stylaster* sizes was calculated for the shallow fixed sites (North Point and Northwest Ridge) and separately for the other deep random sites ranging in depth from 70-120 m. *Stylaster* is generally common above 70 meters and was therefore more abundant on fixed sites than the random sites (n=8,496 shallow, n=1,549 deep). Over half (54%, n=850) of the *Stylaster* at the deeper sites were small at 5 cm wide and 5 cm tall. The highest total count of *Stylaster* at the shallower sites were also small, sized at 5 cm wide to 5 cm tall, but at a lower percent of total (35%) than at the deeper sites. The shallow fixed sites had a greater size variation in *Stylaster* than the deeper sites with the largest (widest and tallest) individuals at the shallow sites. Generally, more *Stylaster* at the deeper sites were a compressed fan shape (large width and small height) whereas the *Stylaster* at the shallower sites were a round shaped morphology with equal height and width measurements.

Sponges and Tunicates

At least 13 taxa of sponges were observed on all lines. Cordell Bank provides habitat for a diversity of sponges and many sponges observed on transect could not be identified so were classified by morphological features. The greatest sponge densities were yellow-brown colored mound sponges that are most likely *Halichondria panacea* (bread crumb sponge). *Halichondria panacea* were uniform in shape and smaller sizes, 85% of total observations measured at 5 cm wide and 5 cm tall.

Larger sponges such as *Xestospongia edapha* (known informally as Cordell Sponge), an unknown large 'plate' sponge, and *Poecillastra* sp. (a type of shelf sponge) were the next most abundant sponges observed. *Xestospongia edapha* were the densest on the shallow rock reefs of North Point and Northwest Ridge. No sponges were observed on line 63 due to this line being comprised of all soft sand sediment. The unknown 'plate' sponge appeared to be very rigid in structure and often had a smooth gray exterior that could be an associated encrusting tunicate or the natural exterior of the sponge. This sponge was most abundant at North Point and found on many of the other random sites, yet it was not documented during the 2014 ROV survey (Graiff and Lipski, 2016). Additionally, 7% (n=26) *Poecillastra* sp. sponges were noted to be unhealthy with an associated unknown smooth brown organism, which may be an encrusting tunicate, covering the top or sides of the sponge.

An unknown species of gray encrusting tunicate, with a large expanse, was commonly observed on most lines in all depth ranges (Table 3, Image Gallery B). The majority of individuals (77% of total, n=374) ranged in width from 20-40 cm and one individual was recorded with a maximum width of 65 cm. The height of all individuals was under 10 cm.

Table 3. Densities of sponges and a gray encrusting tunicate per 1000 m^2. Corresponding percentage of sponge densities (tunicate not included) per line is displayed in Figure 4. *denotes shallow sites

Line	Mound	Xestospongia edapha	Plate	Poecillastra sp.	Unidentified	Stelletta clarella	Barrel	Mycale	Branching	Foliose	Puffball	Shelf	Upright flat	Encrusting Tunicates
18	0	0	0	0	0	0	2	0	0	0	0	1	1	83
31	1090	10	16	3	0	10	10	10	30	3	2	3	2	0
45	259	0	9	2	0	13	0	26	15	2	0	0	4	4
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	3	0	0	29	0	0	3	0	0	1	0	1	1	23
103	10	0	11	15	162	0	21	0	2	10	1	11	11	2
116	449	200	50	8	4	11	9	5	6	13	16	7	13	45
119	681	2	3	0	23	2	4	5	1	3	3	0	2	7
127	63	0	3	7	0	1	8	0	2	1	1	4	5	76
149	425	101	49	164	0	25	14	3	1	7	4	9	2	40
NrthPt*	1817	1935	486	2	0	42	20	23	0	9	10	8	10	38
NWRidge*	1142	739	21	2	0	15	6	6	0	7	8	1	0	13

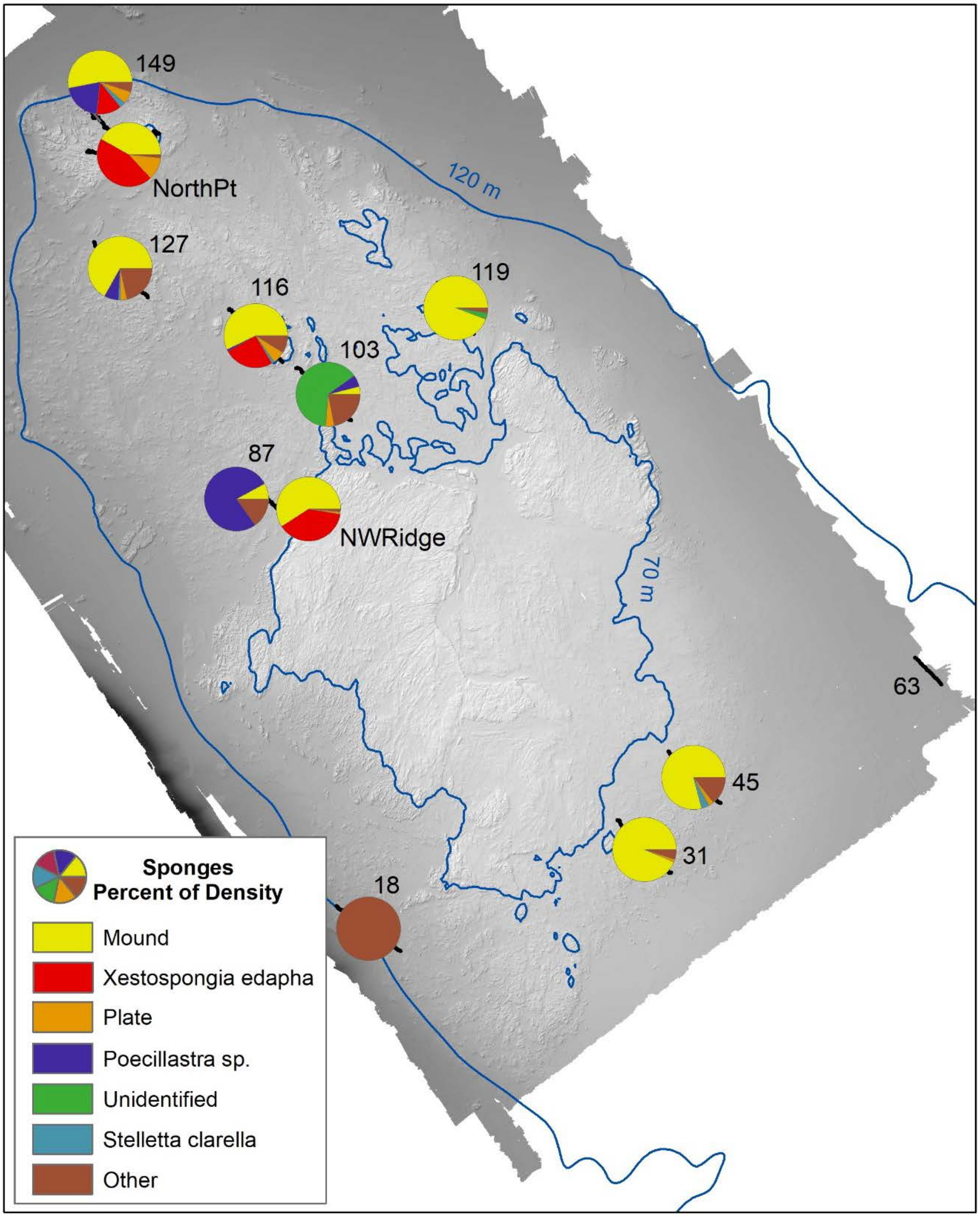

Figure 4. Percent of sponge densities per line.

Fish

At total 9,480 fish from at least 45 different taxa were observed on all transects. The highest density were rockfish (*Sebastes* spp.*)* from 21 species. The highest densities of rockfish were young-of year, and Pygmy Rockfish (*Sebastes wilsoni)* and Rosy Rockfish (*Sebastes rosaceus)*. All lines with hard and mixed substrates provided habitat for rockfish. Line 63 was sand bottom and therefore only flatfish were observed (Table 4). The Blackeye Goby (*Rhinogobiops nicholsii*) was found in similar abundance as *Sebastes rosaceus* (Table 5). The size classes of Yelloweye Rockfish (*Sebastes ruberrimus)* were noted because juveniles are easy to identify by their coloration and are of interest as an 'overfished' species. All lines (except for line 63) had at least one Yelloweye Rockfish recorded and there was an even distribution of counts among sites of individuals categorized as young-of-year/juveniles and those categorized as adults. Over 30% of Yelloweye Rockfish were observed at North Point (8 individuals were adults and 8 individuals were juveniles).

Fish associations with an invertebrate were recorded as a fish resting on or inside an invertebrate or within a body length of the invertebrate. The total number of associations was low (n=25 fish) and observed at the sites with the highest densities of sponges and corals (North Point, Northwest Ridge, and 149) providing more biological habitat for the fish.

Table 4. Densities of fish groups per 1000 m^2. Corresponding percentage of these densities per line is displayed in Figure 5. *denotes shallow sites

Line	Rockfish	Goby	Flatfish	Sculpin	Greenling	Combfish	Ronquil	Poacher	Skate	Fish
18	124	0	5	31	0	1	0	1	0	0
31	399	41	1	1	7	2	2	0	0	0
45	423	81	0	0	2	6	0	0	0	0
63	0	0	99	0	0	0	0	0	0	0
87	238	56	9	8	1	3	0	6	1	1
103	605	144	0	4	2	13	5	0	0	0
116	833	109	1	8	9	10	2	1	0	0
119	535	69	0	0	8	2	0	0	0	0
127	328	37	2	3	0	2	2	5	0	0
149	631	47	0	2	7	1	1	2	0	0
NrthPt*	1257	73	0	1	18	1	0	0	0	0
NWRidge*	631	36	0	1	30	4	0	0	0	0

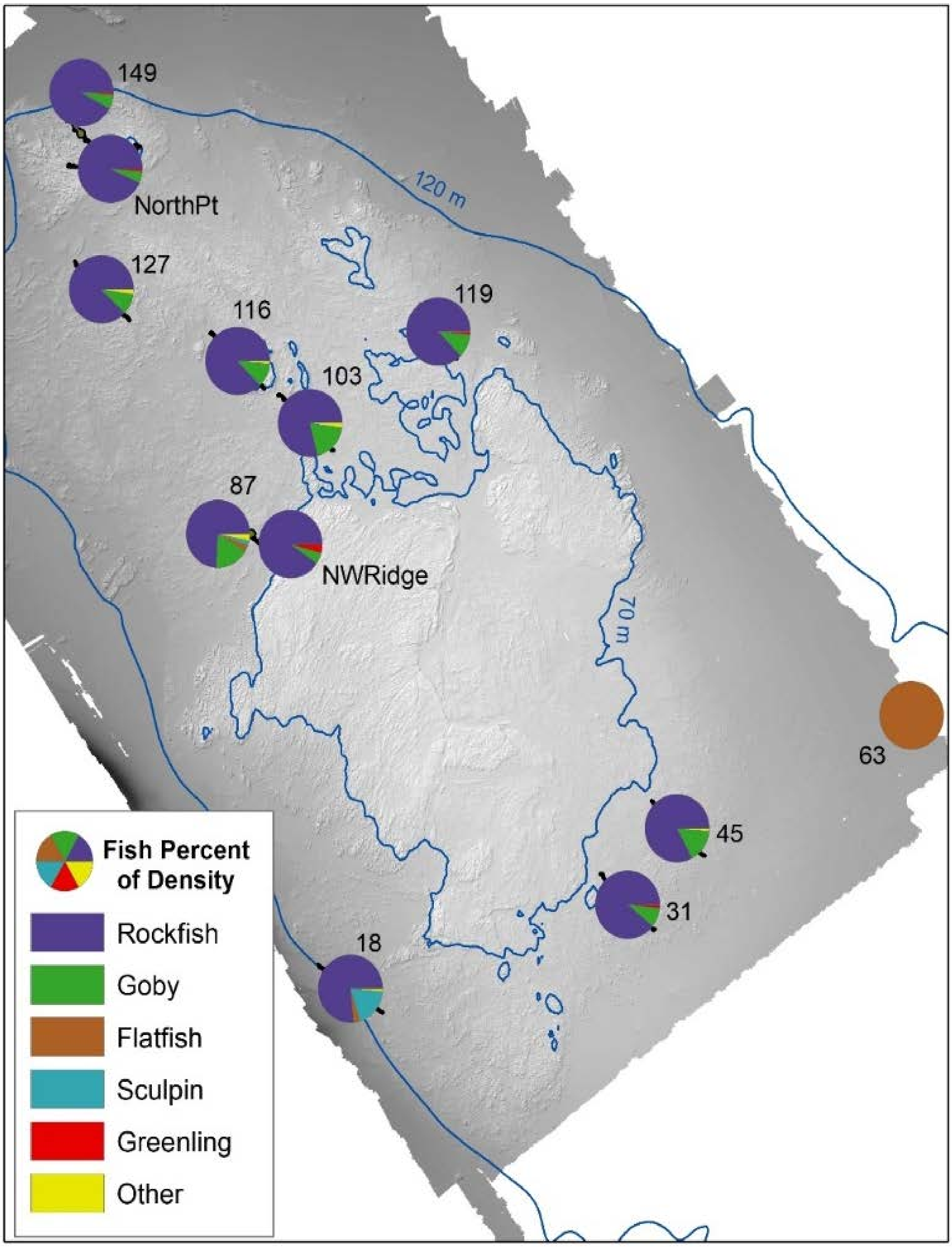

Figure 5. Percent of fish group densities per line. "Other' category includes: Combfish, Ronquil, Poacher, Skate and Unknown fishes.

Table 5. List and total counts of fish taxa observed on all line-transects.

Group	Scientific Name	Common Name	Total Individuals
ROCKFISH	Sebastes caurinus	Copper Rockfish	1
ROCKFISH	Sebastes chlorostictus	Greenspotted Rockfish	42
ROCKFISH	Sebastes constellatus	Starry Rockfish	22
ROCKFISH	Sebastes elongatus	Greenstriped Rockfish	8
ROCKFISH	Sebastes entomelas	Widow Rockfish	1
ROCKFISH	Sebastes flavidus	Yellowtail Rockfish	368
ROCKFISH	Sebastes helvomaculatus	Rosethorn Rockfish	10
ROCKFISH	Sebastes hopkinsi	Squarespot Rockfish	534
ROCKFISH	Sebastes maliger	Quillback Rockfish	10
ROCKFISH	Sebastes miniatus	Vermilion Rockfish	3
ROCKFISH	Sebastes nebulosus	China Rockfish	2
ROCKFISH	Sebastes ovalis	Speckled Rockfish	11
ROCKFISH	Sebastes paucispinis	Bocaccio	15
ROCKFISH	Sebastes pinniger	Canary Rockfish	11
ROCKFISH	Sebastes proriger	Redstripe Rockfish	2
ROCKFISH	Sebastes rosaceus	Rosy Rockfish	992
ROCKFISH	Sebastes ruberrimus	Yelloweye Rockfish	50
ROCKFISH	Sebastes semicinctus	Halfbanded Rockfish	1
ROCKFISH	Sebastes spp	Unidentified Rockfishes	284
ROCKFISH	Sebastes spp	Juvenile Rockfish	3244
ROCKFISH	Sebastes wilsoni	Pygmy Rockfish	2445
ROCKFISH	unknown sebastomus	Sebastomus	106
GOBY	Rhinogobiops nicholsii	Blackeye Goby	948
FLATFISH	Citharichthys sp.	Unidentified Sanddab	74
FLATFISH	Lepidopsetta bilineata	Rock Sole	1
FLATFISH	Lyopsetta exilis	Slender Sole	1
FLATFISH	Microstomus pacificus	Dover Sole	1
FLATFISH	Parophrys vetulus	English Sole	1
FLATFISH	unknown	Flatfishes	14
SCULPIN	Icelinus spp.	Icelinus Sculpins	10
SCULPIN	Icelinus tenuis	Spotfin Sculpin	11
SCULPIN	Paricelius hopliticus	Thornback Sculpin	18
SCULPIN	Radulinus asprellus	Slim Sculpin	2
SCULPIN	unknown	Unidentified Sculpin	34
GREENLING	Hexagrammos decagrammus	Kelp Greenling	4
GREENLING	Ophiodon elongatus	Lingcod	25
GREENLING	Oxylebius pictus	Painted Greenling	74
COMBFISH	Zaniolepis frenata	Shortspine Combfish	43
COMBFISH	Zaniolepis spp	Combfishes	15
RONQUIL	Rathbunella alleni	Stripefin Ronquil	9
RONQUIL	Rathbunella sp.	Unidentified Ronquil	3
RONQUIL	Ronquilus jordani	Northern Ronquil	4
POACHER	unknown agonidae	Poachers	23
POACHER	Xeneretmus triacanthus	Blue Spotted Poacher	1
SKATE	Raja sp.	Unidentified Skate	1
UNKNOWN	unknown	Unidentified fishes	1

Section II: Benthic community percent cover from still images and comparison to 2014 data

A total of 593 still images were analyzed for percent cover of invertebrates and algae for all line-transects (Appendix A) in depths from 58-120 m. The sites North Point and Northwest Ridge account for the depths on average shallower than 70 m. The majority of still images are in the 70-120 m depth range.

A diversity of invertebrates, algae and fish were observed among all still images. Appendix B lists the 55 taxa of invertebrates, 4 taxa of algae and two unknown taxa observed. Point counts from the image analysis were used to calculate percent cover of taxa for each line. Percent cover was combined into groups or phylum (Table 6) and spatially displayed by transect in Figure 6. The total percent per line in table 6 does not equal 100 percent because the percent cover of fish are not reported as these values were minimal and the goal was to characterize benthic invertebrates and algae communities. The group "Habitat" refers to substrate that did not have any invertebrate or algal cover (e.g., bare rock or sand).

On average, over half of the total percent cover for all lines was bare rock or sand substrate that did not have any invertebrate or algal cover (64% ± 22.3). Cnidaria and Chordata were on average the next most abundant in percent cover among lines (10% ± 10.6 and 9% ±6.9 respectively). There was high standard deviation in the means for these two phylum due to greater percent cover on the shallower lines North Point and Northwest Ridge (Table 6, Figure 6). The strawberry anemone (*Corynactis californica)* and an unknown gray encrusting tunicate were the dominate taxa in phylum Cnidaria and Chordata respectively. The unknown biological group accounted for 6% of the average percent cover and was observed on all lines expect for 63 (sand habitat) (Figure 6). This group is made up of two organisms that are encrusting on rock: a textured layer of brown organic matter and a thin-smooth encrusting dark green mat. Other species were observed in multiple phylum (Porifera, Rhodophyta, Echinodermata, Annelida, Bryozoa, Arthropoda and Mollusca) with percent cover ranging from 4% and less (Table 6, Appendix B).

Table 6. Percent cover of phylum or group per line as displayed in Figure 6. *denotes shallow sites

Line	Habitat	Cnidaria	Chordata	Unkn Biological	Porifera	Rhodophyta	Echinodermata	Annelida	Bryozoa	Arthropoda	Mollusca
18	88.85	0.67	2.87	0.12	0.12	0.03	6.53	0.20	0.26	0.00	0.00
31	75.24	4.69	4.31	5.34	6.36	2.59	1.08	0.00	0.00	0.11	0.00
45	84.29	2.55	2.34	4.03	2.12	2.76	1.70	0.00	0.00	0.00	0.00
63	99.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	68.79	5.38	7.27	5.35	1.45	9.44	1.98	0.20	0.00	0.00	0.06
103	60.44	6.46	7.17	16.78	4.28	2.52	1.89	0.13	0.00	0.00	0.00
116	56.64	13.45	10.27	7.58	6.76	3.86	0.89	0.18	0.00	0.04	0.07
119	55.52	6.86	16.64	8.98	3.03	6.81	1.61	0.05	0.00	0.00	0.00
127	63.15	7.56	8.75	7.17	4.19	2.83	5.56	0.22	0.00	0.00	0.00
149	56.46	11.74	11.70	7.62	6.07	3.51	1.88	0.33	0.00	0.08	0.04
NrthPt*	18.73	33.63	23.19	7.02	11.06	4.86	0.72	0.04	0.00	0.04	0.11
NWRidge*	36.43	28.65	16.60	2.77	7.05	6.50	1.09	0.05	0.14	0.05	0.09
AVERAGE	**63.70**	**10.14**	**9.26**	**6.06**	**4.37**	**3.81**	**2.08**	**0.12**	**0.03**	**0.03**	**0.03**
(STDEV)	*(± 22.29)*	*(± 10.62)*	*(± 6.85)*	*(± 4.45)*	*(± 3.26)*	*(± 2.75)*	*(± 1.95)*	*(± 0.11)*	*(± 0.08)*	*(± 0.04)*	*(± 0.04)*

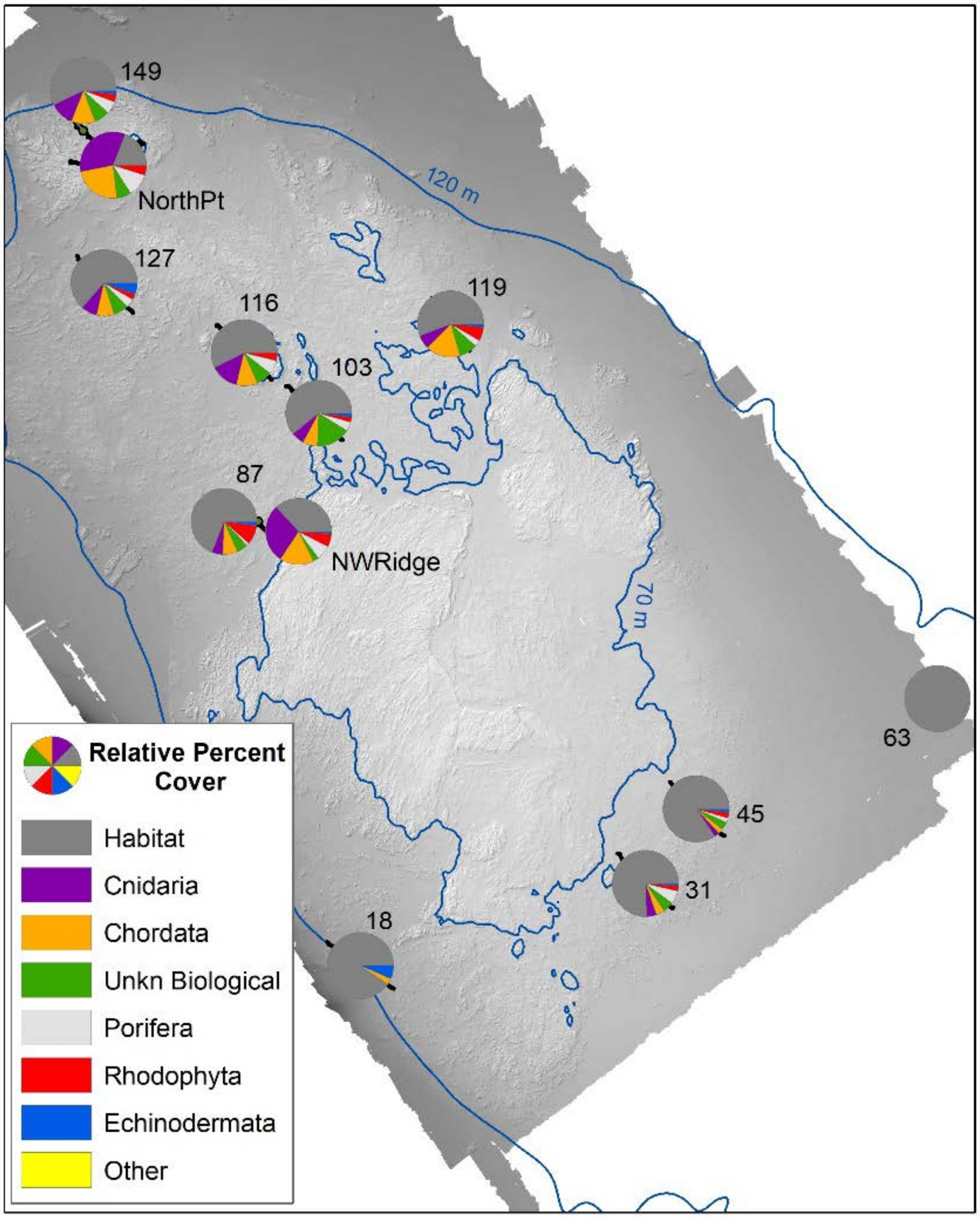

Figure 6. Percent cover of phylum or group observed from analyzed still images per line. 'Other' category includes: Annelida, Bryozoa, Arthropoda and Mollusca.

An image analysis of 538 still images collected in 2014 by CBNMS staff with a ROV used the same point count methods described above to calculate percent cover of taxa per line in depths ranging from 35 to 70 m and allows us to compare to the deeper depth strata in 2017. In 2014 the greatest average percent cover across all lines consisted of the unknown biological group (brown organic matter and smooth green mat) in depths less than 70 m (Graiff and Lipski, 2016). The next most abundant groups in order of decreasing percent cover were Porifera, Cnidaria, and Habitat. In the 35-70 m strata the spatial distribution of percent cover of organisms within each phylum was relatively uniform in proportion among all survey lines (Graiff and Lipski 2016). Thirteen taxa with the greatest percent cover were analyzed with non-metric multidimensional scaling (NMDS) and the ordination results did not define distinct groups or clusters of samples based on the percent cover of taxa. The similarity of the lines surveyed in species composition and abundance illustrates that the approximately 30 meter depth range sampled in 2014 constitutes a habitat strata supporting a similar community. Graiff and Lipski (2016) concluded that distinctive patterns in species composition and abundance may become more apparent as additional years of sampling take place in depths greater than 70 m.

A new NMDS was performed on fourteen taxa that were the most abundant in percent cover for each 2017 and 2014 surveys. These taxa included: unknown brown organic matter, unknown encrusting green organism, encrusting coralline algae, *Balanophyllia elegans, Corynactis californica*, gorgonians, *Paracyathus stearnsii*, *Stylaster* spp., mound sponge, unknown sponge, *Xestospongia edapha*, encrusting sponges, encrusting tunicate and *Polyneura latissimi*. The survey lines were coded for the two depth ranges (strata) sampled for each year. Lines from 2014 are coded as “70 m” to denote the <70 m depth range and lines from 2017 are coded at “120 m” to denote the 70-120 m depth range – with the exception of shallower lines North Point and Northwest Ridge sampled in 2017 are coded 70 m.

The percent cover data were square root transformed and analyzed on the Bray-Curtis similarity matrix. The points (representing lines) in the ordination show two distinct clusters of the two depth strata (Figure 7). Stress of the ordination in 2-dimensions was 0.06 which is a very good representation of groupings in the data (for context a stress value <0.1 corresponds to a good ordination and stress <0.05 gives an excellent representation) (Clarke and Warwick, 2001). Line 18 is the least similar to the other lines in percent cover of taxa. Line 63 was not included in the ordination because all of the percent cover on this line was bare habitat with no taxa. North Point and Northwest Ridge lines fall between the two clusters of 70 m and 120 m lines as the images analyzed from these two sites were generally in the 70 m or less depth range, but some images were captured at depths slightly deeper than 70 m (maximum depth for North Point was 79 m and maximum depth for Northwest Ridge was 76 m).

The vectors overlaid on the ordination are the environmental variables extracted from the habitat rasters for each image. Size of the vector indicates the strength/contribution of the vector. Depth and aspect best explain the similarity of percent cover for the 120 m lines and habitat, slope and rugosity are influencing the similarity of percent cover for the 70 m lines.

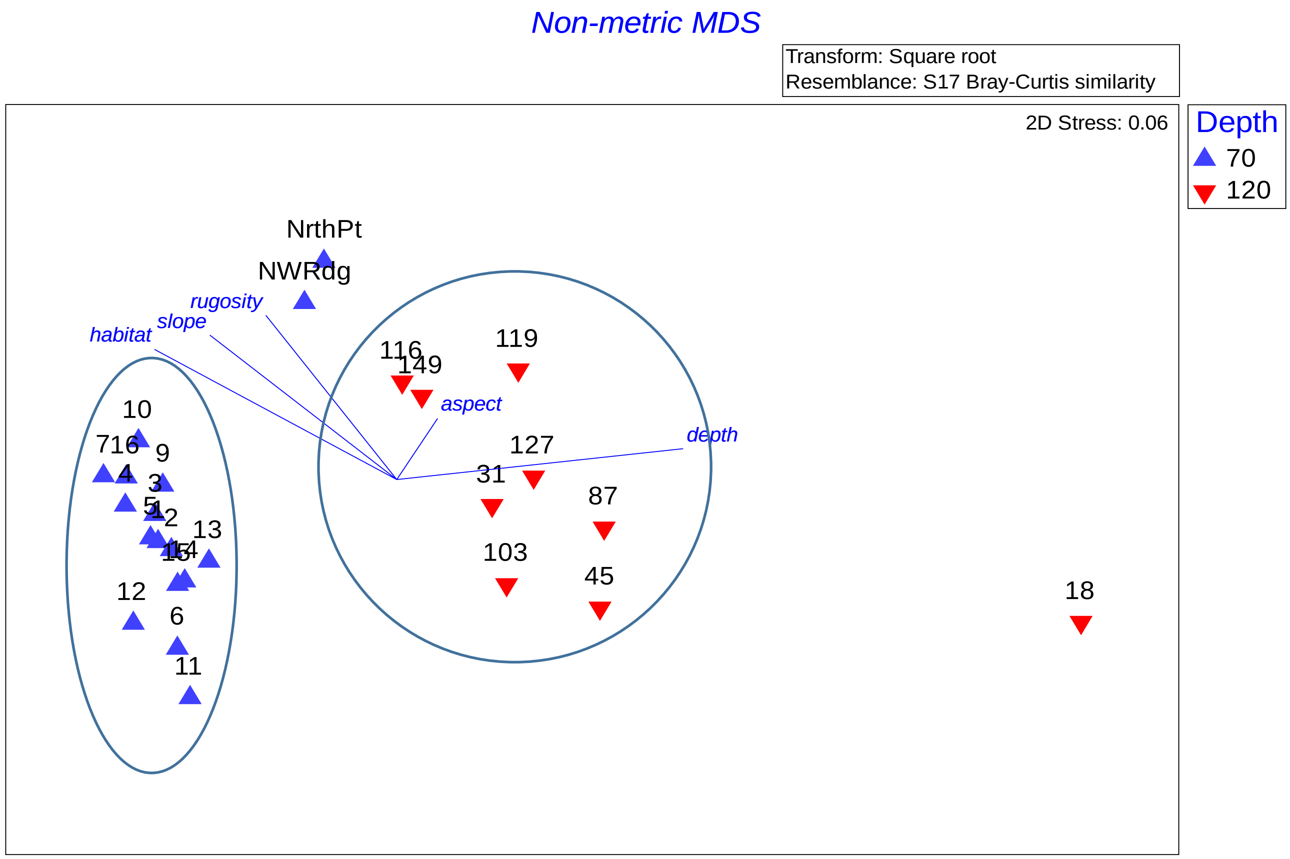

Figure 7. Non metric mulitdimensional (NMDS) ordination of survey lines based on average percent cover of taxa at two depth strata.

An analysis of similarities (ANOSIM) provides a way to test statistically whether there is a significant difference between two or more groups of sampling units. The ANOSIM performed on the percent cover data (square root transformed and analyzed on the Bray-Curtis similarity matrix) for each depth strata (70 m and 120 m) concluded that the two strata are significantly different based on percent cover of the most abundant taxa (R: 0.79; $P < 0.001$)

An additional test called SIMPER (similarity percentage) was performed to understand the contribution each taxa has to the observed similarity (or dissimilarity) between samples (the lines in each depth strata). Table 7 identifies the taxa, listed from the highest to lowest contribution percentage, that are most important to the observed pattern in the NMDS ordination.

Table 7: Similarity percentage (SIMPER) breakdown for 14 taxa between the two depth strata (<70 m and 70-120 m).

Species	Average Abundance Sites <70m	Avergae Abundance Sites 70-120m	Average Dissimilarity	Dissimilarity Standard Deviation	Contribution Percent	Cumulative Percent
Unknown brown organic matter	30.4	3.5	26.2	1.8	36.4	36.4
Encrusting sponges	11.6	1.0	10.4	2.2	14.4	50.8
Corynactis californica	9.5	1.7	8.5	1.1	11.8	62.6
Encrusting tunicates	2.6	7.7	7.3	1.7	10.1	72.7
Encrusting coralline algae	6.7	3.8	4.1	1.1	5.6	78.4
Polyneura latissimi	3.4	0.0	3.3	1.0	4.6	83.0
Stylaster spp	2.4	0.3	2.3	0.9	3.2	86.2
Paracyathus stearnsii	2.8	0.7	2.2	1.3	3.0	89.2
Xestospongia edapha	1.8	0.4	1.7	0.9	2.4	91.6
Unknown sponges	1.8	0.1	1.7	1.5	2.4	93.9
Unknown encrusting green organism	1.9	0.7	1.6	1.5	2.2	96.1
Balanophyllia elegans	2.6	3.1	1.3	1.3	1.8	97.9
Mound sponge	1.0	1.2	1.1	1.2	1.5	99.4
Gorgonians	0.2	0.6	0.5	1.3	0.7	100.0

The species with highest percent contribution (and this relates to the abundance/percent cover) are those most responsible for distinguishing the 70 m (shallow) and 120m (deep) sites. The indicator species are the unknown brown organic matter, encrusting sponges, *Corynactis californica* and encrusting tunicates (Table 7).

Unknown brown organic matter accounts for the highest contribution (36%) in percent cover between the shallow and deep lines. The average abundance (percent cover) was much greater at the shallower sites. Additionally, unknown encrusting sponges along with unknown brown organic matter account for a cumulative percent of 50% for the difference between shallow and deep lines. The average abundance (percent cover) of encrusting sponges was highest at shallow sites. *Corynactis californica* and encrusting tunicates have similar contribution percentages, yet *Corynactis californica* had a greater average abundance on the shallow sites than the deeper sites, while encrusting tunicates displayed greater average abundance on the deeper than the shallower lines.

Stylaster and gorgonian models

Counts of *Stylaster* spp. and gorgonians were recorded as presence and absence data for each image for the 2017 dataset (593 images) and the 2014 dataset (538 images). These data were joined by date and time to the ROV's coordinates and then matched to maps predicting the probability of presence for *Stylaster* spp. and gorgonians on Cordell Bank (see Etherington et al. 2011 for full approach). A confusion matrix was produced to describe the performance of the habitat modeling to the observations of *Stylaster* and gorgonians from the two survey years ranging from 35 to 120 meters (Table 8).

The *Stylaster* model is 82% accurate for predicting the presence and absence of *Stylaster* habitat. The model is the strongest at predicting habitat where *Stylaster* is absent (68%); true negative. The model accurately predicted *Stylaster* presence 14% of the time and 13% of images did not contain *Stylaster* when the model predicted suitable *Stylaster* habitat.

The gorgonian model resulted in just slightly over half (56%) of the images with presence or absence of gorgonians matching the predictive habitat model. The gorgonian model is best at predicting gorgonian habitat absence with 44% of images being a true negative. Only 12% of the images were a true positive which is not much greater than the 11% of false negatives (gorgonian observed in image and model predicted not suitable gorgonian habitat). The model appears to be over predicting suitable gorgonian habitat as 33% of images did not have a gorgonian present when the model predicted the area to be suitable gorgonian habitat.

Table 8. Percentage results of *Stylaster* spp. and gorgonian predictive models and presence/absence data from still images showing true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN).

Stylaster spp.		**Model Prediction**	
		YES	NO
Actual	YES	TP=14%	FN=6%
	NO	FP=13%	TN=68%

Gorgonian		**Model Prediction**	
		YES	NO
Actual	YES	TP=12%	FN=11%
	NO	FP=33%	TN=44%

Discussion

A comprehensive description of Cordell Bank's benthic community was accomplished by our visual surveys, which provided a better understanding of the patterns in species composition, abundance and health as they relate to the physical habitat's characteristics. This study along with the study completed in 2014 lays the groundwork for monitoring and detecting long term change in the benthic communities that make Cordell Bank so biologically unique.

Changes to the condition and health of species is of special interest. Particularly, we focus on corals and sponges because of their long-lived nature and ability to provide structure and habitat for other invertebrates and fish. We observed high counts of gorgonians with associated ovulid snails, possibly *Simnia* sp., unknown zoanthids species and amphipod tubes. This observation of *Simnia* sp. may be the most northern observation for this species (Liggia 2017). Ovulid snails are known to be predators on gorgonian corals (Williams, pers. comm., Gerhart 1990, Goh et al. 1999) and zoantharians are known to be parasites on primnoid corals in the northeast U.S., progressively eliminating gorgonian tissue and then using the coral axis for structure and support, and coral sclerites for protection (Carreiro-Silva, et al. 2017).

Although the ovulid snails were found on corals at Cordell Bank that were still classified as healthy, it is likely that the snails were grazing on the coral tissue, exposing a small area on the axis that allows other organisms to settle. The snails then move onto other healthy corals. Therefore, unhealthy and dying corals were observed without snails. Conversely, the zoanthids and amphipod tubes were always associated on dead or dying corals and likely colonized the structure once the corals' living tissue was eliminated and the axis was exposed. An initial review of still images from submersible surveys at Cordell Bank from 2002-2005 found no occurrences of snails or unhealthy corals, but an initial review of video from 2014 found some *C. marki* with snails and others with epibionts that were not noticed or recorded at the time. This was likely because that survey did not focus on optimum depths for gorgonians, and the corals, snails, and epibionts were less numerous than in 2017. Therefore, the 2017 survey provided the first recording of numerous unhealthy or dead gorgonians in CBNMS. However, a more thorough review of historic data and comparison to recent data needs to be completed. Gorgonians in similar condition were subsequently observed in 2018 in CBNMS and some specimen collections were made, and were also observed in northern Monterey Bay National Marine Sanctuary (Lipski, personal observation). Some corals observed in MBNMS had an associated symbiotic gall barnacle, likely *Conopea* sp., (Van Syoc et al., 2014) that was not observed in CBNMS (Lipski personal observation, Williams pers. comm).

Despite several decades of surveys on Cordell Bank, we are still compiling the species inventory. Some discoveries are a result of better technology to observe and collect specimens, while others may indicate new arrivals or range extensions as a result of changing ocean conditions or recovery from benthic disturbances. New species observations are also extremely valuable to track and monitor long term change in community composition. The small yellow gorgonian observed on many of the transects was thought to be a new finding for CBNMS. However, a subsequent initial review of still images taken from submersible dives at Cordell Bank in 2004 indicates a similar looking coral that may have been overlooked because of its small size and sparse occurrences. An initial review of images and video from 2014 did not reveal any yellow gorgonians, but the survey did not focus on depths where it was found in 2004 or 2017. The yellow coral was more numerous in 2017 but we were unsuccessful in our attempts to collect a specimen at that time. During a ROV cruise on Cordell Bank in 2018 onboard the NOAA ship *Bell. M. Shimada* a specimen of the yellow coral was collected (under sanctuary permit CBNMS-2014-001) and identified and described as a new species, *Chromoplexaura cordellbankensis* (Williams and Breedy 2019). Over half of the *C. cordellbankensis* were single stalked and less than 5 cm tall whereas the more commonly observed red *C. marki* gorgonians were generally larger. Other observations of this species are known from Southern California and those individuals were of similar size (Gary Williams, pers.comm.). The condition and growth of these gorgonians will be recorded in future survey efforts.

The validation of the Cordell Bank predictive habitat model for *Stylaster* spp. and gorgonians using a confusion matrix was valuable to show the strength of the model predicting unsuitable coral habitat for both *Stylaster* spp. and gorgonians as well as determining that the gorgonian model is over predicting suitable habitat. The models were developed in 2010 and have been an important tool to sanctuary staff for designing survey locations and directing management to minimize bottom disturbance to *Stylaster* hotspot areas. The next steps for the coral model are to make it more robust by adding these new data sets.

Another organism of interest to continue monitoring is the unknown species of gray encrusting tunicate that was observed in higher abundances than seen in previous survey years, as early as 2002 and more recently in 2014. Its structure resembles the colonial tunicate *Didemnum vexillum,* a species that has smothered areas of George's Bank in the Gulf of Maine and has been documented in the San Francisco Bay area (Bullard et al. 2007). There is no direct evidence that the gray encrusting tunicate on Cordell Bank is an invasive species and outcompeting other benthic invertebrates. It was often observed growing around cup corals, leaving them undisturbed. It was also commonly seen at multiple dive sites along the central California coast in 2018. A specimen was collected in Greater Farallones National Marine Sanctuary in August 2018 at a site just to the south of CBNMS and is pending identification.

The importance of designing a survey with random and fixed (repeatable) sites is important for uncovering new trends in species diversity and abundance. The stratified random sites provide a comprehensive coverage over the Bank's variety of habitats. The fixed sites give us the strength to control for habitat variables and better understand biological patterns or changes. Specifically, the fixed site Northwest Ridge has now been quantitatively surveyed four times by submersible and ROV. Adding the new fixed site North Point (historically surveyed three times by the Delta submersible) to the benthic survey strategy adds to the power for monitoring long term change. For example, the high counts of young-of year (YOY) and juvenile Yelloweye Rockfish seen in 2017 at North Point adds to other datasets from fixed sites like Northwest Ridge and Northeast Ridge (not sampled in 2017) where high counts of YOY Yelloweye were also observed. Thus, supporting the theory that the preferred habitat for YOY Yelloweye recruitment on Cordell Bank is a narrow band of high relief, rocky substrate between 35 and 60 meters.

Comparison of two depth strata: a more complete picture of the benthic community

Distinctive patterns in species composition and abundance are clear from the analysis of shallow and deep habitat strata. Cordell Bank's upper reefs at depths less than 70 meters have higher percent cover than deeper depths, and in particular depths less than 45 meters are dominated by invertebrates exceeding 100% cover. The analysis of video and still images collected by the ROV statistically supports a prior qualitative observation from imagery of Cordell Bank that there is a change from 100% cover of biota at depths less than 70 m to lower benthic percent cover and more bare rock in depths greater than 70 m.

In addition to differences in taxa abundance, morphological differences were also common between the two depth strata. Specifically, *Stylaster* spp. in the shallow depths were much larger and spherically shaped than *Stylaster* spp. heads observed at deeper depths, which were not only smaller but oblong shaped. It is conceivable that the individuals at deeper depths may be growing fan-shaped and orienting themselves across the current to maximize food capture since currents may not be as strong at deeper depths as on the Bank's shallower reef tops. It is well known that the orientation of many species of corals is perpendicular to prevailing water currents to maximize the amount of water flowing through the polyps at any given time (Grigg, 1972). As monitoring surveys are conducted in future years it will be interesting to see if there is a shift from the currently abundant small sized *Stylaster* to a larger size class of individuals at the deeper sites.

Status of monitoring and relevance to management

National marine sanctuaries are charged with understanding the status and trends of resources within their boundaries and to protect the resources from degradation. Cordell Bank is a unique feature in northern California that supports a vibrant deep-sea community. Benthic communities are vulnerable to the stressors facing global ocean ecosystems including climate change, invasive species and marine debris.

Historic surveys on Cordell Bank have varied from multi-year approaches to single year surveys, using various approaches and technologies, but they provided valuable information about the sanctuary's physical habitat and biological communities that laid the groundwork for current surveys. This 2017 survey, along with the 2014 survey provides a fine scale characterization of the invertebrate and benthic fish community and defines the biological zonation at multiple depth strata on the bank. These are the first surveys implementing the CBNMS long term monitoring plan, which we will continue to use for future surveys.

The CBNMS long term monitoring plan calls for regular monitoring of areas that have been initially characterized. Of the four strata in the plan, Cordell Bank is the best characterized. Cordell Bank strata are scheduled to be revisited in 2020. Deeper areas on the slope and submarine canyons still need further exploration to understand the habitat and community structure. Information gathered from surveys as part of the benthic monitoring plan will inform a 10 year assessment of sanctuary resource status and trends (Sanctuary Condition Reports https://sanctuaries.noaa.gov/science/condition/), a 10 year management plan to guide sanctuary activities, permit issuance, outreach activities, and other management actions.

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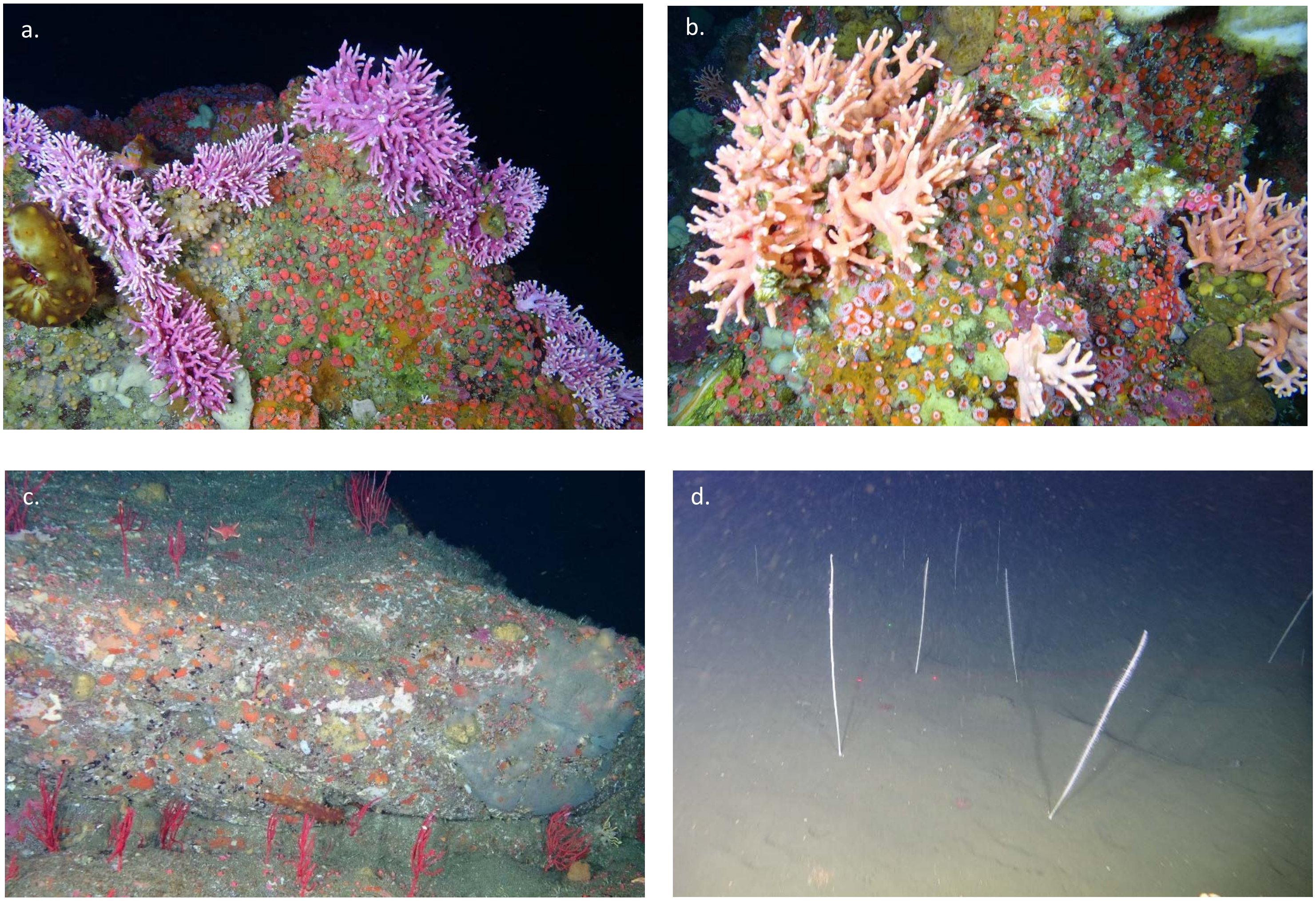
APPENDIX A: Still images analyzed per line for percent cover of invertebrates and algae

Date	Line	Num. of Transects	Total still images
8/21/2017	45	1	10
8/21/2017	31	3	41
8/22/2017	116	4	58
8/22/2017	103	3	48
8/22/2017	127	3	58
8/23/2017	149	3	51
8/23/2017	NORTH PT	3	58
8/23/2017	119	3	41
8/27/2017	87	4	70
8/27/2017	NW RIDGE	2	45
8/28/2017	18	4	70
8/28/2017	63	2	43
	TOTAL	**35**	**593**

APPENDIX B: List of taxa grouped by phylum observed in still images from all line-transects

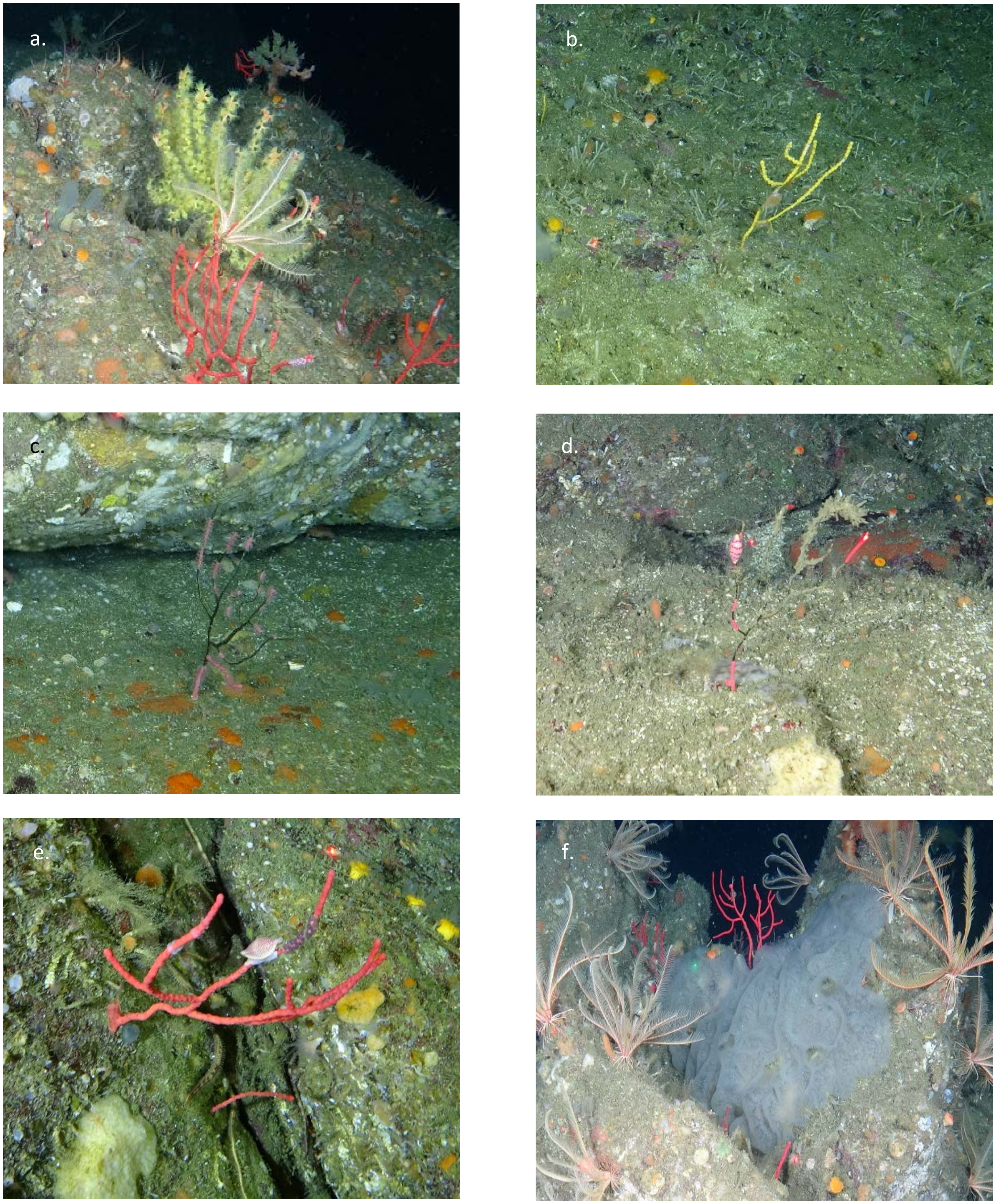
Phylum	Scientific Name	Common name/description
Chordata	*Ascidia paratropa*	Solitary glass tunicate
Chordata	*Cystodytes lobata*	Lobed tunicate
Chordata	Tunicata	Multiple unknown species with encrusting, upright or shelf morphologies
Echinodermata	*Ceramaster* spp.	Cookie star
Echinodermata	*Florometra serratissima*	Crinoid
Echinodermata	*Henricia* spp.	Blood star
Echinodermata	*Luidia foliolata*	Sand star
Echinodermata	*Mediaster aequalis*	Vermillion sea star
Echinodermata	*Ophiuroidea* spp.	Unidentified brittle stars
Echinodermata	*Orthasterias koehleri*	Rainbow star
Echinodermata	*Parastichopus californicus*	California sea cucumber
Echinodermata	*Pateria miniata*	Bat star
Echinodermata	*Psolus* spp.	Sessile sea cucumber
Echinodermata	*Rathbunaster californicus*	Deep-sea sun star
Bryozoa	Bryozoa	Branched bryozoan, unknown species
Mollusca	*Calliostoma annulatum*	Purple ring top snail
Mollusca	*Calliostoma ligatum*	Blue top snail
Mollusca	*Crassadoma gigantea*	Giant rock scallop
Mollusca	*Flabellinopsis iodinea*	Spanish shawl nudibranch
Mollusca	*Fusitriton oregonensis*	Hairy triton snail
Mollusca	Nudibranchia	Nudibranch
Arthropoda	Balanidae	Barnacles - *Balanus nubilus* or *Megabalanus californicus*
Arthropoda	*Loxorhynchus crispatus*	Moss/decorator crab
Annelida	Polychaeta tube	Tube from unknown polychaete
Annelida	Sabellida	Feather duster worms (Sabellidae) and serpulid worms (Serpulidae)
Annelida	Spirobranchus spp.	Christmas tree worm (serpulid)
Cnidaria	Actiniaria	Unidentified anemone
Cnidaria	*Aglaophenia latirostris*	Ostrich plume hydroid
Cnidaria	*Balanophyllia elegans*	Orange cup coral
Cnidaria	Cerianthidae	borrowing/tube anemone
Cnidaria	*Chromoplexaura*	Red or yellow gorgonian
Cnidaria	*Corynactis californica*	Strawberry anemone
Cnidaria	*Epizoanthus scotinus*	orange/yellow zoanthid
Cnidaria	*Garveia annulata*	Orange hydroid
Cnidaria	*Halipteris spp.*	Sea pen
Cnidaria	Hydrozoa	Unidentified hydroid
Cnidaria	*Paracyathus stearnsii*	Brown cup coral
Cnidaria	*Stomphia* spp.	Swimming anemone
Cnidaria	*Stylaster* spp.	Hydrocoral - *S. californicus* or *S. venustus*
Porifera	*Halichondria panicea*	Brown sponge/bread crumb sponge
Porifera	*Leucilla nuttingi*	Urn sponge
Porifera	*Mycale* sp.	Yellow vase sponge
Porifera	Poecillastra sp.	White sponge with dark edges
Porifera	*Stelletta clarella*	Black edge sponge
Porifera	*Xestospongia edapha*	Cordell Sponge
Porifera	Porifera	Unidentified sponge
Porifera	Porifera - barrel	Unidentified barrel sponge
Porifera	Porifera - branched	Unidentified branched sponge
Porifera	Porifera - encrusting	Unidentified encrusting sponge
Porifera	Porifera - foliose	Unidentified foliose sponge
Porifera	Porifera - mound	Unidentified mound sponge
Porifera	Porifera - orange	Orange sponge with large osculum
Porifera	Porifera - puffball	Unidentified puffball sponge
Porifera	Porifera - shelf	Unidentified shelf sponge
Porifera	Porifera - upright flat	Unidentified upright-flat sponge
Rhodophyta	Articulated Corallinaceae	Articulated coralline algae
Rhodophyta	Encrusting Corallinaceae	Encrusting coralline algae
Rhodophyta	*Maripelta rotata*	Purple circular shaped algae
Rhodophyta	*Polyneura latissima*	Most common red algae on Cordell Bank
Unknown	Unknown	Encrusting green organism
Unknown	Unknown	Brown biological material

IMAGE GALLERY A



Coral taxa observed (a) and (b) *Stylaster* spp hydrocoral in different color morphs (c) red *Chromoplexaura* spp. gorgonians (d) *Halipteris spp.* sea pens.

IMAGE GALLERY B



(a) Red gorgonian, *Chromoplexaura marki,* yellow one is covered in an unknown zoanthid (b) new species of gorgonian *Chromoplexaura cordellbankensis* (c) dying *C. marki* with black axis exposed (d) dying *C. marki* with an unknown ovulid snail (possibly *Simnia* sp.) and amphipod mud tubes (e) *C. marki* with an unknown ovulid snail (possibly *Simnia* sp.) (f) unknown gray encrusting tunicate on rocks with *C. marki* and crinoids (*Florometra serratissima*).