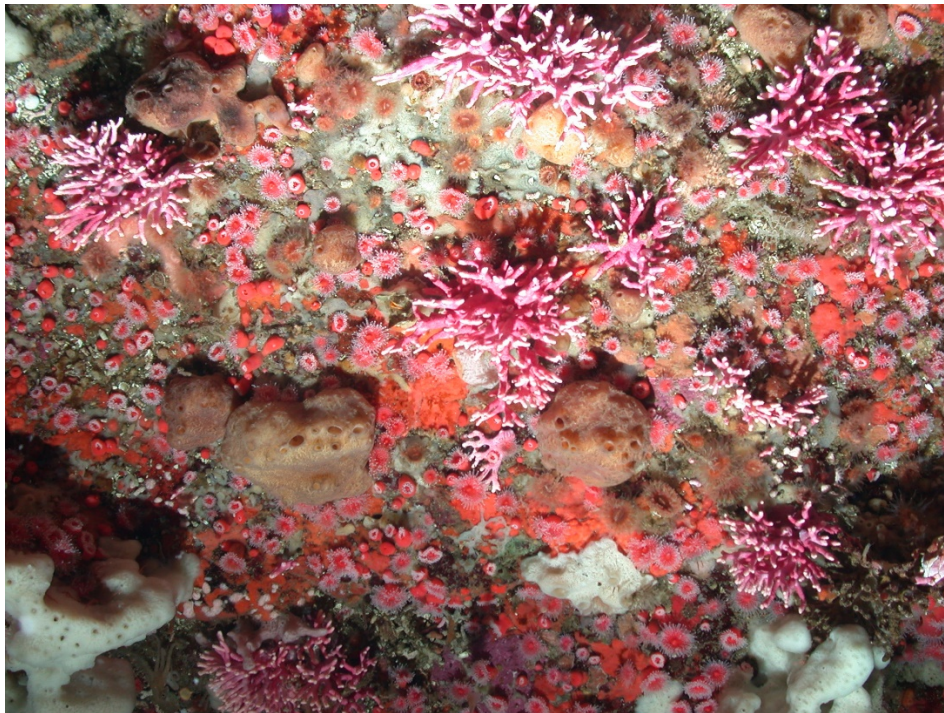


Benthic Community Characterization of the Upper Reefs of Cordell Bank



ROV cruise dates: August 19- 25, 2014

Report completed November 2016
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Abstract

In August 2014, staff from the Cordell Bank National Marine Sanctuary (CBNMS) used their Phantom HD2 Remotely Operated Vehicle (ROV) to conduct quantitative transects over the upper reef areas on Cordell Bank in depths less than 70 meters. The main objectives were to perform a fine scale characterization of the bank's benthic community and to relate species abundance and distribution to habitat variables like depth, slope, aspect direction and topographic position index (TPI). Percent cover of invertebrates and algae was estimated from down facing still images using Coral Point Count with Excel extensions (CPCe 4.1). Fifteen transects were completed and a total of 1,932 still images were taken during the survey. A subsample of 538 images was analyzed for species percent cover. Across all transects, the majority of the analyzed habitat was all rock, totaling 219 m². Mixed rock and sand habitats covered a total area of 55 m². At least 47 taxa of invertebrates, 5 taxa of algae, and two unknown taxa (invertebrate or algae) were observed. The greatest percent cover observed among transects was made up of unknown organisms described as a textured layer of brown biological material or a thin, smooth layer of a dark green organism. Species from ten phyla contributed to diverse assemblages, and associations with habitat variables were described for the most abundant species of Porifera, Cnidaria and Rhodophyta in this report. These descriptions of the bank's benthic community provide a baseline of information against which future surveys can be compared. These comparisons will allow sanctuary researchers and managers to detect large changes in species abundance and composition driven by natural or anthropogenic causes.

Introduction

Cordell Bank is an offshore underwater granitic formation located on the continental shelf approximately 20 nautical miles west of Point Reyes, northern California. Cordell Bank is about 7 kilometers wide and 15 kilometers long, emerging from the soft sediments of the continental shelf at depths of 91-122 meters (m) and with pinnacles coming to within 35 m of the ocean's surface. Cordell Bank is the centerpiece of Cordell Bank National Marine Sanctuary (CBNMS).

The bathymetry and location of Cordell Bank combine to make it a very productive marine environment. The bank is situated downstream from a major and persistent upwelling center at Point Arena. Nutrients and productivity originating from that area are carried over the bank and sustain a thriving biological community (Largier et al. 2006, Halle and Largier 2011). In addition to the Point Arena upwelling center, localized upwelling may also contribute to productivity at Cordell Bank. The bank is surrounded by deep water on three sides due to its location on the edge of the continental shelf and localized upwelling may deliver food and nutrients to organisms living on or around Cordell Bank.

A proportion of Cordell Bank is made up of consolidated granite reef, but much of the bank is a heterogeneous mixture of rock reef, boulders, cobbles, sand and mud. The bank's upper rocky reefs support a rich assemblage of benthic organisms, often exceeding 100 percent cover as animals are layered on top of one another. The invertebrate community at the shallow depths

of the bank is particularly spectacular and well known from photographs to have high percent cover of a colorful array of sponges, corals, anemones, and other invertebrates. Additionally, the clear offshore water has high light penetration that allows for algal photosynthesis far deeper than in nearshore coastal waters. These conditions support benthic algae more commonly associated with shallow nearshore habitats.

Cordell Bank was first surveyed from the 1970s to early 1980s by the non-profit group Cordell Expeditions which used SCUBA to dive on the bank's upper reefs (around 40-50 m). More recently (since 2001) CBNMS has conducted nearly a dozen benthic surveys classifying habitats, enumerating fishes and macro-invertebrates on the bank using a human occupied submersible, ROV and SCUBA divers. Those datasets have documented hundreds of fishes and invertebrates from dozens of species. Also, southern and northern range extensions for numerous species on the bank have been documented (Schmieder 1980, Schmieder 1991). In particular, data mining and verification of museum specimens confirmed that both *Stylaster venustus* and *Stylaster californicus* (species of hydrocorals) are present on Cordell Bank, making this location an important intersection for these two species that have northern and southern distributions, respectively (Etherington et al. 2011).

These studies have provided information for a general characterization of biota on the bank. However, there has not been a fine scale survey of invertebrate and algae species distribution and abundance in the benthic community to inform a quantitative assessment of biota on the bank. This characterization was needed for 1) a more thorough understanding of the Cordell Bank benthic community composition, 2) information about the spatial distribution of species and how species distribution relates to habitat characteristics, and 3) to provide baseline metrics to allow for monitoring this complex ecosystem over time and in response to stressors or management actions.

The purpose of this study was to conduct ROV dives over the upper reefs of Cordell Bank in depths less than 70 m to characterize the benthic community by estimating percent cover of organisms and relating species abundance and distribution to habitat variables like depth, slope, aspect direction and topographic position index (TPI).

Methods

Field Survey

Operations were conducted August 19-25, 2014 onboard the NOAA R/V *Fulmar* using the CBNMS Phantom HD2 ROV. The ROV was outfitted with three cameras to collect photographic and video images. A standard definition video camera (Deep Ocean Engineering) on a motorized tilt was mounted on the front center of the ROV to be forward-looking. During surveys the video camera angle was maintained at approximately 60 degrees from vertical. Standard definition (SD) video was continuously recorded to mini digital video (MiniDV) tapes. A pair of parallel lasers were used for scale, set 10 cm apart and positioned in the center of the video frame for sizing objects viewed in images. A high-definition still camera (Insite Pacific

Scorpio Plus) on loan from the Undersea Vehicles Program at University of North Carolina at Wilmington was mounted on the top lateral bar of the ROV frame at an angle of 90 degrees to capture downward images. Still images were manually captured approximately every 30 seconds using Insite Pacific custom user interface software on a topside laptop and stored on the camera's storage card until they were downloaded to a hard drive after the ROV was recovered. A strobe light (Insite Pacific) illuminated the camera field of view when the still camera was triggered and three other lights (Deep Sea Power and Light) provided lighting for the video cameras. In addition, a GoPro Hero 3 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.

The ROV dives consisted of a series of pre-determined transects approximately 1 km in length targeting consolidated rock and were designed to sample a variation in depth, slope and aspect direction shallower than the 70 m isobath on Cordell Bank. These variables were extracted from a 3 m resolution digital elevation model (DEM) produced from multibeam and backscatter data collected in October 2005 by the Seafloor Mapping Lab at California State University, Monterey Bay, aboard the R/V *Ventresca* (see Young et al. 2010 for full methods). A DEM is a raster data set that consists of elevation values at regularly spaced intervals.

While on transect, the ROV maintained a consistent height and speed from the bottom; 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 which 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).

Data Processing and Image Analysis

ROV and ship tracking data were recorded at two second intervals. The locations were smoothed with a filter over a 12-point sampling window. Positions with a distance greater than 0.1 degrees from the previous position were removed.

Benthic community data were collected from each transect by analyzing the downward facing still images. Still images were first assessed for suitability for analysis based on the following criteria: sharp focus with bottom comprised of greater than 50 percent rock, minimal shadowing from rock overhangs, and paired lasers in middle of image. Habitat type was classified using categories of substratum type based on particle size and vertical relief as described in Stein et al (1992). Images that were excessively dark or blurry and greater than 50 percent sand bottom were excluded from the final analysis.

All images suitable for benthic community analysis were imported into Coral Point Count with Excel extensions (CPCe 4.1; Kohler and Gill 2006). The CPCe software was developed by the National Coral Reef Institute (NCRI) to analyze images by overlaying a specified number of random points onto the image and the features underlying the points are user-identified. Coverage statistics are calculated and are automatically saved as Excel spreadsheets for data

storage and subsequent analysis. 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.

Images used for analysis were first scaled in CPCe using the 10 cm distance between the two lasers mounted on the ROV and captured on each photo to determine image area. 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 (Pante and Dustan 2012). Percent cover of all observed taxa was calculated and pooled for all the analyzed images within a transect. In addition, a select list of species were enumerated per image and recorded in a separate spreadsheet. These species were: *Stylaster* spp., red gorgonian corals ('*Swiftia*' type), sponges *Xestospongia edapha* and *Stelletta clarella*, *Strongylocentrotus* spp. (sea urchins) and all species of sea stars. These species are easily identifiable as individual organisms and were deemed important 'indicator species' for monitoring and detecting temporal change. The densities of these species were calculated by dividing the total number individuals by the estimated area of each image.

Within ArcGIS 10.4 various tools were used to derive habitat descriptor rasters from the DEM to be associated with invertebrate species observations. These rasters included: depth, slope, aspect direction and topographic position index (TPI). Aspect represents the compass direction that a slope faces. TPI indicates the position of a given point relative to the overall surrounding landscape and can therefore be used to delineate landforms such as peaks, ridges, cliffs, slopes, flat plains and valleys. TPI was calculated at different scales (30 m, 60 m, 120 m, 240 m) to differentiate between small scale and large scale features (e.g., tops of pinnacles to an entire reef). Positive TPI values indicate that the central point is located higher than its average surroundings such as upper reaches of a mounded feature and the top of a rise. Negative values indicate a position lower than the average such as flat and low sloping environments. On both ends of the scale, larger values reveal major landscape features, such as a high peak or deep valley, while smaller values highlight smaller features, such as minor ridges and crevices. Subsequent data figures will display TPI at the larger scale of 240 m.

The analyzed images were assigned 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 were associated and extracted in ArcGIS 10.4. 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 red gorgonians documented during the image analysis were used to verify the predictive coral model.

Percent cover of the most abundant species were analyzed using non metric multidimensional scaling (NMDS) on the Bray-Curtis similarity matrix in PRIMER v6 (Clarke and Warwick, 2001). The data matrix consisted of samples: images per transect (total 538) and variables: percent

cover of the most abundant taxa. 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, TPI 30 m, TPI 60 m, TPI 120 m and TPI 240 m) 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.

Results

Fifteen transects were completed from 46-76 m during the 6-day cruise (figure 1). A total of 16 transects were designed for the survey, however transect number 8 was not completed due to time restraints. A total of 1,932 still images were taken during the survey, ranging from 96-158 images per transect. After the initial evaluation of images suitable for analysis, a total of 538 images were analyzed for the entire survey with a range of 30-54 images per transect. A total area of 273.8 m² was covered from the 538 analyzed images from the 15 transects. Transect area analyzed ranged in total area from 14.95 m² – 23.63 m² because of the variation in the number of images analyzed per transect (table 1).

The majority of images excluded from the analysis were overly dark due to the ROV's strobe light malfunctioning or the resolution quality was too low to confidently identify organisms. A major factor influencing image quality and resolution was the drastic changes in rugosity on the bank, thus the ROV would be too high or too close to the bottom when the habitat transitioned from steep pinnacles to lower relief rock or sand channels along a transect.

Table 1. Transects completed on Cordell Bank from Aug 19-25, 2014.

Date	Location	Transect Number	Depth Min (m)	Depth Max (m)	Images Analyzed	Total Image Area (m²)
8/19/2014	Middle Bank	11	57	66	54	23.63
8/19/2014	Middle Bank	12	48	61	34	17.33
8/20/2014	Middle Ridge	5	51	67	40	18.99
8/20/2014	Middle Ridge	6	52	64	38	17.85
8/20/2014	Northeast Ridge	1	55	68	43	21.30
8/21/2014	Northwest Ridge	9	53	74	32	17.24
8/21/2014	Northwest Ridge	10	55	73	34	17.76
8/21/2014	Northeast Ridge	3	55	65	30	17.22
8/23/2014	Southwest Ridge	13	62	76	32	14.95
8/23/2014	Southwest Ridge	14	60	71	30	15.28
8/23/2014	Southwest Ridge	15	59	68	31	17.86
8/24/2014	Craine's Point	16	46	69	30	17.38
8/24/2014	Northeast Ridge	4	48	66	33	18.41
8/24/2014	Northeast Ridge	2	60	70	39	17.79
8/25/2014	Northern Ridge	7	51	68	38	20.82

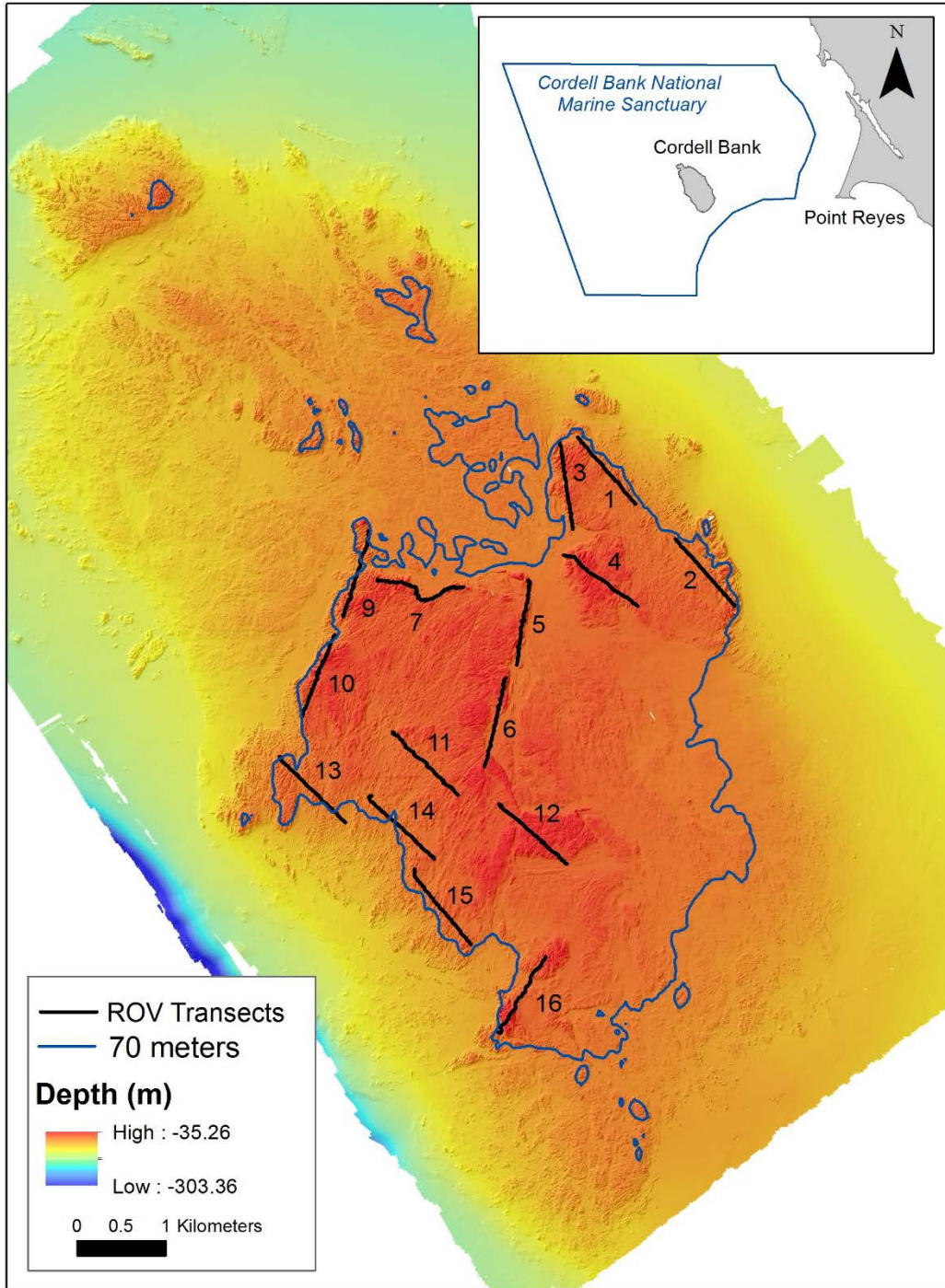


Figure 1. Locations of ROV transects on Cordell Bank. Transect numbers correspond to Table 1.

Habitat

Across all transects the majority of the analyzed habitat was all rock, totaling 219 m². Rock and sand habitats covered 55 m² total area for all transects (figure 2). Rock habitat covered more than 70 percent of all transects except for transect 6 which had an almost equal area of rock and rock and sand habitats. Since the goal of this work was to characterize invertebrate cover on hard bottom habitats, a total of 96 images that contained greater than 50 percent sand bottom were excluded from analysis.

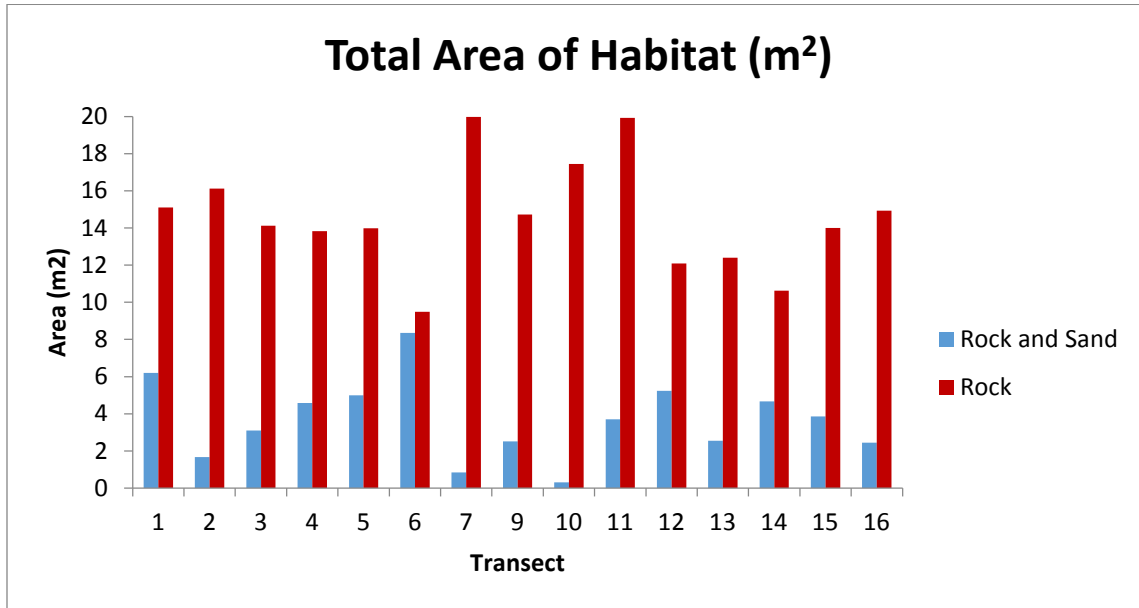


Figure 2. Total area of habitat from analyzed images per transect.

Species community

A diverse assemblage of fish, invertebrate and algae taxa were observed among all transects. At least 9 taxa of fish, 47 taxa of invertebrates, 5 taxa of algae, and two unknown taxa (invertebrate or algae) were observed (table 2). Since the goal of conducting these transects was to characterize the encrusting benthic community, all further results after the species list in table 2 will exclude abundance and distribution information of fish.

Table 2. List of taxa grouped by phylum observed from all transects surveyed on Cordell Bank.

Phylum	Scientific Name	Common name/description
Chordata	Cottidae	Unidentified sculpins
Chordata	<i>Hemilepidotus hemilepidotus</i>	Red irish lord
Chordata	<i>Ophiodon elongatus</i>	Lingcod
Chordata	<i>Oxylebius pictus</i>	Painted greenling
Chordata	<i>Rhinogobiops nicholsii</i>	Blackeye goby
Chordata	<i>Sebastes</i> spp (YOY)	Young of year rockfish
Chordata	<i>Sebastes flavidus</i>	Yellowtail rockfish
Chordata	<i>Sebastes maliger</i>	Quillback rockfish
Chordata	<i>Sebastes rosaceus</i>	Rosy rockfish
Chordata	<i>Ascidia paratropa</i>	Solitary glass tunicate
Chordata	<i>Cystodytes lobata</i>	Lobed tunicate
Chordata	Tunicata	Encrusting tunicate, unknown species
Echinodermata	<i>Ceramaster</i> spp.	Cookie star
Echinodermata	<i>Henricia</i> spp.	Blood star
Echinodermata	<i>Mediaster aequalis</i>	Vermillion sea star
Echinodermata	<i>Ophiuroidea</i> spp.	Unidentified brittle stars
Echinodermata	<i>Orthasterias koehleri</i>	Rainbow star
Echinodermata	<i>Parastichopus californicus</i>	California sea cucumber
Echinodermata	<i>Pateria miniata</i>	Bat star
Echinodermata	<i>Pisaster giganteus</i>	Giant spined star
Echinodermata	<i>Poraniopsis inflata</i>	Spiny colorful star
Echinodermata	<i>Pteraster tessellatus</i>	Cushion star
Echinodermata	<i>Pycnopodia helianthoides</i>	Sunflower star
Echinodermata	<i>Strongylocentrotus</i> spp.	Urchins - <i>S. franciscanus</i> or <i>S. purpuratus</i>
Echinodermata	<i>Stylasterias forreri</i>	Fish eating star
Bryozoa	Bryozoa	Branched bryozoan, unknown species
Mollusca	Nudibranchia	Nudibranch
Mollusca	Pectinidae	Unknown scallop
Arthropoda	Balanidae	Barnacles - <i>Balanus nubilus</i> or <i>Megabalanus californicus</i>
Arthropoda	<i>Loxorhynchus crispatus</i>	Moss/decorator crab
Annelida	Polychaeta tube	Tube from unknown polychaete
Annelida	Sabellida	Feather duster worms (Sabellidae) and serpulid worms (Serpulidae)
Cnidaria	<i>Balanophyllia elegans</i>	Orange cup coral
Cnidaria	<i>Corynactis californica</i>	Strawberry anemone
Cnidaria	<i>Garveia annulata</i>	Orange hydroid
Cnidaria	Alcyonacea	Red gorgonian
Cnidaria	<i>Paracyathus stearnsii</i>	Brown cup coral
Cnidaria	<i>Stylaster</i> spp.	Hydrocoral - <i>S. californicus</i> or <i>S. venustus</i>
Cnidaria	<i>Urticina columbiana</i>	Sand rose anemone
Cnidaria	<i>Urticina piscivora</i>	Fish eating anemone
Porifera	<i>Iophon</i> spp.	"Finger" sponge
Porifera	<i>Halichondria panicea</i>	Brown sponge/bread crumb sponge
Porifera	<i>Leucilla nuttingi</i>	Urn sponge
Porifera	<i>Mycale</i> sp.	Yellow vase sponge
Porifera	<i>Polymastia pachymastia</i>	Aggregated vase sponge
Porifera	<i>Sphaciospongia confoederata</i>	Gray moon sponge
Porifera	<i>Stelletta clarella</i>	Black edge sponge
Porifera	<i>Xestospongia edapha</i>	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 - mound	Unidentified mound sponge
Porifera	Porifera - orange	Orange sponge with large osculum
Porifera	Porifera - shelf	Unidentified shelf sponge
Porifera	Porifera - vase	Colonial small vases often have brittle stars or shrimp living inside
Phaeophyceae	<i>Desmarestia dudresnayi</i> subsp. <i>tabacoides</i>	Brown algae
Rhodophyta	Articulated Corallinaceae	Articulated coralline algae
Rhodophyta	Encrusting Corallinaceae	Encrusting coralline algae
Rhodophyta	<i>Maripelta rotata</i>	Purple circular shaped algae
Rhodophyta	<i>Polyneura latissima</i>	Most common red algae on Cordell Bank
Unknown	Unknown	Encrusting green organism
Unknown	Unknown	Brown biological material

The point counts of taxa from the analyzed images were used to calculate percent cover for each transect. Percent cover was combined into groups or by phylum (table 3) and displayed by transect in figure 3. The total percent per transect in table 3 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, the greatest percent cover observed among transects on the bank was made up of unknown organisms (36.4% ± 13.4) described as a textured layer of brown biological material or a thin, smooth layer of a dark green organism. Porifera and Cnidaria were on average the next most abundant in percent cover among transects (19.1% ±5.3 and 15.7% ±9.36, respectively). Habitat that was not covered with any living organisms made up on average 13% ±4.7. Rhodophyta covered on average 11.4% ±6.9 among transects. Other phylum observed with percent cover ranging from 2.8% - 0.03% included Echinodermata, Chordata, Annelida, Bryozoa, Phaeophyceae, Arthropoda and Mollusca (table 3). The spatial distribution of percent cover of organisms within each phylum is relatively uniform in proportion among transects (figure 3) but will be described in greater detail in the following sections focused on the species within the groups that have the greatest total percent cover on the bank: unknown biological material, Porifera, Cnidaria, and Rhodophyta.

Table 3. Percent cover of phylum or group per transect as displayed in figure 3.

Line	Unkn Biological	Porifera	Cnidaria	Habitat	Rhodophyta	Echinodermata	Chordata	Annelida	Bryozoa	Phaeophyceae	Arthropoda	Mollusca
1	49.06	17.02	16.66	7.37	6.00	2.80	0.72	0.09	0.00	0.00	0.00	0.00
2	37.83	24.71	11.65	15.67	5.50	3.04	0.82	0.36	0.06	0.10	0.05	0.00
3	33.47	14.04	24.84	9.40	13.88	2.22	1.01	0.13	0.27	0.00	0.00	0.00
4	14.35	22.30	19.11	20.54	19.27	2.67	0.85	0.12	0.24	0.30	0.18	0.00
5	38.00	16.58	16.49	10.65	12.61	4.55	0.56	0.20	0.05	0.00	0.05	0.00
6	35.96	13.09	5.54	18.54	20.74	4.70	0.58	0.00	0.00	0.74	0.00	0.00
7	20.86	24.01	23.61	18.58	11.16	1.20	0.05	0.16	0.00	0.11	0.00	0.05
9	34.73	21.90	21.93	8.96	6.16	3.06	1.44	0.44	0.88	0.06	0.00	0.00
10	20.64	26.05	35.88	7.13	6.49	1.37	0.95	0.30	0.47	0.00	0.12	0.00
11	62.29	8.70	2.30	5.43	18.50	1.23	0.74	0.33	0.00	0.00	0.00	0.11
12	29.88	15.68	6.85	16.41	26.46	3.43	0.29	0.12	0.29	0.35	0.00	0.18
13	49.94	19.48	9.98	12.55	3.59	2.94	0.57	0.57	0.00	0.00	0.13	0.06
14	47.53	16.96	7.30	15.54	7.59	4.47	0.28	0.07	0.00	0.00	0.07	0.00
15	48.16	17.89	8.11	15.99	5.89	2.84	0.26	0.52	0.00	0.00	0.00	0.00
16	22.71	27.82	24.82	12.80	7.45	2.16	1.15	0.49	0.07	0.00	0.07	0.00
AVERAGE	36.36	19.08	15.67	13.04	11.42	2.85	0.68	0.26	0.16	0.11	0.04	0.03
(STDEV)	(±13.36)	(±5.32)	(±9.36)	(±4.71)	(±6.92)	(±1.13)	(±0.37)	(±0.18)	(±0.25)	(±0.21)	(±0.06)	(±0.05)

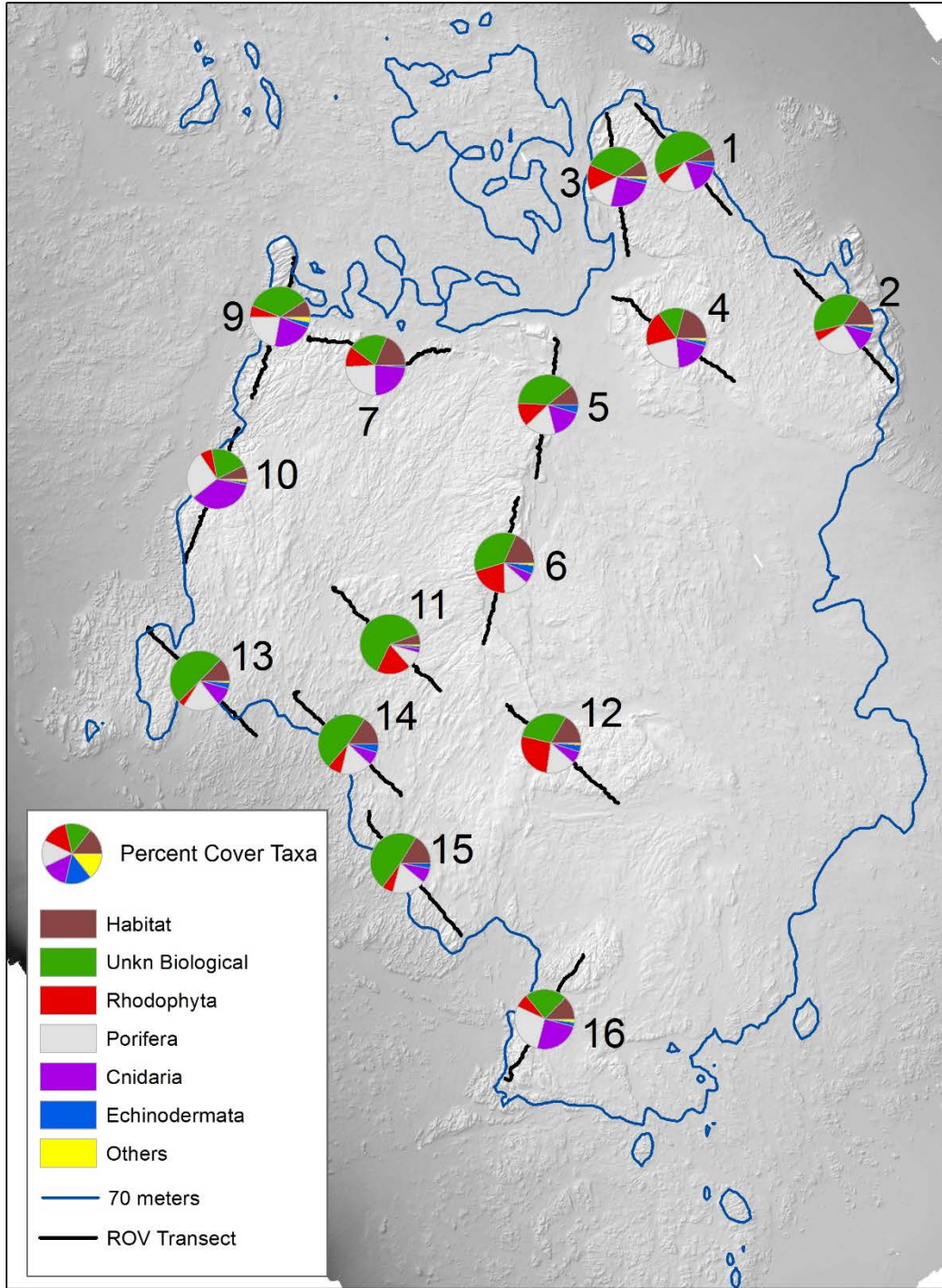


Figure 3. Percent cover of phylum or group observed from analyzed images per transect. Pie chart symbol position is centered on transect line for reference. 'Others' category includes: Chordata, Annelida, Bryozoa, Phaeophyceae, Arthropoda, and Mollusca.

Percent Cover of Species Relative to Group

Unknown Organisms

The most abundant organism among all transects on Cordell Bank was an unknown brown biological material that had a fuzzy texture (figure 4 and table 4, image gallery a). This material could be a combination of diatoms, hydroids or organic detritus, to name a few possibilities. Overall, the average percent cover of the brown biological material increased with deeper depths, was found across all aspect directions, increased in lower sloping habitats and lower positive levels of TPI (at the larger scale of 240 m), which are indicative of flat and low sloping environments. There was, however, a spike in average percent cover of the brown biological material in higher slope (27.51 – 32.5) and higher positive level of TPI (475.1 – 525) environments (figure 5).

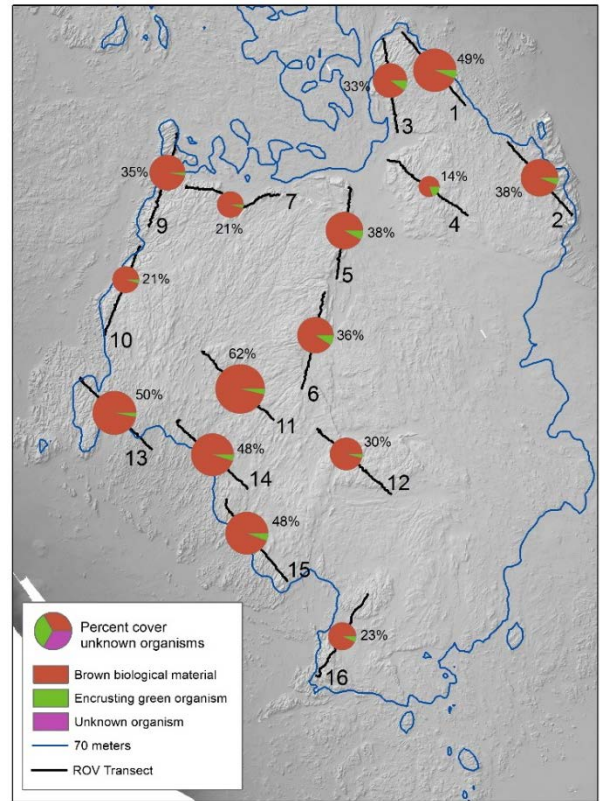


Figure 4. Relative percent cover of unknown biological organisms from analyzed images per transect. Pie chart symbol position is centered on transect line for reference. Percentage corresponds to total percent cover of the unknown organisms per transect.

Table 4. Relative percent cover of unknown biological organisms displayed in figure 4.

Line	Brown biological material	Encrusting green organism	Unknown organism
1	45.87	3.10	0.09
2	35.52	2.26	0.05
3	30.00	3.21	0.27
4	11.61	2.75	0.00
5	34.83	3.06	0.10
6	32.70	3.27	0.00
7	19.97	0.85	0.05
9	33.73	0.94	0.06
10	19.58	0.89	0.18
11	60.05	2.23	0.00
12	28.63	1.18	0.06
13	48.44	1.44	0.06
14	45.11	2.22	0.20
15	45.31	2.78	0.06
16	21.08	1.56	0.07
AVERAGE	34.16	2.12	0.08
(STDEV)	(±13.10)	(±0.90)	(±0.08)

A smooth encrusting dark green organism was also observed on all transects on Cordell Bank (figure 4 and table 4, image gallery b). This unknown organism could be a type of cyanobacteria as the depth distribution was too deep to be a type of Chlorophyte (green algae). Overall, the average percent cover of the encrusting green organism was greatest from 56-65 m, was found across all aspect directions, increased in lower sloping habitats and lower positive and negative levels of 240 m scale TPI, indicative of flat substrates (figure 5).

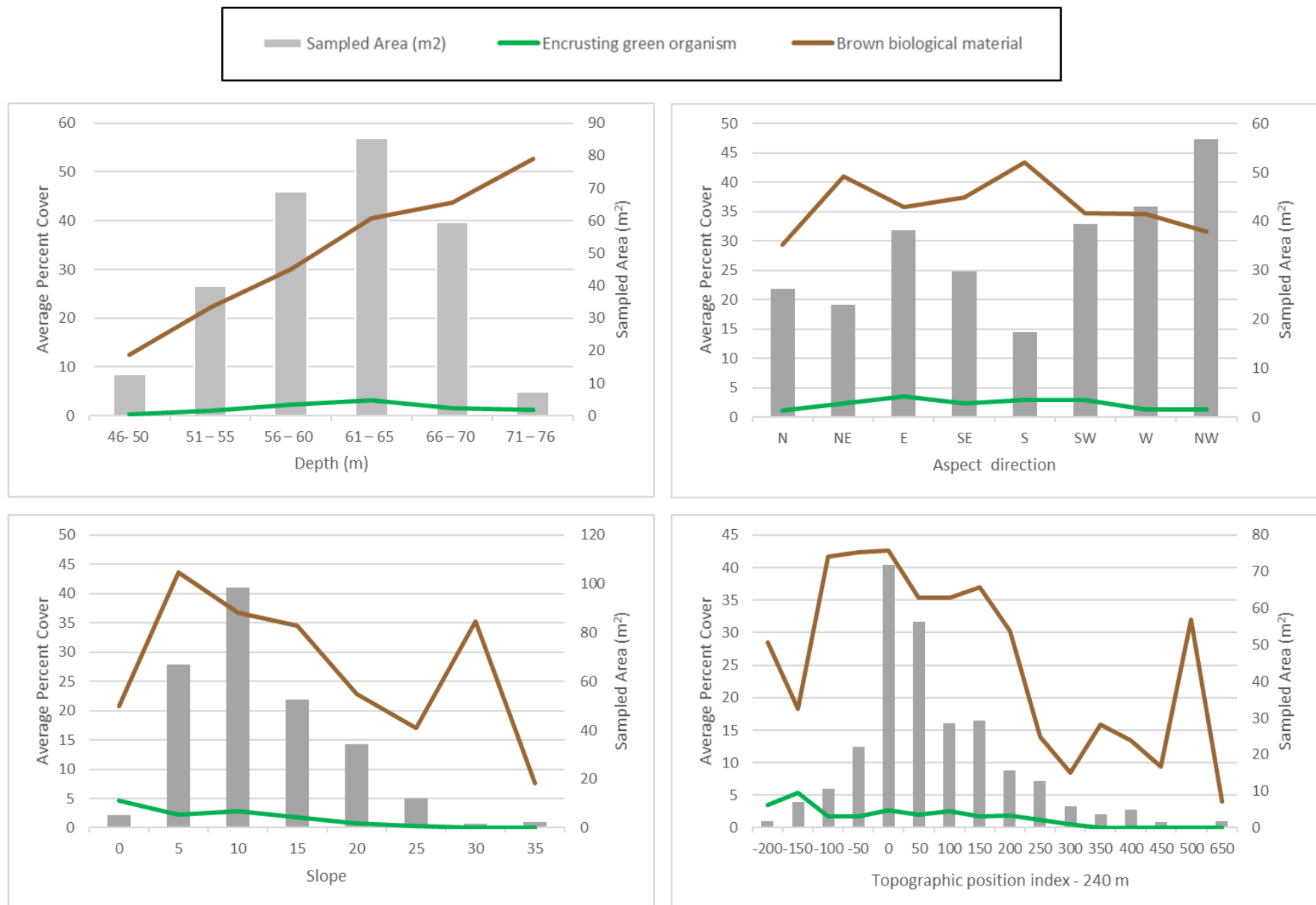


Figure 5. Average percent cover of unknown biological organisms relative to depth, aspect, slope, and topographic position index (TPI) at the 240m scale. Gray bars indicate the total amount of sampled area for each habitat class. The x-axis labels represent the mid-points of aspect, slope and TPI classes (e.g. S aspect class includes compass directions 157.5 to 202.5, 10° slope class includes 7.5-12.5° slopes, 200 TPI class includes 175-225 TPI values).

Porifera – sponges

A diversity of sponges with encrusting and upright morphologies were common among all transects on Cordell Bank. The greatest average percent cover across transects of all documented sponges were encrusting taxa that often varied in colors from red, orange, and white (figure 6 and table 5, image gallery e). Average percent cover of encrusting sponges were distributed across both shallower and deeper depths as well as aspect directions with the greatest average percent cover on North and West facing substrates. Generally, the average percent cover of encrusting sponges increased with increasing slope, while there were no distinct patterns in average percent cover related to TPI 240 m (figure 7).

Sponges that could not be classified by a distinct morphology were categorized as unidentified Porifera and were also found among all transects (figure 6 and table 5). The average percent cover of these sponges was uniform across all depths, aspect directions and slopes. There is a slight increasing trend in average percent cover with higher positive TPI 240 m levels, indicative of the upper reaches of a mounded feature and the top of a rise (figure 7).

The sponge *Xestospongia edapha* is a rigid upright white sponge with large oscula that is easily identifiable and commonly found on the bank, and is referred to by CBNMS staff as “Cordell sponge”. *Xestospongia edapha* was observed in lower average percent cover relative to encrusting and unidentified sponges and was not observed on transects 6, 11 and 12 (figure 6 and table 5, image gallery f). Average percent cover of *X. edapha* was greatest in shallower depths of 46-60 m and associated with North and West facing substrates. There is a clear trend of increasing average percent cover with increasing slope and therefore an association with substrate that is the top of a rise (higher positive TPI values) (figure 7).

The average percent cover of unidentified mound sponges and 12 other sponges identified to species or by morphology varied across transects and were overall low relative to the cover of all sponges observed (figure 6 and table 5) and therefore it is difficult to determine distinct trends in average percent cover values relative to habitat variables (figure 7).

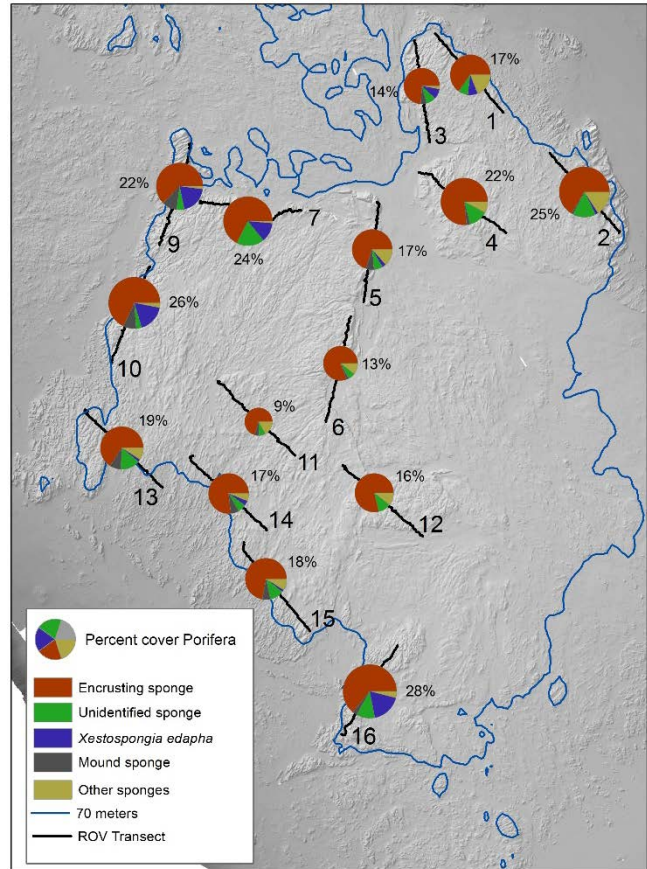


Figure 6. Relative percent cover of Porifera from analyzed images per transect. Pie chart symbol position is centered on transect line for reference. Percentage corresponds to total percent cover of Porifera per transect.

Table 5. Relative percent cover of Porifera displayed in figure 6.

Line	Porifera - encrusting	Porifera	Xestospongia edapha	Porifera - mound	Porifera - orange	Stelletta clarella	Halichondria panicea	Porifera - branched	Porifera - shelf	Porifera - vase	Polymastia pachymastia	Iophon spp.	Porifera - barrel	Leucilla nuttingi	Mycale sp.	Sphaciospongia confederata
1	11.03	1.31	1.32	0.09	1.13	0.00	1.52	0.19	0.14	0.14	0.00	0.14	0.00	0.00	0.00	0.00
2	16.35	3.70	0.42	0.31	0.57	0.00	0.00	0.63	0.21	2.22	0.00	0.00	0.10	0.21	0.00	0.00
3	10.39	1.22	1.28	0.73	0.21	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	15.00	2.56	0.18	0.49	0.55	2.55	0.00	0.68	0.00	0.00	0.18	0.12	0.00	0.00	0.00	0.00
5	11.56	1.16	0.50	1.12	0.50	0.00	1.33	0.00	0.05	0.10	0.05	0.20	0.00	0.00	0.00	0.00
6	10.55	0.90	0.00	0.26	0.37	0.00	0.00	0.00	0.63	0.00	0.05	0.32	0.00	0.00	0.00	0.00
7	14.93	4.06	2.84	0.16	0.26	1.70	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	13.68	1.19	4.32	2.27	0.31	0.00	0.00	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
10	17.28	0.90	4.42	2.03	0.12	0.65	0.00	0.12	0.29	0.00	0.00	0.00	0.24	0.00	0.00	0.00
11	6.13	0.67	0.00	0.45	0.33	0.00	0.82	0.19	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00
12	12.37	1.65	0.00	0.00	0.24	0.00	1.07	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	12.80	2.90	0.38	1.64	0.51	0.00	0.00	0.38	0.70	0.00	0.00	0.00	0.19	0.00	0.00	0.00
14	13.02	1.15	0.68	1.09	0.27	0.00	0.00	0.20	0.13	0.00	0.34	0.00	0.07	0.00	0.00	0.00
15	12.91	2.01	0.26	1.10	1.03	0.00	0.00	0.00	0.45	0.00	0.00	0.06	0.00	0.00	0.00	0.06
16	17.72	3.11	4.97	0.75	0.00	0.20	0.00	0.07	0.20	0.07	0.74	0.00	0.00	0.00	0.00	0.00
AVERAGE (STDEV)	13.05 (±3.00)	1.90 (±1.10)	1.44 (±1.78)	0.83 (±0.71)	0.43 (±0.31)	0.34 (±0.76)	0.32 (±0.56)	0.20 (±0.22)	0.19 (±0.23)	0.17 (±0.57)	0.09 (±0.20)	0.06 (±0.10)	0.03 (±0.08)	0.01 (±0.04)	0.01 (±0.05)	0.00 (±0.02)

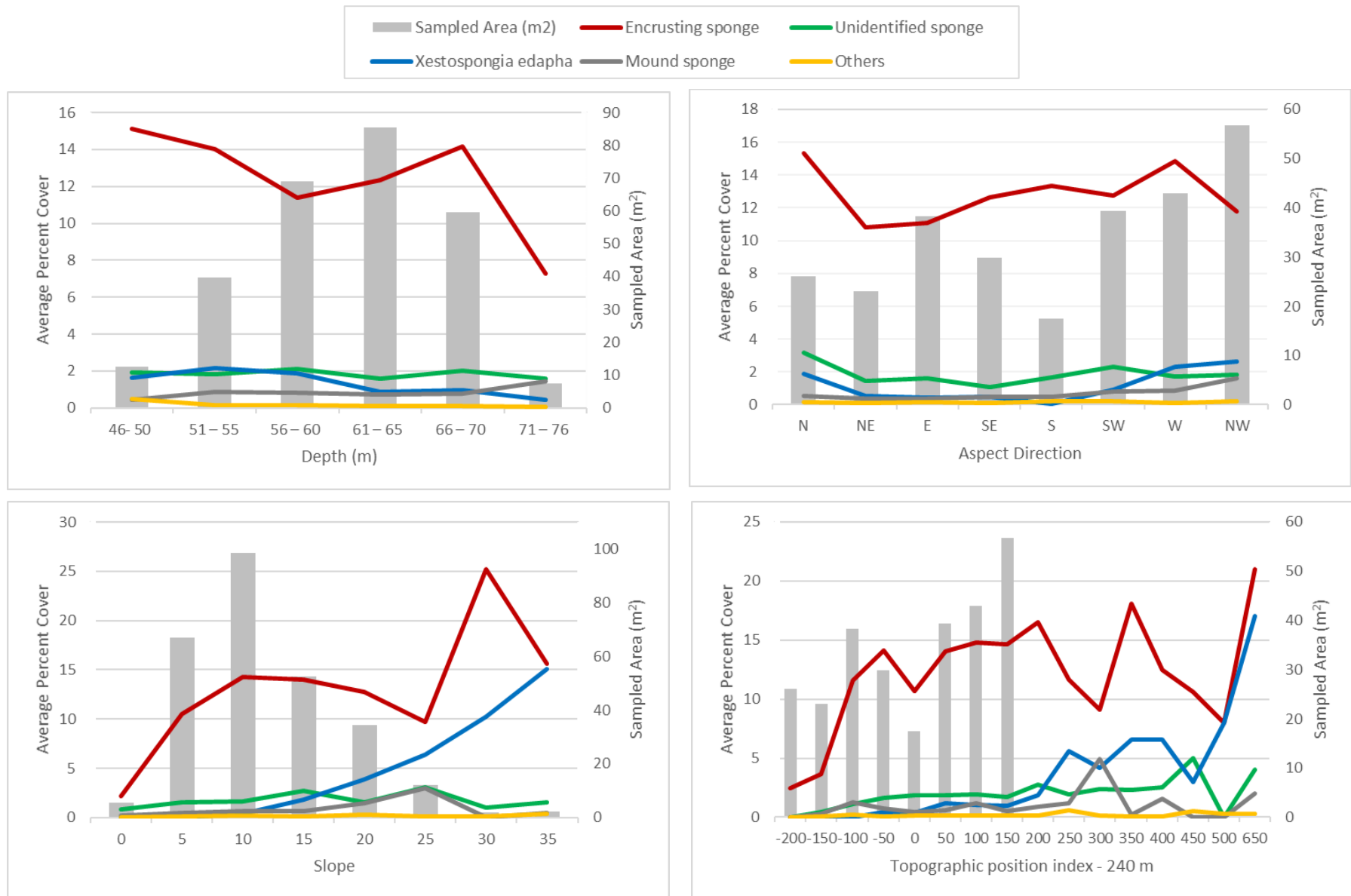


Figure 7. Average percent cover of Porifera relative to depth, aspect, slope, and topographic position index (TPI) at the 240 m scale. Gray bars indicate the total amount of sampled area for each habitat class. The x-axis labels represent the mid-points of aspect, slope and TPI classes (e.g. S aspect class includes compass directions 157.5 to 202.5, 10^o slope class includes 7.5-12.5^o slopes, 200 TPI class includes 175-225 TPI values).

Densities of *Xestospongia edapha* and *Stelletta clarella* were calculated using the total counts from the 538 analyzed images divided by the total area of each transect. Figure 8 displays graduated symbols of *X. edapha* and *S. clarella* density range per m². *Xestospongia edapha* displayed the highest densities on transects 3, 7, 9, 10 and 16 that are along the edge of the 70 m isobath facing to the North and Northwest and the lowest densities were on transects 6, 11 and 12 which are generally located within the center of the 70 m isobath. Densities of *S. clarella* were overall low but like *X. edapha* were also generally more abundant on transects that are along the edge of the 70 m isobath facing to the North and Northwest.

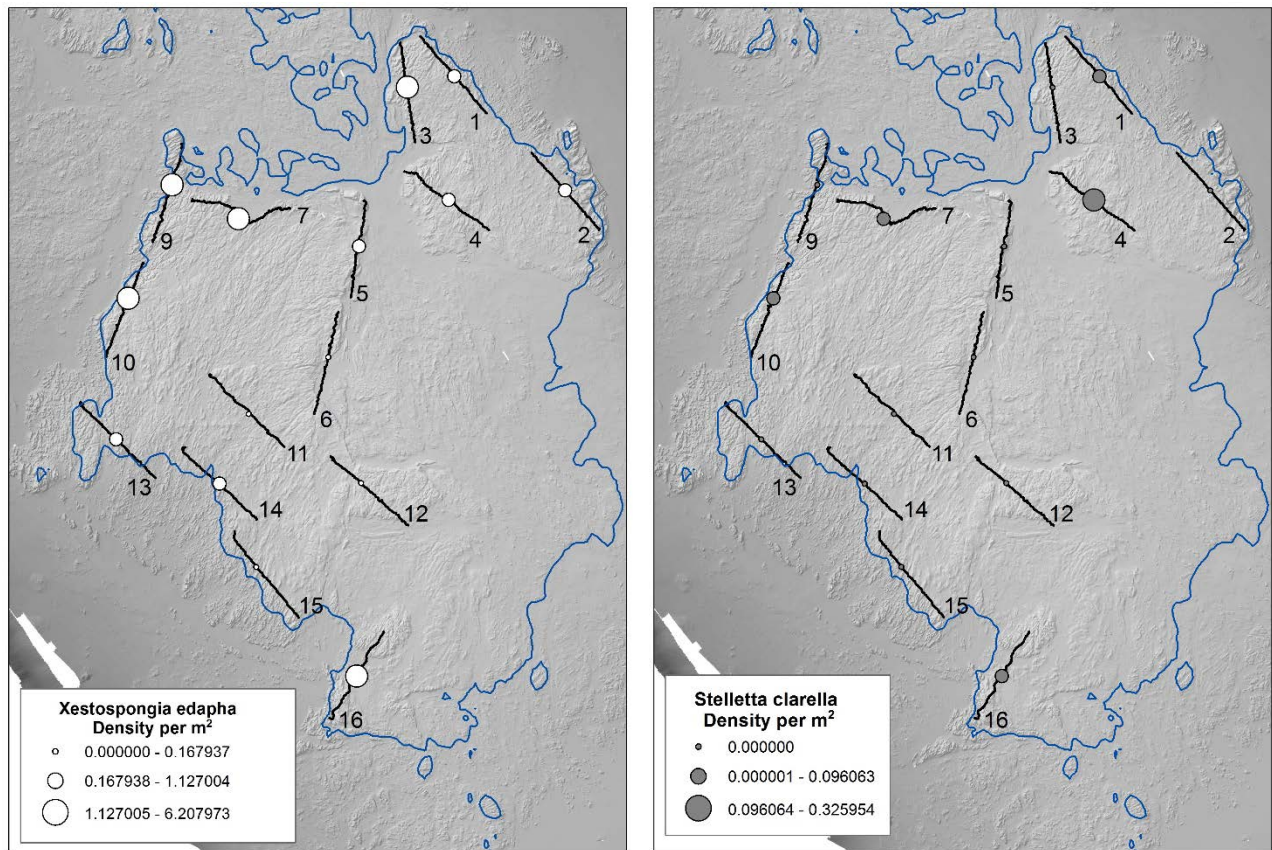


Figure 8. Density of *Xestospongia edapha* and *Stelletta clarella* per m² from all transects. Graduated symbol position is centered on transect line for reference.

Cnidaria – corals, anemones, and hydroids

The most abundant Cnidaria found among all transects was *Corynactis californica* (strawberry anemone) (figure 9 and table 6, image gallery f) with greatest average percent cover peaking at shallow depths (51-60 m), steeply sloped substrates (12.5 to 37.5 degrees) and associated with Northwest, North, West and Southwest facing substrates that are the upper reaches of a mounded feature and the top of a rise as indicated by the higher positive TPI values (figure 10).

Two species of cup corals were observed among all transects, *Paracyathus stearnsii* (brown cup corals) and *Balanophyllia elegans* (orange cup corals) (figure 9 and table 6, image gallery e). Average percent cover of *P. stearnsii* was highest in shallower depths of 50-60 m while the average percent cover of *B. elegans* increased in depths greater than 60 m. Average percent cover of *P. stearnsii* increased with higher sloped substrates, while *B. elegans* did not display a strong affiliation with habitats with high or low slopes. Generally, both species of cup corals were equally distributed across substrates facing all aspect directions and across all negative and positive TPI values, indicative of flat and mounded substrates (figure 10).

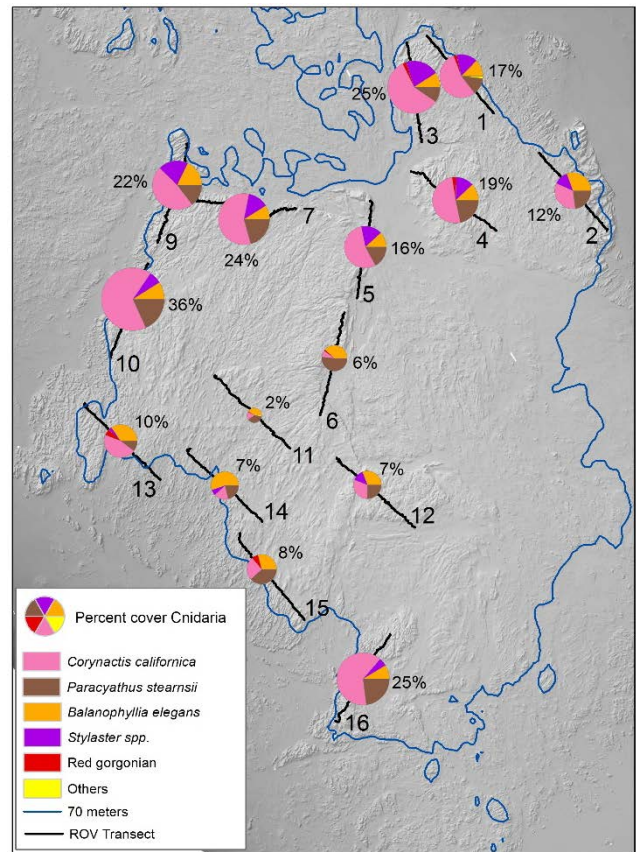


Figure 9. Relative percent cover of Cnidaria from analyzed images per transect. Pie chart symbol position is centered on transect line for reference. Percentage corresponds to total percent cover of Cnidaria per transect.

Table 6. Relative percent cover of Cnidaria displayed in figure 9.

Line	<i>Corynactis californica</i>	<i>Paracyathus stearnsii</i>	<i>Balanophyllia elegans</i>	<i>Stylaster spp.</i>	Red gorgonian	<i>Garveia annulata</i>	<i>Urticina piscivora</i>	<i>Urticina columbiana</i>
1	9.11	2.12	2.11	2.65	0.38	0.19	0.09	0.00
2	3.93	2.68	3.55	1.49	0.00	0.00	0.00	0.00
3	14.41	2.36	2.27	5.13	0.60	0.00	0.07	0.00
4	9.73	4.14	2.26	2.43	0.55	0.00	0.00	0.00
5	8.98	2.81	1.96	2.65	0.10	0.00	0.00	0.00
6	0.42	2.90	2.11	0.00	0.11	0.00	0.00	0.00
7	13.53	4.89	2.07	3.12	0.00	0.00	0.00	0.00
9	10.49	3.16	3.93	4.29	0.00	0.06	0.00	0.00
10	23.74	6.53	3.21	2.34	0.00	0.06	0.00	0.00
11	0.41	0.89	0.93	0.00	0.04	0.04	0.00	0.00
12	2.06	1.71	2.08	0.88	0.06	0.00	0.00	0.06
13	4.58	1.01	3.46	0.32	0.63	0.00	0.00	0.00
14	1.22	1.54	3.99	0.47	0.07	0.00	0.00	0.00
15	2.07	3.06	2.33	0.06	0.59	0.00	0.00	0.00
16	15.66	5.67	2.14	1.22	0.07	0.07	0.00	0.00
AVERAGE	8.02	3.03	2.56	1.80	0.21	0.03	0.01	0.00
(STDEV)	(±6.81)	(±1.65)	(±0.86)	(±1.60)	(±0.25)	(±0.05)	(±0.03)	(±0.02)

Other coral species found on the bank in lower percent cover were *Styaster* spp. (hydrocoral) and an unidentified species of red gorgonian (image gallery a, c, d). *Styaster* spp. occurred on more transects and displayed preference for particular habitat variables than was observed with the red gorgonians. Average percent cover of *Styaster* spp. was greatest in shallow depths (46-56 m) and decreased with increasing depth. *Styaster* spp. percent cover increased with steeply sloped and mounded substrates (higher TPI) facing to the North, Northwest, Southwest and West. The low percent cover of red gorgonians makes it difficult to interpret associations with habitat characteristics. Generally, gorgonians were broadly distributed across a range of depths, slopes, aspect directions and TPI indices (figure 10).

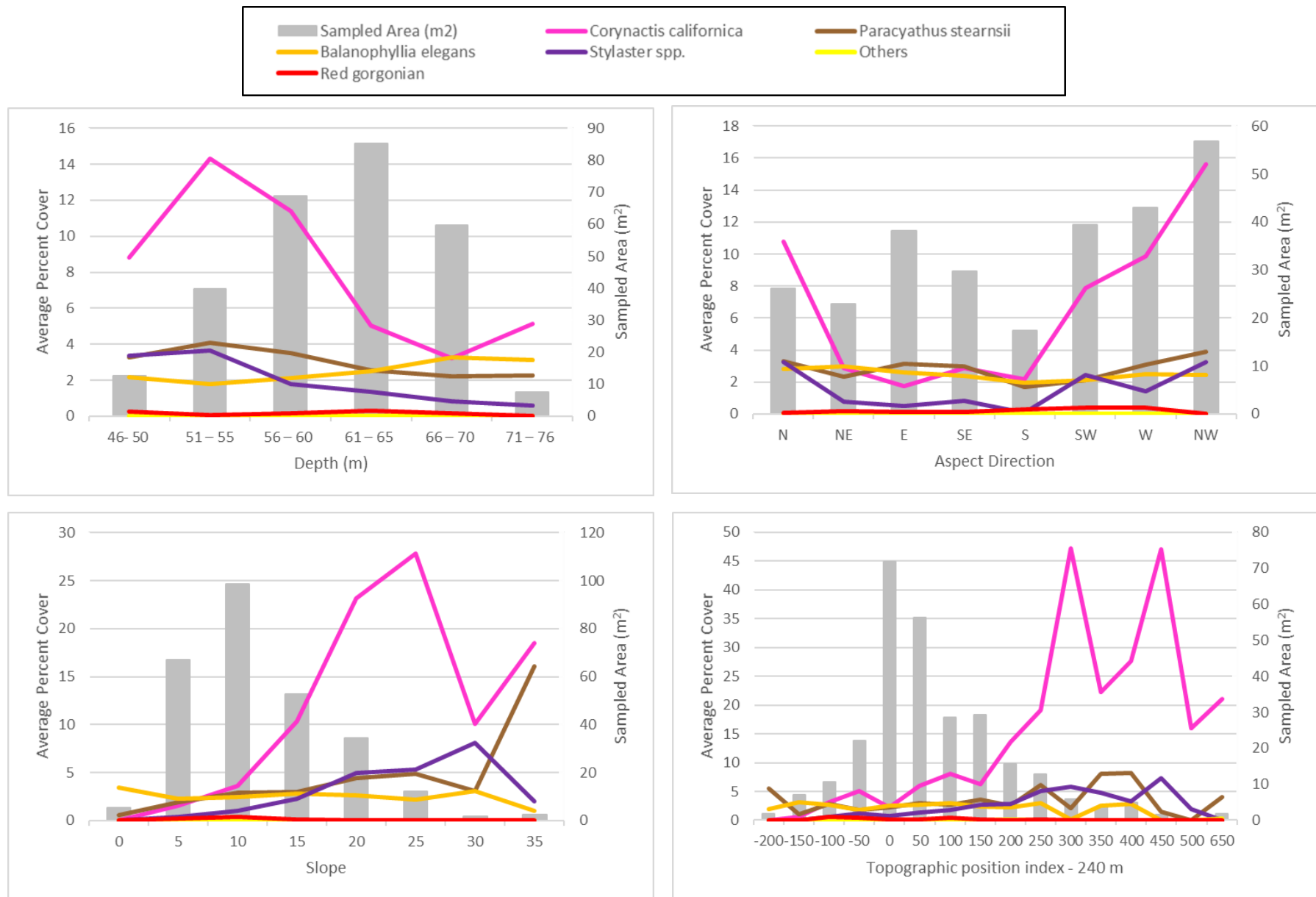


Figure 10. Average percent cover of Cnidaria relative to depth, aspect, slope, and topographic position index (TPI) at the 240 m scale. Gray bars indicate the total amount of sampled area for each habitat class. The x-axis labels represent the mid-points of aspect, slope and TPI classes (e.g. S aspect class includes compass directions 157.5 to 202.5, 10° slope class includes 7.5-12.5° slopes, 200 TPI class includes 175-225 TPI values).

Densities of *Stylaster* spp. and red gorgonians were calculated using the total counts from the 538 analyzed images divided by the total area of each transect. Figure 11 displays graduated symbols of *Stylaster* spp. and red gorgonian density range per m². Interestingly there was a general trend that *Stylaster* spp. and gorgonian densities were inverse among transects, such as where *Stylaster* spp. were more abundant, red gorgonians were less abundant and vice versa. For example, *Stylaster* spp. density was greatest on transects 7, 9 and 10 which are oriented on the Northwest edge of the 70 m isobath and gorgonians were absent from these transects. Red gorgonians displayed moderate density on transects 5, 6, 13 and 15 where *Stylaster* spp. were much less common. Etherington et al. (2011) also identified that *Stylaster* spp. and red gorgonians occupied different niches and spatial distribution across the bank as a result of their respective preferences for specific habitat variables.

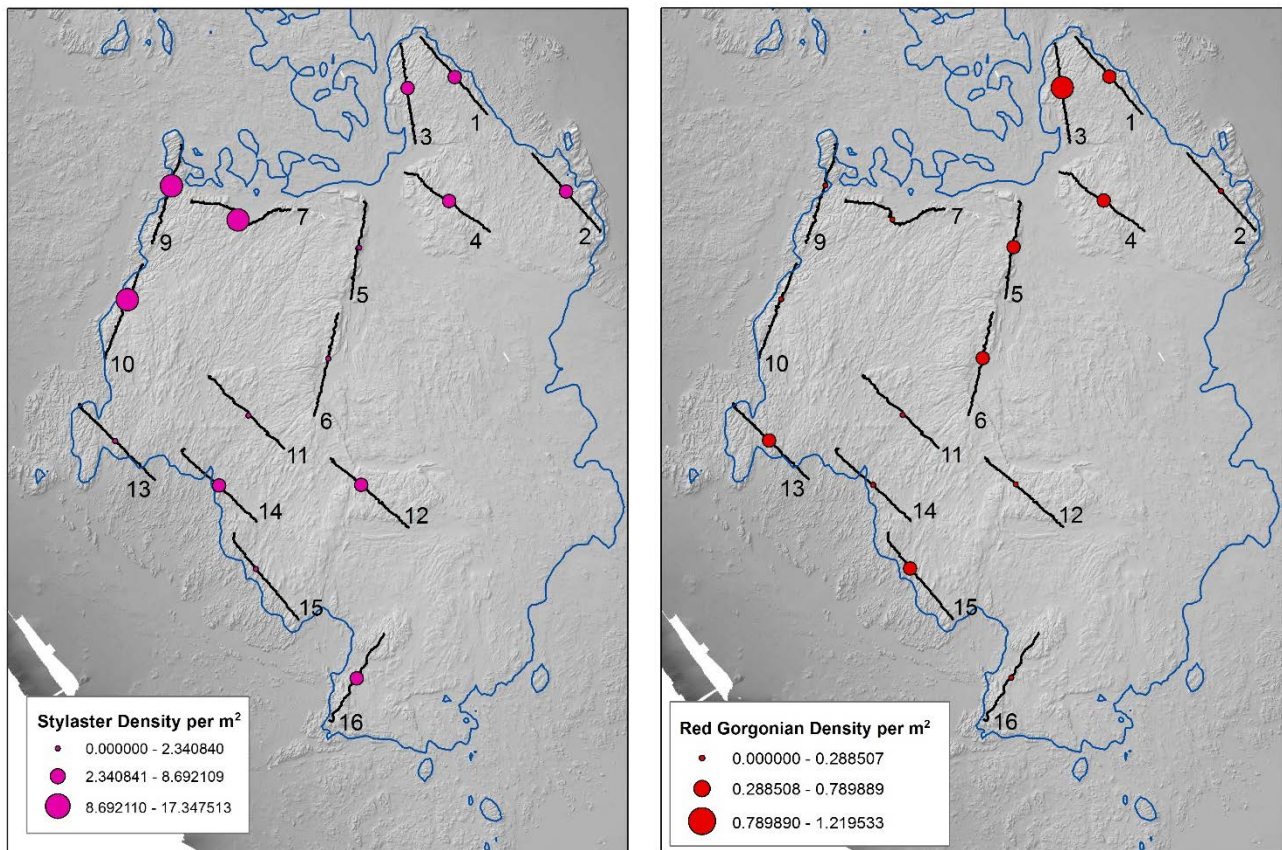


Figure 11. Density of *Stylaster* spp. and red gorgonians per m² from all transects. Graduated symbol position is centered on transect line for reference.

Counts of *Stylaster* spp. and red gorgonians were recorded for every image and converted into presence and absence data. 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 from this study.

The presence model for *Stylaster* spp. displayed 71% accuracy in predicting *Stylaster* spp. presence and absence from this survey. Of the 538 sampled images, 105 (20%) accurately matched the model's predicted presence of *Stylaster* spp. and 276 images (51%) accurately matched the model's prediction of *Stylaster* spp. being absent. False positive results (model predicted *Stylaster* spp. presence, but no *Stylaster* spp. were observed) accounted for 25% of the data and false negative results (model predicted *Stylaster* spp. absence, but *Stylaster* spp. were observed) accounted for only 4% of the data (table 7).

Table 7. Numerical and percentage results of *Stylaster* spp. predictive model and presence/absence data extracted from still images showing true positives, true negatives, false positives and false negatives.

Stylaster spp. - Numerical n = 538		Model Prediction	
		1	0
Actual	1	105	20
	0	137	276

Stylaster spp. - Percentage		Model Prediction	
		1	0
Actual	1	20%	4%
	0	25%	51%

The presence model for red gorgonians displayed 51% accuracy in predicting red gorgonian presence and absence. Of the 538 sampled images, only 41 (8%) accurately matched the model's predicted presence of red gorgonians and the model more accurately predicted the absence of red gorgonians at 43%. False positive results (model predicted red gorgonian presence, but no red gorgonians were observed) accounted for 45% of the data and false negative results (model predicted red gorgonian absence, but red gorgonians were observed) accounted for only 5% of the data (table 8).

Table 8. Numerical and percentage results of red gorgonian predictive model and presence/absence data extracted from still images showing true positives, true negatives, false positives and false negatives.

Red Gorgonian - Numerical n = 538		Model Prediction	
		1	0
Actual	1	41	25
	0	241	231

Red Gorgonian - Percentage		Model Prediction	
		1	0
Actual	1	8%	5%
	0	45%	43%

Rhodophyta – red algae

Four types of red algae were observed on the bank. Two of the most abundant algae taxa that were present among all transects were a hard encrusting coralline algae (image gallery b and e) and *Polyneura latissimi* that forms relatively large blades (up to 15 cm tall) (figure 12 and table 9). Average percent cover of both taxa was greatest at shallower depths and decreased with increasing depths. Generally, the percent cover of the encrusting corallinaceae and *P. latissimi* was greatest on lower sloped substrates. Average percent cover of both taxa displayed similar trends in the variation of landform preference (TPI values) as well as associating with substrates facing different aspect directions (figure 13).

Table 9. Relative percent cover of Rhodophyta displayed in figure 12.

Line	Encrusting Corallinaceae	<i>Polyneura latissimi</i>	<i>Maripelta rotata</i>	Articulated Corallinaceae
1	3.94	1.08	0.98	0.00
2	5.03	0.16	0.32	0.00
3	7.50	5.78	0.60	0.00
4	14.26	4.16	0.85	0.00
5	8.45	3.51	0.65	0.00
6	9.92	10.24	0.58	0.00
7	6.11	3.67	1.38	0.00
9	4.71	1.39	0.06	0.00
10	5.05	1.21	0.24	0.00
11	6.76	10.18	1.56	0.00
12	16.56	9.60	0.18	0.12
13	3.34	0.13	0.13	0.00
14	4.82	2.02	0.75	0.00
15	4.21	0.91	0.78	0.00
16	4.14	2.55	0.76	0.00
AVERAGE (STDEV)	6.99 (±3.89)	3.77 (±3.58)	0.65 (±0.44)	0.01 (±0.03)

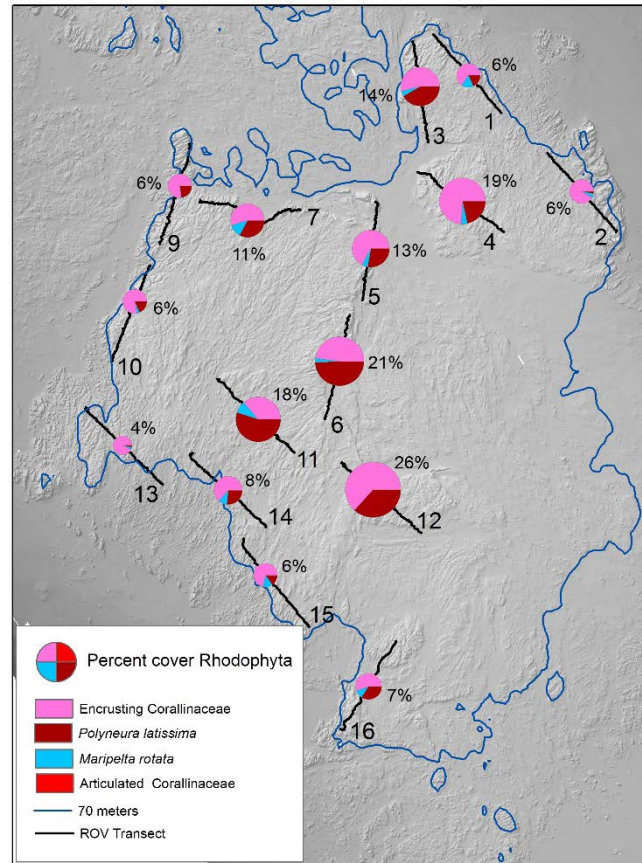


Figure 12. Relative percent cover of Rhodophyta from analyzed images per transect. Pie chart symbol position is centered on transect line for reference. Percentage corresponds to total percent cover of Rhodophyta per transect.

Maripelta rotata was observed among all transects but in lower percent cover relative to encrusting corallinaceae and *P. latissimi* (figure 12 and table 9). *Maripelta rotata* has a mushroom shaped blade that is an adaptation to maximizing light absorption in low light levels. The low percent cover of *M. rotata* makes it difficult to determine associations with habitat characteristics. Generally, *M. rotata* were found across a range of depths, slopes, aspect directions and TPI indices (figure 13).



Figure 13. Average percent cover of Rhodophyta relative to depth, aspect, slope, and topographic position index (TPI) at the 240 m scale. Gray bars indicate the total amount of sampled area for each habitat class. The x-axis labels represent the mid-points of aspect, slope and TPI classes (e.g. S aspect class includes compass directions 157.5 to 202.5, 10° slope class includes 7.5-12.5° slopes, 200 TPI class includes 175-225 TPI values).

Non-metric multidimensional scaling

The taxa included in the non-metric multidimensional scaling (NMDS) data matrix were those that displayed the greatest percent cover among transects: unknown brown biological material, unknown encrusting green organism, encrusting sponges, unknown sponge, mound sponge, *Xestospongia edapha*, *Corynactis californica*, *Paracyathus stearnsii*, *Balanophyllia elegans*, *Stylaster* spp., red gorgonian, encrusting coralline algae and *Polyneura latissimi*. The percent cover data were square root transformed and analyzed on the Bray-Curtis similarity matrix. Overall, the results from the NMDS do not define distinct groups or clusters of samples based on the percent cover of taxa. The points (representing images) in the ordination are symbolized by transect number and are generally mixed and closely spaced together and therefore similar in species composition. Also, the vectors representing habitat variables did not display a meaningful relationship to the ordination of biological data. Stress of the ordination in 2-dimensions was 0.19 which is considered as giving a potentially useful ordination, but for context a stress value <0.1 corresponds to a good ordination and stress <0.05 gives an excellent representation (Clarke and Warwick, 2001) (figure 14).

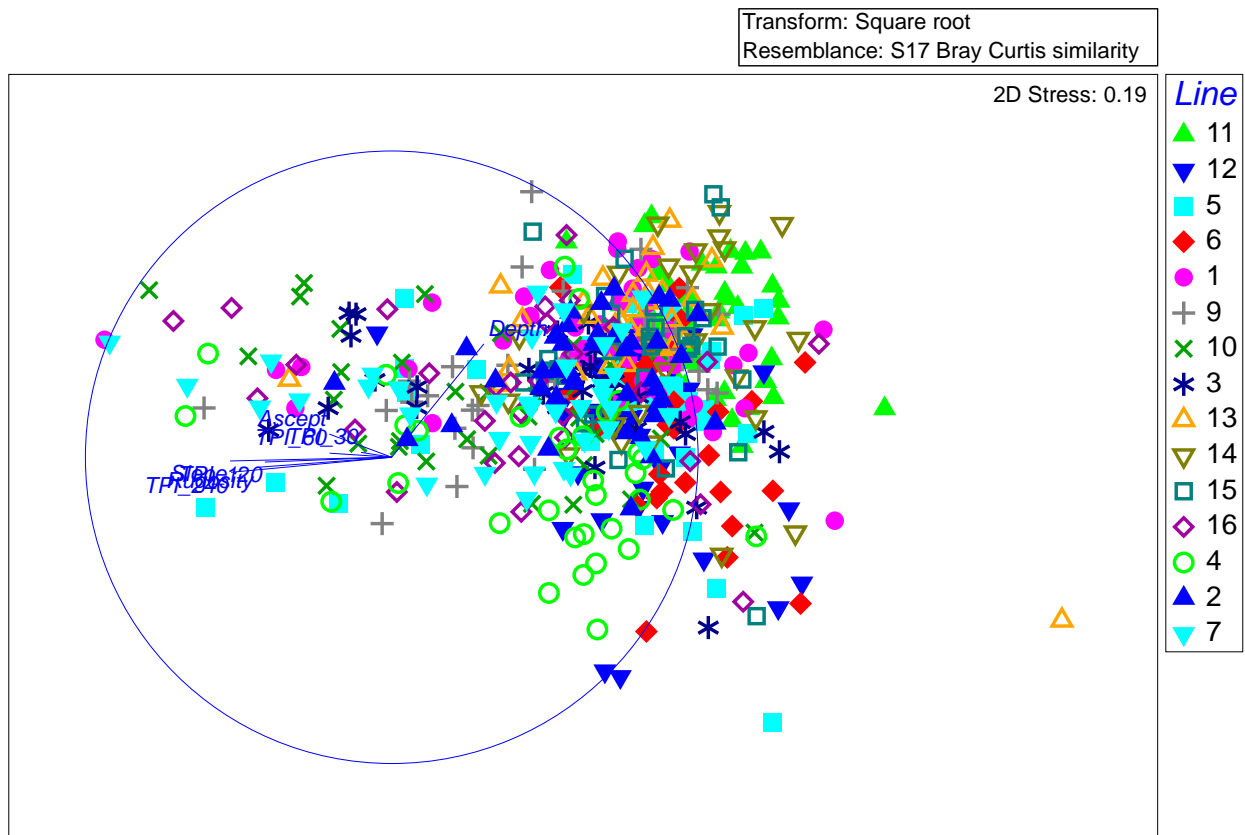


Figure 14. Non metric multdimensional (NMDS) of images analyzed for taxa percent cover per transect.

Discussion

This fine-scale characterization of the upper reef benthic community on Cordell Bank revealed patterns in taxa that had not been evident from previous surveys that had different scales, goals, and survey technologies. Most often Cordell Bank's living reefs are described as a colorful compilation of anemones, sponges and corals, and these were all present in high abundances, but it was surprising to quantify the high percent cover of the unknown brown biological material and smooth dark green encrusting organisms, which had not previously been quantified on Cordell Bank. Prior to this survey, all of the benthic data on Cordell Bank was collected from forward facing underwater video and because this survey used downward facing still images to estimate percent cover, the detection of the unknown encrusting organisms was higher than was possible from historic video imagery. It is also likely that the unknown encrusting organisms were misidentified as uncolonized habitat from the previous surveys using video. The brown biological material could be a combination of diatoms, hydroids or organic detritus and the green organism could be a type of cyanobacteria. Collections made by divers from Cordell Expeditions in the late 1970s and early 1980s did find multiple species of hydroids, diatoms and one unidentified species of blue-green algae that were attached to larger collected specimens (Schmeider 1985). However, a description of the continual mats of the brown and green encrusting organisms are not described (Schmeider 1991). In our survey, the highest densities of the unknown encrusting organisms increased in depths below 60 m and these depths were beyond the range that the Cordell Expedition divers primarily surveyed. Both the brown and green unknown organisms need to be collected for taxa identification.

There were interesting patterns in taxa abundance and distribution with habitat variables. Encrusting sponges had the highest percent cover among all sponges and were generally found across the full range of depths, slopes, aspect directions and TPI values surveyed. Similar to the unknown encrusting organisms, Cordell Bank's encrusting sponges often get overlooked, most likely because their three dimensional counterparts, like *Xestospongia edapha* ("Cordell sponge"), are more distinctive and easily detected from underwater video. The three dimensional or 'upright sponges' displayed habitat associations that are most advantageous for their feeding strategy. They are observed on higher sloping substrates usually at the top of a rise or pinnacle that best exposes them to flowing water carrying organic matter for feeding. The density estimates of *Xestospongia edapha* and *Stelletta clarella* illustrate that these species are more prevalent along the edge of the 70 m isobath facing into the North and Northwest prevailing current, whereas the lowest densities generally occurred within the center of the bank where water flow may not be as strong.

The taxa observed within phylum Cnidaria showed associations with specific habitat variables and can be divided into two groups: species associated with shallow, high sloped habitats and species associated with deep, low sloped habitats. It was not surprising that the data showed *Corynactis californica* (strawberry anemones) dominated the shallowest and steepest sloped habitats on the bank, because images from previous surveys showed continuous mats of the brightly colored pink and red polyps on the shallow rock reefs of Cordell Bank. An observation that had not been documented in previous benthic surveys on the Bank was the presence of *C.*

californica deeper than 70 m, and surprisingly they were observed as solitary polyps versus the more common colonial mats of polyps observed in shallower depths.

Like *C. californica*, *Stylaster* spp. (hydrocoral) was also most abundant in shallow and high sloped substrates. In the shallow depths, the sizes of *Stylaster* spp. heads were much larger and spherically shaped than *Stylaster* spp. heads observed at deeper depths, which were not only smaller but oblong shaped (image gallery c and d). It would be interesting to look further into this variation in *Stylaster* spp. morphology, as 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 or food as abundant at deeper depths than at the Bank's shallower reef tops. Both *Stylaster* spp. and *C. californica* were more abundant on edges of the Bank that were oriented into the prevailing Northwest current as this could be advantageous for food delivery. The red gorgonians were more often found in deeper, lower sloped habitats. Overall, percent cover was low relative to the other corals, as this study most likely did not encompass the gorgonian's full depth range. Etherington et al. (2011) found gorgonian observations ranged from 53 to 139 m. Therefore, the predictive habitat model for *Stylaster* spp. and red gorgonians developed by Etherington et al. (2011) more accurately predicted the habitat for *Stylaster* spp. than red gorgonians when matched to this dataset due to the depths sampled and preferred habitats for these two taxa.

The fact that Rhodophyta (red algae) were present on all transects and were most abundant from 46 to 65 m is indicative of the relatively clear water allowing high light penetration to the bank. Previous surveys have also indicated that Rhodophyta are common on Cordell Bank. Collections from Cordell Expeditions found 22 species of Rhodophyta, of which 20 species were depth extensions and 3 were range extensions (Schmedier, 1985). This is somewhat extraordinary because on the California coast very few benthic algae are found below 40 m (Abbott and Hollenberg, 1976). Rhodophyta absorb blue-green light at depth since light loses its intensity as it penetrates the water column and loses red and violet wavelengths. This survey corroborates the Cordell Expeditions' findings of *Polyneura latissimi*, *Maripelta rotata* and encrusting corallinaceae as the most abundant of the Rhodophyta observed. In addition to high light penetration for photosynthesis, the success of the bank's algae community may also be attributed to the low abundance of grazers, specifically urchins. Only three urchins (*Strongylocentrotus* spp.) were counted from all of the images analyzed.

In addition to percent cover and abundance and distribution of taxa related to habitat characteristics, this study looked at community composition with a multivariate statistical technique, non-metric multidimensional scaling, which revealed the relative similarity of the transects surveyed in species composition and abundance. This finding illustrates that the approximately 30 meter depth range constitutes a habitat strata supporting a similar community. Distinctive patterns in species composition and abundance may become more apparent as additional years of sampling take place in depths greater than 70 m.

This fine-scale quantitative assessment of the invertebrate and algal communities on the upper reefs of Cordell Bank not only provides a detailed characterization of this strata, but it also

creates a baseline for future comparative studies. The detailed descriptions of the community assemblages, relative abundances, and associations with specific habitat variables will allow sanctuary researchers and managers to compare these data with future results and detect large changes in species abundance and composition that could be a result of natural or anthropogenic causes. Stressors that managers of CBNMS are particularly concerned about include ocean acidification, decreases in oxygen, increasing water temperature, invasive species, and disease.

Shifts in ocean chemistry can lead to stressful conditions for some species, such as plankton and organisms like corals that have shells or skeletons made of calcium carbonate. Increasing ocean acidity reduces free calcium needed for organisms to create shells and can dissolve shells as acidity increases (NOAA Ocean Acidification Steering Committee 2010). Larval stages of many organisms are particularly susceptible to negative impacts from acidification. The US west coast is especially vulnerable to changes in ocean chemistry because of the combination of naturally acidified water that is upwelled and anthropogenic carbon inputs (Feely et al. 2008). Species on Cordell Bank that may be vulnerable include calcium carbonate structured corals such as *Stylaster* spp. (hydrocorals), *Balanophyllia elegans*, *Paracyathus stearnsii* (cup corals), as well as other organisms like coralline algae and echinoderms.

Invasive species are another potential threat to species composition on the bank and could alter abundance and diversity of native species. A number of invasive species are present in the marine environment near CBNMS, but none are known to currently exist in the sanctuary, and none were observed during this survey. A concern for CBNMS management is to monitor for the colonial tunicate *Didemnum vexillum* as this species 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).

Natural mortality events can drastically impact species populations and two unprecedented events recently occurred along the west coast of North America. In 2011, a harmful algal bloom along California's Sonoma coast killed tens of thousands of rocky shore invertebrates including *Strongylocentrotus purpuratus* (purple sea urchin) and *Haliotis rufescens* (red abalone) (Hewson et al. 2014). This event was not known to impact Cordell Bank at the time and no evidence of it was seen during this survey.

An epidemic of sea star wasting disease extending from Canada to Southern California was first documented in 2013 and has been linked to a densovirus (Jurgens et al. 2015). Many of the sea star species impacted by the wasting syndrome are found on Cordell Bank: *Pycnopodia helianthoides* (sunflower star), *Orthasterias koehlerii* (rainbow star), *Pisaster giganteus* (giant star), *Solaster* spp. (sun star), *Dermasterias imbricata* (leather star), *Mediaster aequalis* (vermilion star), *Leptasterias* spp. (six-armed star), *Patiria miniata* (bat star) and *Henricia* spp. (blood star) (seastarwasting.org). This was the first systematic survey at Cordell Bank since the outbreak occurred and within Echinodermata at least 10 species of sea stars were observed, of which 6 are species listed as those to be affected by sea star wasting syndrome in nearshore habitats along the US west coast. The condition of all sea stars was noted as they were

identified and no individuals displayed characteristics of wasting syndrome such as deteriorating tissue, lesions or missing arms. The cooler water temperature at Cordell Bank compared to temperatures in nearshore waters may be a factor for sea star survival, as was found in the Pacific Northwest (Eisenlord et al. 2016). Cordell Bank may be a sanctuary from sea star wasting disease. However, rising sea temperatures could impact Cordell Bank and sanctuary staff plan to monitor the condition of organisms as well as their distribution and abundance.

This study laid the groundwork for being able to detect and evaluate changes to the Cordell Bank ecosystem. Continued monitoring of Cordell Bank's benthic community is needed to ensure that effects from environmental stressors are identified early as they could have detrimental effects to the currently thriving community. Sanctuary managers also want to be able to detect positive changes that may result from management actions such as protections or restoration.

Following this survey and analysis, CBNMS is preparing for future surveys by evaluating science and information needs and developing a long term plan for research and monitoring of benthic communities. CBNMS is also upgrading their ROV by purchasing and installing a new high definition video camera and new lights. This will greatly improve the imagery collected and may allow for better identification of taxa. These efforts will support an effective and efficient monitoring plan of Cordell Bank's benthic community.

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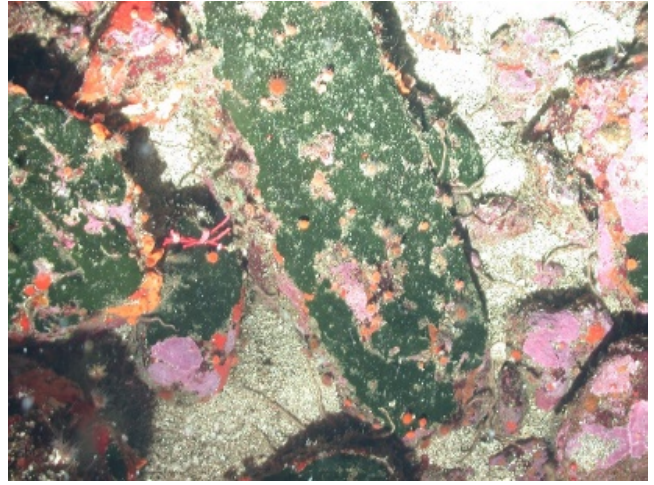
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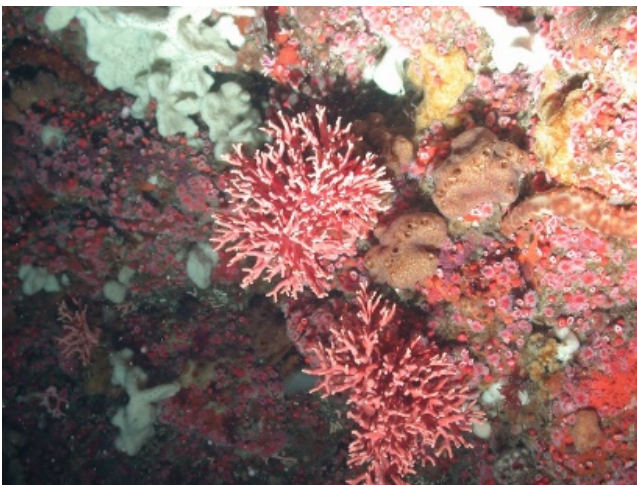
Image Gallery



a) Rock covered in unknown brown biological material and red gorgonian in lower left of image.



b) Unknown encrusting green organism and encrusting coralline algae on boulders.



c) Large *Stylaster* spp. heads on shallow rock with sponges and *Corynactis californica*.



d) Small *Stylaster* spp. heads on deeper rock and lower percent cover of invertebrates than in shallower areas.



e) Red and orange encrusting sponges, encrusting purple coralline algae and a few cup corals.



f) *Xestospongia edapha* ("Cordell sponge") and *Corynactis californica*.