Office of National Marine Sanctuaries
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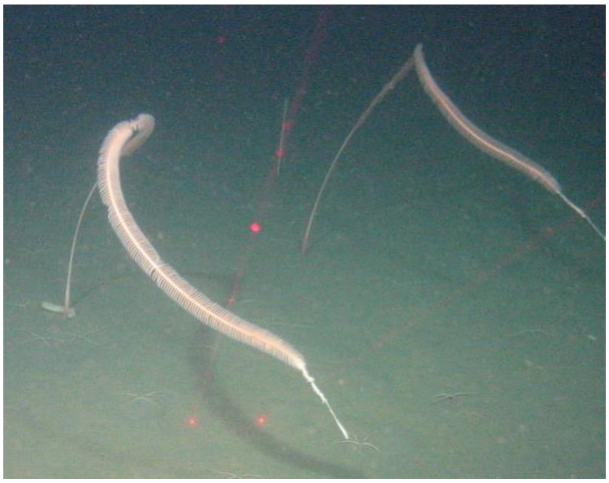
NATIONAL MARINE SANCTUARIES CONSERVATION SERIES

Characterization of Cordell Bank and Continental Shelf and Slope: 2021 ROV Surveys



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Cover photo (clockwise from top left): Upper reef crests of Cordell Bank provide habitat for a variety of colorful invertebrates; blackgill rockfish (*Sebastes melanostomus*) hiding under a rock ledge on the continental slope; *Swiftia sp*. gorgonian on the continental slope; *Halipteris californica* sea pens on the CBNMS continental shelf. Photos: NOAA

About the National Marine Sanctuaries Conservation Series

The Office of National Marine Sanctuaries, part of the National Oceanic and Atmospheric Administration, serves as the trustee for a system of underwater parks encompassing more than 620,000 square miles of ocean and Great Lakes waters. The 15 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our nation's maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage. Sites range in size from less than one square mile to almost 583,000 square miles. They serve as natural classrooms and cherished recreational spots, and are home to valuable commercial industries.

Because of considerable differences in settings, resources, and threats, each national marine sanctuary has a tailored management plan. Conservation, education, research, monitoring, and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The National Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary System. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific or historical research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and social sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate. All publications are available on the Office of National Marine Sanctuaries website.

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Abstract

Greater Farallones and Cordell Bank National Marine Sanctuaries coordinated a joint cruise to survey Cordell Bank National Marine Sanctuary, Greater Farallones National Marine Sanctuary, and northern Monterey Bay National Marine Sanctuary using a remotely operated vehicle in August 2021. This report summarizes the four remotely operated vehicle dives completed in Cordell Bank National Marine Sanctuary. The objectives of these dives were to survey soft sediment habitat on the shelf in areas expected to have varying trawl intensity, to explore a new area of the slope to characterize habitat, and to return to a previously surveyed area on Cordell Bank to monitor for changes. Data collected included visual imagery (stills and 6 hours of video); oceanographic metrics from a conductivity, temperature, and depth sensor; and navigational information. On the area of the slope that was explored, the majority of low-relief rock and mixed substrates were mud-draped, and few corals and sponges were observed. The flat rock with overhanging shelfs and bands of jagged rocks the size of cobbles provided excellent habitat for fish, particularly high abundances of blackgill rockfish (*Sebastes melanostomus*). On the shelf, all substrate was characterized as mud, and sea pens and flatfish were present in typical densities in both the trawled and non-trawled areas. Throughout the surveys on the shelf and slope, there were abundant dead pyrosomes on the seafloor that were predated on by brittle stars, sea stars, and urchins. At the North Point monitoring site on Cordell Bank, densities of indicator species such as hydrocoral (*Stylaster californicus*), strawberry anemone (*Corynactis californica*), and various sponges were similar to previous surveys (2017 and 2018). The extent of encrusting tunicates and size of rockfish at Cordell Bank were also assessed. Conducting remotely operated vehicle surveys helps expand understanding of the patterns in habitats and species diversity and richness to inform effective sanctuary research and management.

Key Words

California continental shelf and slope, Cordell Bank, deep-water benthic habitats, corals, sponges, rockfishes, national marine sanctuaries, remotely operated vehicle

Chapter 1:
Introduction and Cruise Objectives

Cordell Bank National Marine Sanctuary (CBNMS) and Greater Farallones National Marine Sanctuary (GFNMS) led an expedition aboard the National Oceanic and Atmospheric Administration (NOAA) research vessel *Fulmar* to explore and characterize benthic habitats in three national marine sanctuaries in August 2021. The team used Marine Applied Research and Exploration's remotely operated vehicle (ROV) *Beagle* to visually and systematically survey deep-water benthic habitats in CBNMS, GFNMS, and Monterey Bay National Marine Sanctuary. ROV survey days were divided between CBNMS and GFNMS. Both sites had similar study objectives of characterizing deep-sea habitats and communities (corals, sponges, groundfishes, etc.) to inform sanctuary management of living resources. Dives were completed in areas with various substrate types that were recently closed or reopened to commercial bottom trawling, areas in which survey data were historically collected for long term monitoring, and areas that had not been previously explored.

CBNMS is following a long-term benthic science plan to explore, characterize, and monitor benthic habitats (Lipski, 2016). Four dives were conducted in CBNMS. These dives had multiple science and management objectives:

1. For the first time, explore and characterize habitat in an area of the slope that was recently (January 1, 2020) designated as essential fish habitat (EFH) and closed to commercial bottom trawling;
2. Survey soft sediment habitat on the shelf in areas exposed to varying levels of bottom trawl effort;
3. Return to a previously surveyed area on Cordell Bank to monitor for long-term changes in biological communities.

Despite weather and equipment challenges, all of these objectives were met. Data collected included visual imagery (stills and video), navigation information from the ROV, and oceanographic data from the conductivity, temperature, and depth sensor (CTD). This project supports priorities of Office of National Marine Sanctuaries West Coast Region, as well other NOAA agencies, who also provided funding (e.g., Deep-sea Coral Research and Technology Program, National Oceanographic Partnership Program, and NOAA Ocean Exploration).

ROV Dive Sites and Video Analysis

Four dives were conducted in CBNMS from August 25–29, 2021 (Figure 1; Table 1) using the ROV *Beagle*. Five survey days were planned, but because of weather and operations issues, three survey days were completed. A total of six hours of digital video were recorded. At dive sites FOB01, 362, and Fixed Shelf 1, the planned dive lines were 1–2 km in length. Multiple quantitative transects approximately 150 m in length were conducted with an approximate distance of 100 to 150 m between each quantitative transect. At the repeated monitoring site on Cordell Bank, North Point, the ROV quantitatively surveyed the entire 1-km-long dive line. Following the cruise, the line was subset into quantitative transects for analysis that were each

10 minutes in duration with 10-minute elapsed time distance between each transect, following methods previously used in 2017 and 2018 (Graiff et al., 2019; Graiff & Lipski, 2020).

While on transect, the ROV pilot strived to maintain a consistent height and speed from the bottom, targeting about 1 m off the bottom and a speed of 0.5 to 1 kt. During the dive, the ROV's position was tracked using an ORE Trackpoint III ultra-short baseline acoustic positioning system, which provided bearing and range from the NOAA Ship *Fulmar* to the ROV. The quantitative transects were used to classify substrate (habitat type), identify species, and count 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, flat rock, boulder, cobble), mixed (hard substrata combined with mud or sand), and soft (mud or 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 a set of paired scaling lasers spaced 10 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. Animal densities are reported as number per square meter to be comparable to previous benthic characterization reports conducted in CBNMS in order to track changes over time. Marine debris was also identified and georeferenced. Environmental data were collected by a CTD sensor and dissolved oxygen sensor on the ROV during each dive. Although a manipulator arm and biobox were present on the ROV, because of operational constraints, no invertebrate specimens were collected.

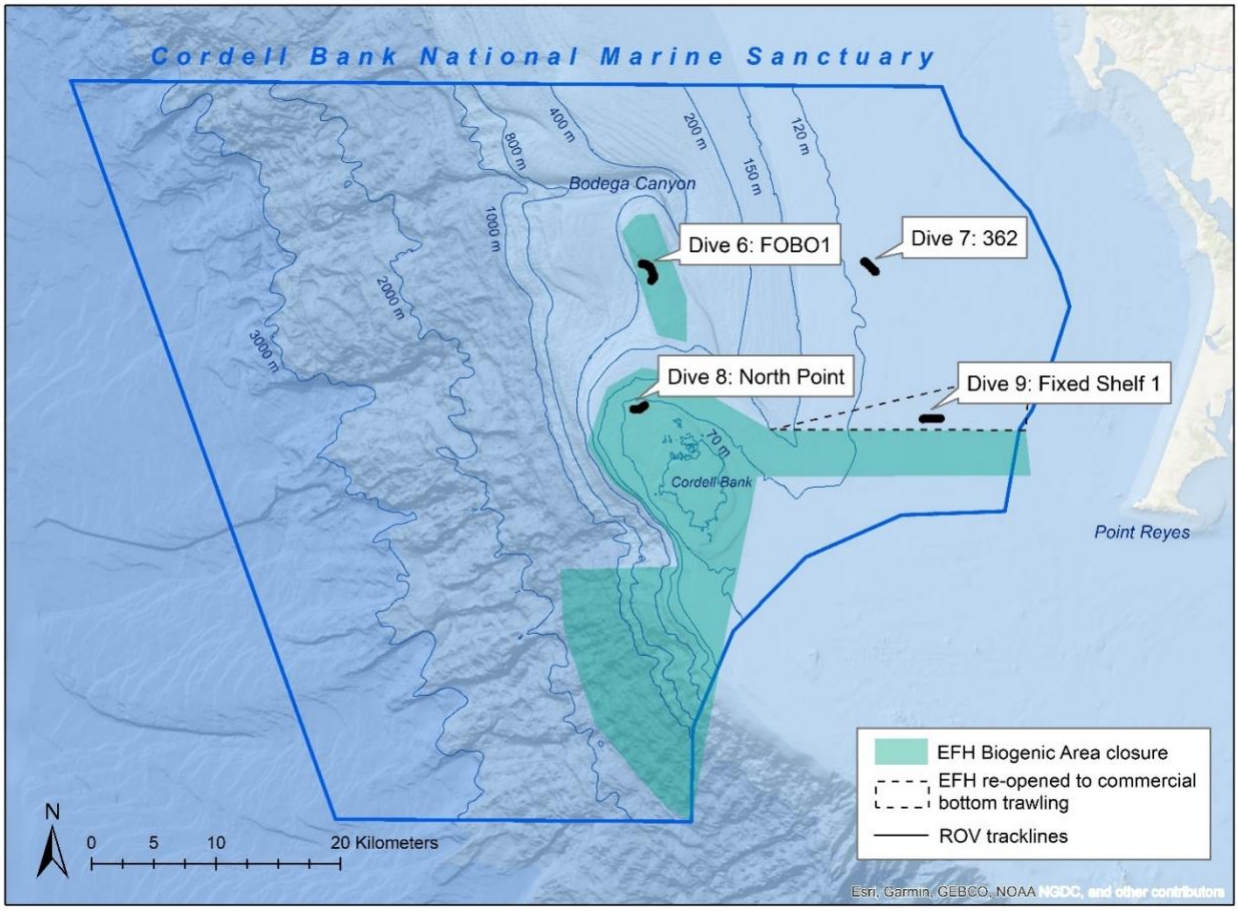


Figure 1. ROV dive numbers and names at survey sites in CBNMS showing boundaries of EFH closures and re-opened areas.

Table 1. Dive details for the four ROV dives displayed in Figure 1.

Date	Dive Number	Name/Location	Number of Quantitative Transects	Minimum Depth (m)	Maximum Depth (m)
8/25/2021	6	FOB01	7	311	369
8/25/2021	7	362	4	109	118
8/29/2021	8	North Point	4	56	81
8/30/2021	9	Fixed Shelf 1	5	105	110

Chapter 2:
Characterizing New Areas on the Slope

Using maps created from bathymetric and backscatter data collected during a mapping cruise on the NOAA ship *Okeanos Explorer* in 2009, an unexplored rock feature, "the gooseneck," was identified on the slope to the north of Cordell Bank and to the south of Bodega Canyon. This area was of interest for exploration because hard substrates and high slope are indicators of potentially suitable substrate for corals, sponges, and fish. Additionally, the feature is located within a newly established EFH area closed to the impacts of commercial bottom trawling. The new closure was designated on January 1, 2020 as part of the final rule of Amendment 28 (50 C.F.R. § 660). This report describes the first visual survey, and the data collected provide a baseline assessment of the condition of biological communities and substrates at this feature. The data also add to existing datasets to further develop an overall characterization of the CBNMS slope.

Data Summary for Dive Six: FOB01 (The Gooseneck)

Habitat

Seven transects were used to survey a total area of 2,138 m^2 at a depth of 322–364 meters on the continental slope at dive site FOB01 (Figure 2; Appendix A). The bottom type throughout this dive site was primarily mixed substrates consisting of rock and soft sediments. The majority of the rock substrates were categorized as low-relief consolidated flat rock or mixed loose rocks the size of cobbles. The low-relief flat rock was often covered with a mud veneer or was interspersed with patches of mud. The areas categorized as sediment were all mud bottom. The small area categorized as hard substrate on transect three was a high-relief rock wall that plateaued to flat rock. Other areas of high-relief rock observed on this dive were off-transect, and thus were not captured in the habitat analyses on the quantitative transects.

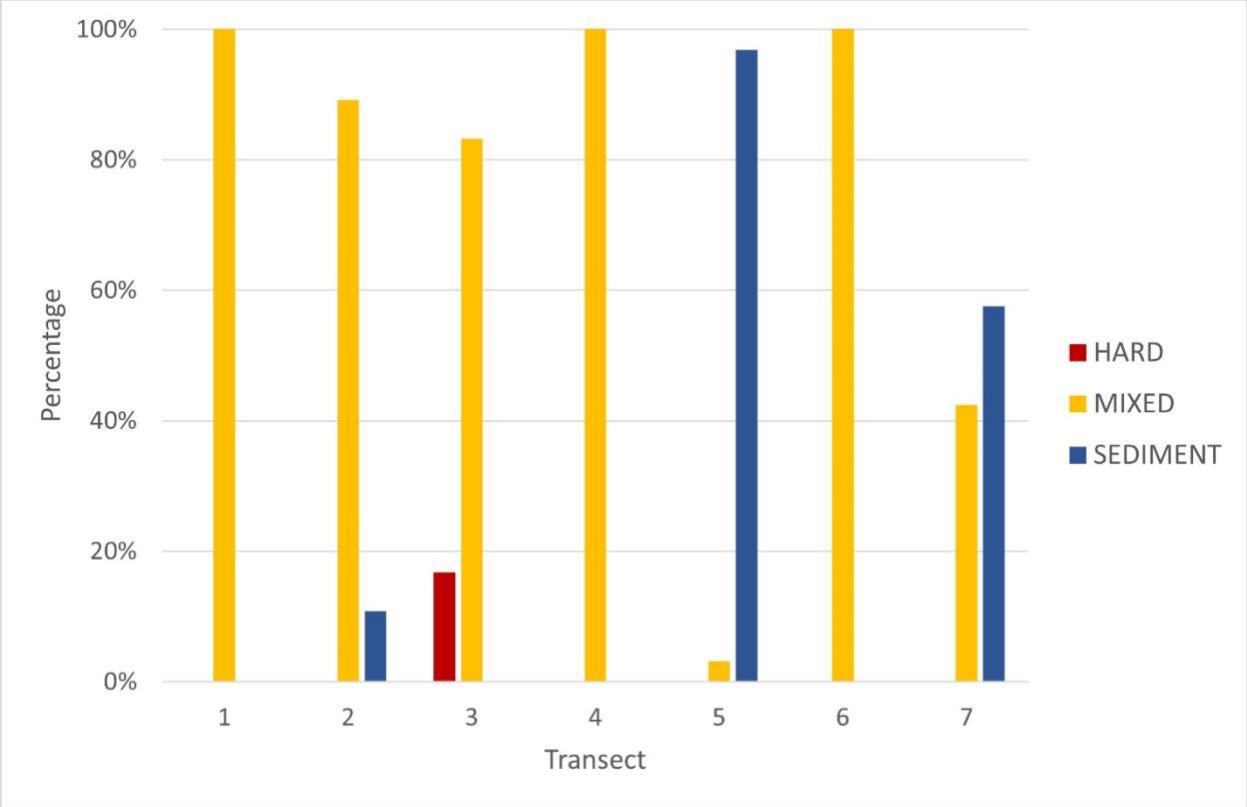


Figure 2. Percent of total habitat area surveyed per transect on dive 6 (FOB01), summarized into three habitat categories: hard, mixed, and sediment. The total area surveyed on the dive was 2,138 m^2.

Environmental Data

The CTD and oxygen sensors on the ROV collected measurements every second while on the bottom. The mean, minimum, and maximum data for dive 6 are listed in Table 2.

Table 2. Mean, minimum, and maximum CTD and oxygen instrument data collected on the bottom during dive 6.

Metric (Unit)	Average	Minimum	Maximum
Depth (m)	343	311	369
Temperature (°C)	8.3	7.7	8.9
Salinity (psu)	34.2	33.8	34.3
O_2 concentration (ml/L)	0.9	0.7	1.2
O_2 saturation (%)	13.5	10.6	18.8

Invertebrates

The mixed mud and rock habitats at FOB01 (where the rock was often covered in a mud veneer) had a low diversity and density of corals and sponges. Three coral species and at least six sponge species were observed (Table 3). Red, fan-shaped gorgonians in the genus *Swiftia* were most common among the corals (n = 12) at 25% of total corals and sponges, and were small in height (5–10 cm). A group of *Swiftia* was observed on one boulder. Other corals observed in low densities were the primnoid *Plumarella longispina* (n = 5) and the mushroom coral

Heteropolypus ritteri (*n* = 4). Off-transect, there was one observation of small, white corals grouped on a boulder. The thicker branches on some of the individuals looked similar to *Anthothela* sp. that were collected in 2019 on an Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS) cruise (M. Everett, personal communication, May 31, 2022). A sample should be collected if observed on future cruises.

There was slightly more diversity within the sponge group, but very low densities were recorded. The three most abundant sponges were shelf sponge *Poecillastra* spp. (*n* = 9), brown barrel sponge *Rhabdocalyptus dawsoni* (*n* = 7), and foliose-morphology sponges of unknown species (*n* = 6). The *R. dawsoni* barrel sponges reached a maximum height of 45 cm. Condition of corals and sponges was good. Brown material was observed on one *Swiftia* sp. colony; this was most likely amphipod tubes. All other individuals were healthy. A complete species list of other invertebrates observed at FOB01 is available in Appendix B.

A new and noteworthy observation from this dive was the high abundance of dead pyrosomes on the seafloor. Pyrosomes are free-floating, colonial tunicates that usually live in the upper layers of the open ocean. They have been collected in net tows on ACCESS pelagic monitoring cruises conducted jointly by CBNMS, GFNMS, and Point Blue Conservation Science. This was the first sighting of individuals and groups of pyrosomes laying on the bottom in CBNMS. The frequency of dead pyrosomes on the seafloor was qualitatively estimated on transect per minute. The highest count of approximately 20–30 pyrosomes in one minute was observed only once across all transects. Three of the one-minute segments had clusters of approximately 15–20 pyrosomes. Overall, the majority (70%) of the one-minute segments had 0–5 pyrosomes and the next most common range of pyrosomes observed per minute was ≥10 individuals. The distribution of dead pyrosomes along transects was random, often collecting around rock features or as single individuals spaced apart on open expanses of mud bottom. Invertebrates were observed preying on the dead pyrosomes, including large aggregations of the pink urchin *Strongylocentrotus fragilis* and two species of sea stars, *Stylasterias forreri* and *Rathbunaster californicus* (but at a lower frequency than the urchins).

Table 3. Coral and sponge taxa observed on dive 6, reported as total number, percent of total corals and sponges, density per square meter, and height range, and depth range.

Category	Scientific Name	Common Name	Count	Percent of Total	Density per m^2	Height Range (cm)	Depth Range (m)
Coral	*Heteropolypus ritteri*	Mushroom coral	4	8	0.002	10–15	331–353
Coral	*Plumarella longispina*	Primnoid	5	10	0.002	10–15	331–332
Coral	*Swiftia sp.*	Gorgonian	12	25	0.006	5–10	333–360
Sponge	*Mycale* sp.	Upright flat sponge (yellow)	1	2	0.0005	10	345
Sponge	*Poecillastra* spp.	Fringed shelf sponge	9	19	0.004	5–10	358–362
Sponge	*Polymastia* spp. #1	White nipple foliose sponge	1	2	0.0005	10	338
Sponge	*Rhabdocalyptus dawsoni*	Brown barrel sponge	7	15	0.003	15–45	330–349

Category	Scientific Name	Common Name	Count	Percent of Total	Density per m^2	Height Range (cm)	Depth Range (m)
Sponge	Unknown	Unknown foliose sponges	6	13	0.003	5	362–364
Sponge	Unknown	Unknown mound sponges	3	6	0.001	5–10	332–364

Fish

Fish observed at FOB01 were more diverse than corals and sponges. The greatest densities were observed among rockfish, particularly blackgill rockfish (*Sebastes melanostomus*) and rosethorn rockfish (*Sebastes helvomaculatus*). More than half (n = 34) of the blackgill rockfish were large in size, measuring 35–45 cm in body length, and preferred habitats made up of flat rock, often hiding under the small ledges or at the edge of the rock-mud transition. Three species of flatfish and three species of skates were observed. A high abundance of hagfish (*Eptatretus* spp.) was also observed (Table 4). Additionally, a very large isopod latched onto the back of a longnose skate (*Raja rhina*) was observed. Isopods and other crustaceans commonly latch onto the claspers or cloaca and sometimes the pelvic fins of sharks and rays; this one in particular was very large (J. Bizzarro, personal communication, September 1, 2021).

Table 4. Fish taxa observed on dive 6 reported as total number, percent of total fish, density per square meter, size class range (cm) and depth ranges (m).

Group	Family	Scientific Name	Common Name	Count	% of Total	Density per m^2	Size Class Range (cm)	Depth Range (m)
Flatfish	Pleuronectidae	*Lyopsetta exilis*	Slender sole	2	0.6	0.0009	20	324–353
Flatfish	Pleuronectidae	*Microstomus pacificus*	Dover sole	27	8	0.01	15–35	324–362
Flatfish	Pleuronectidae	*Parophrys vetulus*	English sole	1	0.3	0.0005	30	323
Flatfish	Pleuronectidae	Unknown Pleuronectidae	Unidentified flatfishes	1	0.3	0.0005	20	324
Skate	Rajidae	*Bathyraja interrupta*	Sandpaper skate	1	0.3	0.0005	50	358
Skate	Rajidae	*Raja inornata*	California skate	1	0.3	0.0005	50	323
Skate	Rajidae	*Raja rhina*	Longnose skate	4	1	0.002	50–70	323–360
Rockfish	Scorpaenidae	*Sebastes aurora*	Aurora rockfish	5	1	0.002	20–25	329–339
Rockfish	Scorpaenidae	*Sebastes babcocki*	Redbanded rockfish	5	1	0.002	20–25	332–360
Rockfish	Scorpaenidae	*Sebastes diploproa*	Splitnose rockfish	18	5	0.008	15–25	323–354

Group	Family	Scientific Name	Common Name	Count	% of Total	Density per m^2	Size Class Range (cm)	Depth Range (m)
Rockfish	Scorpaenidae	*Sebastes helvomaculatus*	Rosethorn rockfish	49	15	0.02	15–30	324–361
Rockfish	Scorpaenidae	*Sebastes melanostomus*	Blackgill rockfish	54	16	0.03	25–45	330–363
Rockfish	Scorpaenidae	*Sebastes saxicola*	Stripetail rockfish	2	0.6	0.0009	15–20	331–337
Rockfish	Scorpaenidae	*Sebastes* spp. (sebastomus subgenus)	Unidentified Sebastomus	24	7	0.01	10–25	324–361
Rockfish	Scorpaenidae	*Sebastes* spp.	Unidentified rockfishes	16	5	0.007	15–30	324–357
Rockfish	Scorpaenidae	*Sebastolobus alascanus*	Shortspine thornyhead	2	0.6	0.0009	30	333–334
Rockfish	Scorpaenidae	*Sebastolobus altivelis*	Longspine thornyhead	1	0.3	0.0005	5	338
Rockfish	Scorpaenidae	*Sebastolobus* spp.	Unidentified thornyheads	31	9	0.01	10–25	323–362
Eelpout	Zoarcidae	*Lycodes cortezianus*	Bigfin eelpout	7	2	0.003	30–40	331–355
Other	Agonidae	Agonidae	Unidentifed poacher	29	9	0.01	15–25	323–358
Other	Anoplopomatidae	*Anoplopoma fimbria*	Sablefish	1	0.3	0.0005	45	339
Other	Chimaeridae	*Hydrolagus colliei*	Spotted ratfish	8	2	0.004	30–45	331–360
Other	Cottidae	*Icelinus filamentosus*	Threadfin sculpin	3	0.9	0.001	20	338–357
Other	Cottidae	*Icelinus* spp.	Unidentified Icelinus sculpins	7	2	0.003	15–20	333–357
Other	Merlucciidae	*Merluccius productus*	Pacific hake	2	0.6	0.0009	40–45	323–352
Other	Myxinidae	*Eptatretus* spp.	Unidentified hagfish	33	10	0.02	25–40	323–361

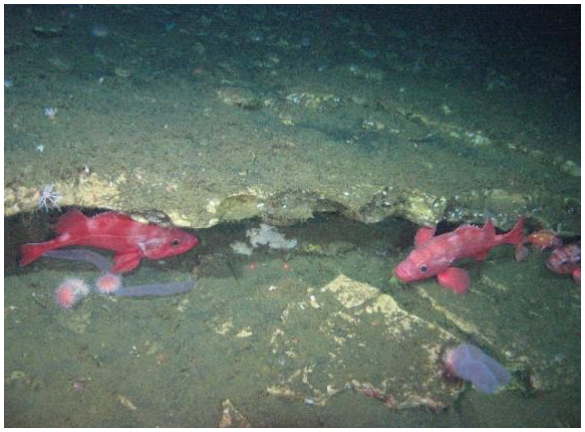
Marine Debris and Anthropogenic Observations

There were no observations of derelict fishing gear or other marine debris on this dive.

Image Gallery: Dive Six

Aggregations of the pink urchin *Strongylocentrotus fragilis* feeding on dead pyrosomes. Photo: NOAA

Rathbunaster californicus sun stars feeding on dead pyrosomes. Photo: NOAA



Large blackgill rockfish (*Sebastes melanostomus*) were often seen under or near rock ledges created by flat rock. Photo: NOAA

Large isopod (circled in red) latched onto the back of a longnose skate, *Raja rhina.* Photo: NOAA

Chapter 3:
Assessing Soft Sediment Habitat on the Shelf in Areas with Varying Trawl Intensity

The continental shelf within CBNMS is primarily low-relief mud and sand sediments from 70–200 meters. The shelf makes up 356 square miles (or approximately 28%) of the sanctuary's seafloor. Previous surveys on the shelf (2004 and 2007) were conducted using a towed camera sled, however the majority of the sanctuary's shelf has not been visually surveyed using quantitative methods. 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, 2016). The monitoring plan's survey design includes stratified random transects as well as fixed sites that had been historically sampled and will be repeatedly sampled into the future for comparison among years.

Both a random site and fixed site on the shelf were surveyed on this cruise. Line 362 was randomly selected from the benthic monitoring plan's map grid and is within an area that has higher seafloor contact (effort) by bottom trawl gear compared to other areas of the CBNMS slope and shelf. Commercial trawling data from federal groundfish fisheries operating within the boundaries of CBNMS, analyzed by NOAA's California Current Integrated Ecosystem Assessment Team based on analytical approaches used in their report (Harvey et al., 2021), show that trawling mainly occurs on the CBNMS shelf and soft upper slope habitats. Bottom trawl contact has decreased from 2009–2019 in most areas of CBNMS, with the exception of a band of 2 x 2-km grid cells stretching north-south along the sanctuary's eastern boundary, where line 362 is located. There have been no previous visual surveys in this area.

The fixed site surveyed on this cruise is referred to as shelf 1 and is located within a section of the Cordell Bank/Biogenic Area EFH that was reopened to commercial bottom trawling on January 1, 2020. The Pacific Fisheries Management Council completed a review and determined that new information from a multi-year public process justified developing modifications to groundfish EFH as part of Amendment 28. The ROV survey described here was the first quantitative survey of shelf 1 and provides visual data for this site 20 months after the final ruling on Amendment 28 went into effect, opening the area to commercial bottom trawling.

For both line 362 and shelf 1, particular interest was given to enumerating corals, as they are long-lived, slow-growing species that are vulnerable to impacts from bottom trawling. Fish species were also enumerated.

Data Summary for Dive Seven: Line 362

Habitat

A total area of 1,038 m^2 was surveyed on the continental shelf from 115–118 meters at dive site 362 (Figure 3; Appendix A). The four transects were 100% mud bottom.

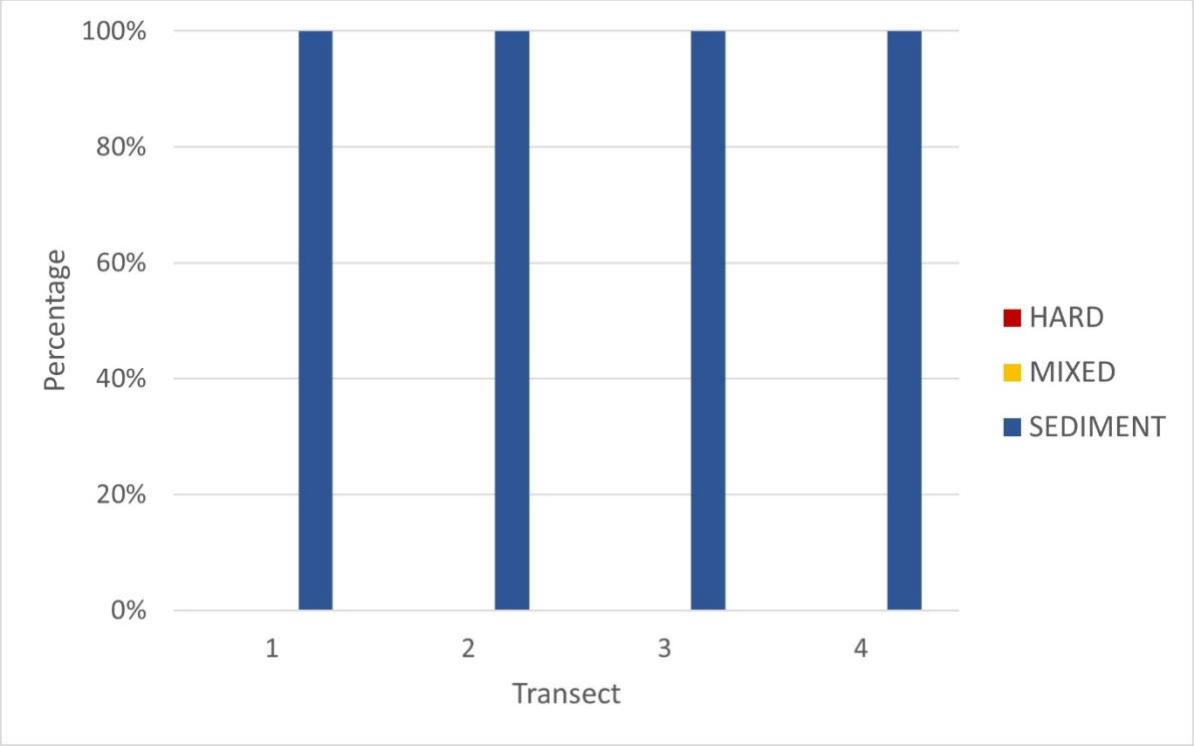


Figure 3. Percent of total habitat area surveyed per transect on dive 7 (line 362). All transects were 100% soft sediment. The total area surveyed during the dive was 1,038 m^2.

Environmental Data

The CTD and oxygen sensors on the ROV collected measurements every second while on bottom. The mean, minimum, and maximum data for dive 7 are listed in Table 5.

Table 5. Mean, minimum, and maximum CTD and oxygen instrument data collected on the bottom during dive 7.

Metric (Unit)	Average	Minimum	Maximum
Depth (m)	116	109	118
Temperature (°C)	9.9	9.9	9.9
Salinity (psu)	34.0	34.0	34.0
O_2 concentration (ml/L)	1.8	1.8	1.9
O_2 saturation (%)	28.6	28.1	29.2

Invertebrates

The only corals observed were sea pens, *Halipteris californica*, at a density of nearly one sea pen per square meter (Table 6). The sea pens were often very tall, reaching a maximum height of 140 cm. Sea pen condition was recorded, and 39 individuals (or 4.5% of total sea pens) were not upright and in dead or dying condition due to unknown reasons. A complete species list of other invertebrates observed at site 362 is available in Appendix B.

Dead pyrosomes were observed on the seafloor and were evenly distributed along all transects at a frequency of approximately <10 or 10–15 individuals per minute. The pyrosomes often

collected and wrapped around the base of sea pens. At the end of the dive, a large number of pyrosomes collected in a trough-shaped depression in the mud and were being eaten by Ophiurina brittle stars.

Table 6. Coral taxa observed on dive 7 reported as total number, percent of total corals and sponges, density per square meter, height range (cm), and depth range (m).

Scientific Name	Common Name	Count	Percent of Total	Density per m^2	Height Range (cm)	Depth Range (m)
Halipteris californica	Sea pens	858	100	0.8	5–140	116–118

Fish

Fish observed on transects were more diverse than invertebrates and were primarily flatfish species, as expected on soft substrate at this depth (Table 7). Sanddabs (*Citharichthys* spp.) were the most abundant taxon, accounting for 52% of total fish. Unidentified flatfish (21% of total fish observed) were often buried in the mud, making identification difficult. Only two species of rockfish were observed: stripetail rockfish (*Sebastes Saxicola*; $n = 15$) and halfbanded rockfish (*Sebastes semicinctus*; $n = 1$).

Table 7. Fish taxa observed on dive 7 reported as total number, percent of total fish, density per square meter, size class range (cm), and depth range (m).

Group	Family	Scientific Name	Common Name	Count	% of Total	Density per m^2	Size Class Range (cm)	Depth Range (m)
Flatfish	Paralichthyidae	*Citharichthys* spp.	Unidentified sanddab	106	52	0.1	10–20	116–118
Flatfish	Pleuronectidae	*Glytocephalus zachirus*	Rex sole	4	2	0.004	20	116
Flatfish	Pleuronectidae	*Lyopsetta exilis*	Slender sole	23	11	0.02	10–20	116–118
Flatfish	Pleuronectidae	*Microstomus pacificus*	Dover sole	2	1	0.002	20–25	116
Flatfish	Pleuronectidae	Unknown Pleuronectidae	Unidentified flatfishes	42	21	0.04	5–25	116–118
Skate	Rajidae	*Raja rhina*	Longnose skate	1	0.5	0.001	50	116
Rockfish	Scorpaenidae	*Sebastes saxicola*	Stripetail rockfish	15	7	0.01	15–20	117
Rockfish	Scorpaenidae	*Sebastes semicinctus*	Halfbanded rockfish	1	0.5	0.001	15	117
Other	Agonidae	Agonidae	Unidentified poachers	4	2	0.004	15–20	117–118
Other	Cottidae	Cottidae	Unidentified sculpin	3	1	0.003	10	116
Other	Cottidae	*Radulinus asprellus*	Slim sculpin	2	1	0.002	15	117–118
Other	Hexagrammidae	*Zaniolepis* spp.	Unidentified combfishes	1	0.5	0.001	15	116

Marine Debris and Anthropogenic Observations

There were no observations of derelict fishing gear or other marine debris. One anthropogenic depression in the mud, shaped like a trough with rounded edges, was observed at the end of the dive. The mark was short in length and had a larger depression in the middle of two crossing straight marks, where dead pyrosomes collected. This is not the typical configuration of a naturally formed wave in soft sediment. It is possible that the depression was created by deploying and/or dragging during recovery of a crab pot or bottom-contact trawl net, which are fishing activities allowed in this area. The rounded sides of the trough could be indicative that the marks were older and had been smoothed by water movement. Tall and healthy sea pens were observed near the end of the mark, and there were no observations of sea pens knocked over in or near the mark.

Data Summary for Dive Nine: Fixed Shelf 1

Habitat

A total area of 1,202 m² was surveyed using five transects on the continental shelf from 106–110 meters at dive site shelf 1 (Figure 4; Appendix A). The seafloor habitat was 100% mud bottom.

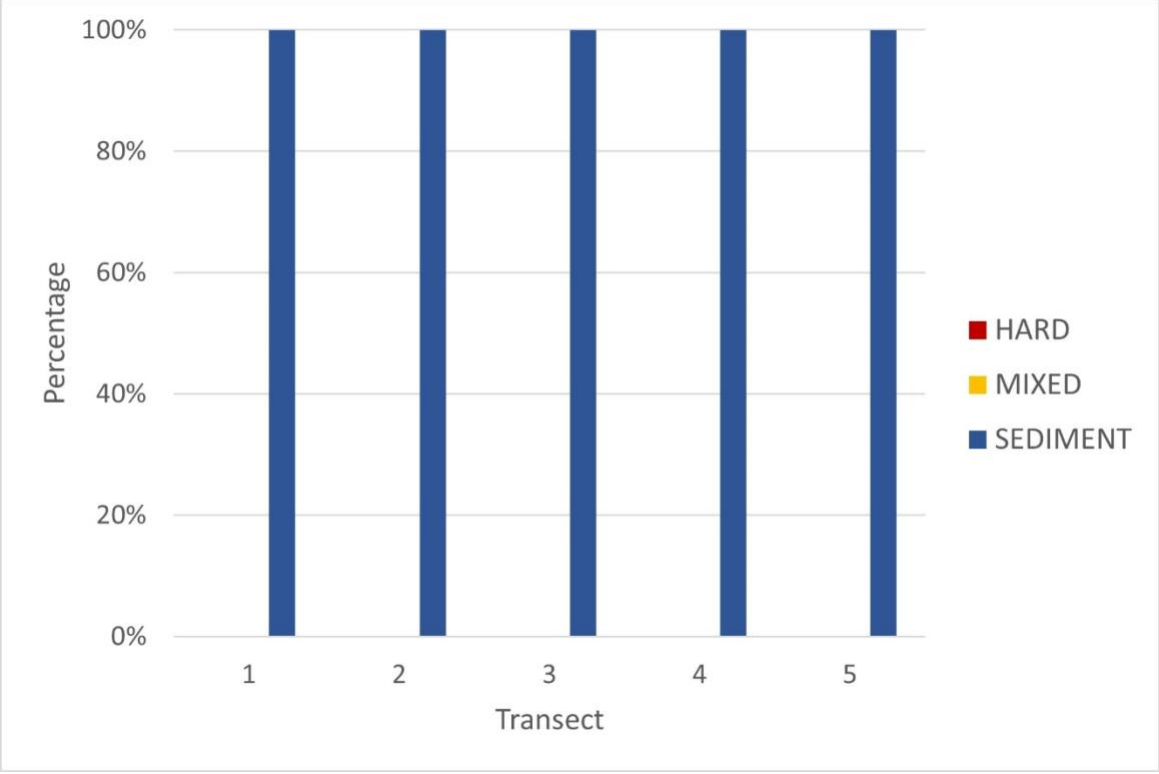


Figure 4. Percent of total habitat area surveyed per transect on dive 9 (fixed shelf 1). All transects were 100% soft sediment. The total area surveyed was 1,202 m^2.

Environmental Data

The CTD and oxygen sensors on the ROV collected measurements every second while on the bottom. The mean, minimum, and maximum data for dive 9 are listed in table 8.

Table 8. Mean, minimum, and maximum CTD and oxygen instrument data collected on the bottom during dive 9.

Metric (Unit)	Average	Minimum	Maximum
Depth (m)	108	105	110
Temperature (°C)	10.0	9.9	10.0
Salinity (psu)	33.9	33.9	33.9
O_2 concentration (ml/L)	2.0	1.8	2.1
O_2 saturation (%)	31.8	27.6	32.8

Invertebrates

The only corals observed were sea pens, *Halipteris californica*, at a density of nearly one sea pen per square meter (Table 9). The condition of sea pens was recorded, and 97 individuals (or approximately 11% of total sea pens) were not upright and in dead or dying condition due to unknown reasons. Three of these dislodged and dead sea pens were near trough marks in the mud. A complete species list of other invertebrates observed at shelf 1 is available in Appendix B.

Dead pyrosomes were present at this dive site, but in lower abundance than that observed at shelf site 362. Approximately ≤5 dead pyrosomes were counted per minute throughout all transects.

Table 9. Coral taxa observed on dive 9 reported as total number, percent of total corals and sponges, density per square meter, height range (cm), and depth range (m).

Scientific Name	Common Name	Count	Percent of Total	Density per m2	Height Range (cm)	Depth Range (m)
Halipteris californica	Sea pens	913	100	0.8	5–110	106–110

Fish

Fish taxa observed on transects were diverse, and flatfish were observed in the greatest densities. Sanddabs (*Citharichthys* spp.) were the most abundant taxon (44% of total fish). Other flatfish observed included petrale sole (*Eopsetta jordani*; n = 2), rex sole (*Glytocephalus zachirus*; n = 15), and a relatively high abundance of slender sole (*Lyopsetta exilis*; n = 60). Unidentified flatfish (27% of total fish observed) were often buried in the mud, making identification difficult. Other fish taxa observed include eelpouts, sablefish, sculpins, combfish, and hagfish (Table 10).

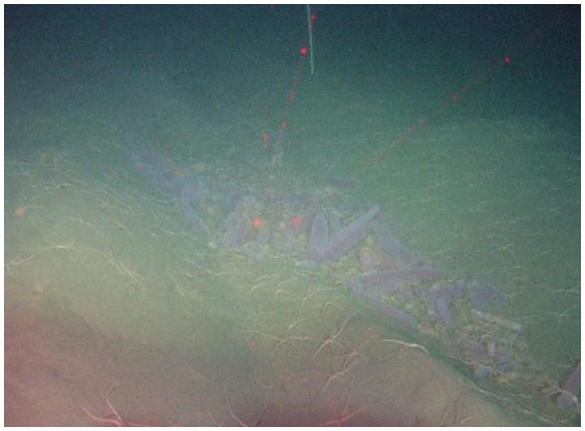
Table 10. Fish taxa observed on dive 9 reported as total number, percent of total fish, density per square meter, size class range (cm), and depth range (m).

Group	Family	Scientific Name	Common Name	Count	Percent of Total	Density per m^2	Size Class Range (cm)	Depth Range (m)
Flatfish	Paralichthyidae	*Citharichthys* spp.	Unidentified sanddab	192	44	0.2	10–20	106–110
Flatfish	Pleuronectidae	*Eopsetta jordani*	Petrale sole	2	0.5	0.002	30	107
Flatfish	Pleuronectidae	*Glytocephalus zachirus*	Rex sole	15	3	0.01	20–25	106–110
Flatfish	Pleuronectidae	*Lyopsetta exilis*	Slender sole	60	14	0.05	10–20	106–110
Flatfish	Pleuronectidae	Pleuronectidae	Unidentified flatfishes	117	27	0.1	5–20	106–110
Rockfish	Scorpaenidae	*Sebastes saxicola*	Stripetail rockfish	5	1	0.004	15	107–110
Eelpout	Zoarcidae	*Lycodes cortezianus*	Bigfin eelpout	15	3	0.01	15–25	106–110
Eelpout	Zoarcidae	Zoarcidae	Unidentified eelpout	1	0.2	0.001	15	110
Other	Agonidae	Agonidae	Unidentified poachers	3	0.7	0.002	15–20	110
Other	Anoplopomatidae	*Anoplopoma fimbria*	Sablefish	1	0.2	0.001	40	107
Other	Cottidae	Cottidae	Unidentified sculpin	4	0.9	0.003	10–15	107–108
Other	Hexagrammidae	*Zaniolepis latipinnis*	Longspine combfish	14	3	0.01	15–20	106–110
Other	Hexagrammidae	*Zaniolepis* spp.	Unidentified combfishes	9	2	0.007	15–20	107–110
Other	Myxinidae	*Eptatretus* spp.	Unidentified hagfish	2	0.5	0.002	25–30	107–108

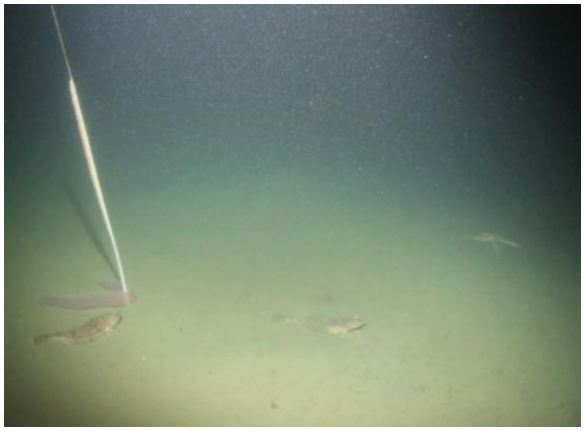
Marine Debris and Anthropogenic Observations

Multiple (n = 12) track marks or troughs in the mud were observed throughout this dive. The characteristics of the marks varied, but they all appeared to be created by anthropogenic forces and were not sediment waves made by subsurface currents or animals. Seven of the marks were shallow troughs with rounded top edges, and the marks were often curved versus straight in direction and were not very long. A start and end point were visible in the video frame. Healthy and upright sea pens were often observed near these marks. It's possible that these marks were created by the deployment or retrieval of crab pots. Conversely, two other marks were deep and wide troughs that were straight in length. There was evidence of significant scour in the mud next to these troughs, and nearby sea pens were knocked over. Something heavy was dragged through the mud at these locations, and it is possible, although not confirmed, that the marks were created by bottom trawl gear. This area was opened to bottom trawling on January 1, 2020.

Image Gallery: Dives Seven and Nine



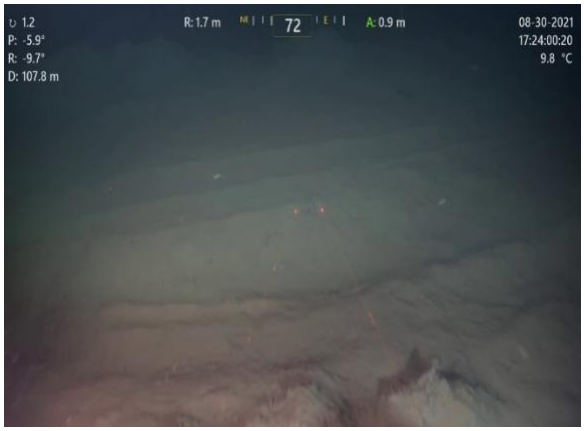
A large number of dead pyrosomes, collected in a trough-shaped depression on line 362, were being eaten by Ophiurina brittle stars. Photo: NOAA



Flatfish and sea pens were the dominant taxa observed at shelf sites. Dead pyrosomes often collected at the base of sea pens. Photo: NOAA

An anthropogenic mark (theorized to be from a crab pot) in the mud, with dead pyrosomes and a dislodged sea pen at shelf 1. Photo: NOAA

An anthropogenic mark (theorized to be from a crab pot) in the mud at shelf 1. Photo: NOAA



Multiple drag marks (theorized to be from bottom trawl and roller gear) in the mud at shelf 1. Photo: NOAA

Scour mark at shelf 1 from something heavy being dragged through the mud. Photo: NOAA

Chapter 4:
Long-term Monitoring on Cordell Bank

The site North Point on Cordell Bank was established as a long-term monitoring site in 2016 when 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, 2016). As a fixed site, North Point will be repeatedly surveyed into the future for comparison among years. Conducting quantitative transects in the same area over the long term (decades) enables identification of changes in coral and sponge health, counts of young-of year rockfish, and detection of invasive species. North Point was quantitatively surveyed by an ROV in 2017 and 2018. This 2021 survey adds to the invertebrate and fish datasets previously collected at this site to monitor patterns or changes in the benthic communities over time.

Data Summary for Dive Eight: North Point

Habitat

A total area of 1,422 m² was surveyed using four transects on Cordell Bank from 55–80 meters at dive site North Point (Figure 5; Appendix A). The primary substrate sampled at North Point was high-relief hard rock and boulders, accounting for 52–100% of the total area for each of the four transects. The mixed habitats included rock ridge or boulders with sand. The soft sediment habitats observed on transect two were small areas of flat sand between areas of rock that are characteristic of this depth and location on Cordell Bank.

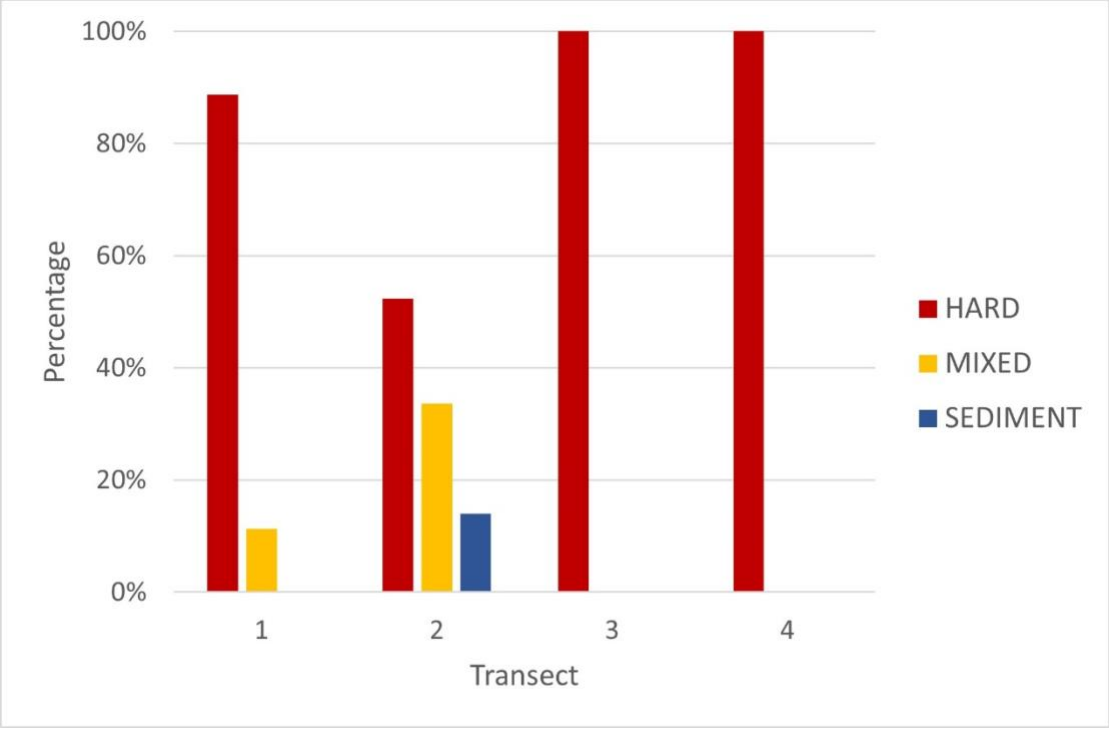


Figure 5. Percent of total habitat area surveyed per transect on dive 8 (North Point), summarized into three habitat categories: hard, mixed, and sediment. The total area surveyed was 1,422 m^2.

Environmental Data

The CTD and oxygen sensors on the ROV collected measurements every second while on the bottom. The mean, minimum, and maximum data for dive 8 are listed in Table 11.

Table 11. Mean, minimum, and maximum CTD and oxygen instrument data collected on the bottom during dive 8.

Metric (Unit)	Average	Minimum	Maximum
Depth (m)	70	56	81
Temperature (°C)	10.1	10.0	10.2
Salinity (psu)	33.9	33.9	33.9
O_2 concentration (ml/L)	2.2	2.1	2.3
O_2 saturation (%)	34.1	33.1	36.5

Invertebrates

The dominant coral at North Point was the hydrocoral *Stylaster californicus*, with a density of two individuals per square meter (Table 12). The health of *S. californicus* was very good; two individuals were <50% dead, three individuals were 70–80% dead, and two individuals were completely dead and had fallen to the seafloor from the upper reefs. No *Chromoplexaura marki* or *C. cordellbankensis* gorgonian corals were observed during the 2021 survey of North Point. This may be a result of the location of the 2021 transects, which were in smaller areas within the preferred deeper depth range of these species. *Chromoplexaura* gorgonians were observed between 68–83 meters at North Point in 2018 (Graiff & Lipski, 2020).

The most dominant sponge was "Cordell sponge" (*Xestospongia edapha*), with a density of three individuals per square meter. Unidentified mound sponges were the second most abundant type of sponge observed (two per m^2). At least eight other taxa of sponges were observed at North Point, all of which are species or morphological types historically observed on Cordell Bank (Table 12). A complete species list of other invertebrates observed at North Point is available in Appendix B.

There is interest in monitoring a species of gray encrusting tunicate in the family Didemnidae. This tunicate was first observed on Cordell Bank as early as 2002 and was quantified in 2017 and 2018 (Graiff et al., 2019; Graiff & Lipski, 2020). It has also been observed and collected in Greater Farallones and Monterey Bay national marine sanctuaries. The number of observations recorded during the 2021 survey at North Point was much higher than documented in 2017 and 2018. In 2021, a total of 967 individuals (0.7 per m^2; Table 12) were documented, compared to 42 in 2017 (0.04 per m^2; Graiff et al., 2019) and 35 in 2018 (0.03 per m^2; Graiff & Lipski, 2020).

At this time, there is no direct evidence that this tunicate is an invasive species, and it does not appear to be outcompeting other benthic invertebrates on the bank. CBNMS will continue to monitor the abundance and distribution of this encrusting tunicate. Monitoring for the colonial tunicate *Didemnum vexillum* is also a priority for CBNMS management, 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).

Table 12. Coral and sponge taxa observed on dive 8 reported as total number, percent of total corals and sponges, density per square meter, height range (cm), and depth range (m).

Category	Scientific Name	Common Name	Count	Percent of Total	Density per m^2	Height Range (cm)	Depth Range (m)
Coral	*Coenocyathus bowersi*	Cup coral	26	0.2	0.02	5–10	63–73
Coral	*Stylaster californicus*	California lace coral	3234	29	2	5–20	55–78
Sponge	*Mycale* spp.	Upright flat sponge (yellow)	102	1	0.07	5–25	55–79
Sponge	*Poecillastra* spp.	Fringed shelf sponge	1	0.01	0.001	10	71
Sponge	*Stelletta clarella*	Black edge sponge	71	0.6	0.05	5–15	63–79
Sponge	*Xestospongia edapha*	Cordell sponge	3776	34	3	5–25	55–79
Sponge	Unknown	Unknown Barrel sponges	62	0.6	0.04	5–50	57–79
Sponge	Unknown	Unknown Branching sponges	5	0.04	0.004	5	76
Sponge	Unknown	Unknown Foliose sponges	30	0.3	0.02	5–15	55–77
Sponge	Unknown	Unknown Leathery shelf sponges	694	6	0.5	5–15	56–79
Sponge	Unknown	Unknown Mound sponges	2243	20	2	5–10	55–79
Sponge	Unknown	Unknown Shelf sponges	5	0.04	0.004	10–15	73–77
Other	Didemnidae	Gray tunicate	967	9	0.7	5–15	57–79

Fish

A high diversity of fish was documented at North Point. At least 13 species of rockfish were observed; juvenile or young-of-year rockfish (*Sebastes* spp.) were the most abundant, at a density of one individual per square meter. Pygmy rockfish (*Sebastes wilsoni*) represented 16% of total fish observed, and squarespot rockfish (*Sebastes hopkinsi*) represented 12% of total fish observed. Other rockfish species that had similar densities include rosy rockfish (*Sebastes rosaceus*), widow rockfish (*Sebastes entomelas*), and yellowtail rockfish (*Sebastes flavidus*; Table 13). An uncommon sighting for Cordell Bank was a tiger rockfish (*Sebastes nigrocinctus*) and a wolf eel (*Anarrhichthys ocellatus*) hiding near each other in a boulder pile.

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. Fewer juvenile

yelloweye rockfish and more larger and older individuals were observed during the 2021 survey compared to 2017 and 2018 (Figure 6). Only one individual was equal to or less than 10 cm in length (juvenile); two individuals were 15–25 cm in length and the majority (n = 19) were 30–55 cm in length (adults). Yelloweye rockfish in northern and central California become sexually mature around 40 cm fork length (appoximately 20 to 22 years of age). Growth slows considerably at age 30, making generalizations about age at length difficult (Love et al., 2002).

Table 13. Fish taxa observed on dive 8 reported as total number, percent of total fish, density per square meter, size class range (cm), and depth range (m).

Group	Family	Scientific Name	Common Name	Count	% of Total	Density per m^2	Size Class Range (cm)	Depth Range (m)
Rockfish	Scorpaenidae	*Sebastes entomelas*	Widow rockfish	246	8	0.2	25–35	61–77
Rockfish	Scorpaenidae	*Sebastes flavidus*	Yellowtail rockfish	184	6	0.1	30–35	55–79
Rockfish	Scorpaenidae	*Sebastes hopkinsi*	Squarespot rockfish	368	12	0.3	10–20	55–79
Rockfish	Scorpaenidae	*Sebastes maliger*	Quillback rockfish	8	0.3	0.006	30–35	57–73
Rockfish	Scorpaenidae	*Sebastes nigrocinctus*	Tiger rockfish	1	0.03	0.001	30	75
Rockfish	Scorpaenidae	*Sebastes paucispinis*	Bocaccio	1	0.03	0.001	35	68
Rockfish	Scorpaenidae	*Sebastes pinniger*	Canary rockfish	4	0.1	0.003	30–45	57–76
Rockfish	Scorpaenidae	*Sebastes rosaceus*	Rosy rockfish	242	8	0.2	15–30	55–79
Rockfish	Scorpaenidae	*Sebastes rosenblatti*	Greenblotched rockfish	2	0.07	0.001	30	70
Rockfish	Scorpaenidae	*Sebastes ruberrimus*	Yelloweye rockfish	22	1	0.02	10–55	56–79
Rockfish	Scorpaenidae	*Sebastes wilsoni*	Pygmy rockfish	475	16	0.3	10–15	65–80
Rockfish	Scorpaenidae	*Sebastes* spp. (Sebastomus subgenus)	Unknown Sebastomus	3	0.1	0.002	10–15	66–73
Rockfish	Scorpaenidae	*Sebastes* spp.	Unidentified rockfishes	1	0.03	0.001	20	71
Rockfish	Scorpaenidae	*Sebastes* spp. young-of-year	Juvenile rockfish	1369	45	1	5–10	55–79
Greenlings	Hexagrammidae	*Hexagrammos decagrammus*	Kelp greenling	1	0.03	0.001	30	73
Greenlings	Hexagrammidae	*Ophiodon elongatus*	Lingcod	4	0.1	0.003	40–50	55–75
Greenlings	Hexagrammidae	*Oxylebius pictus*	Painted greenling	11	0.4	0.008	10–15	57–77
Other	Anarhichadidae	*Anarrhichthys ocellatus*	Wolf-eel	1	0.03	0.001	50	75
Other	Bathymasteridae	*Rathbunella* spp.	Unidentified ronquil	1	0.03	0.001	20	73

Group	Family	Scientific Name	Common Name	Count	% of Total	Density per m^2	Size Class Range (cm)	Depth Range (m)
Other	Gobiidae	*Rhinogobiops nicholsii*	Blackeye goby	68	2	0.05	10–15	55–80

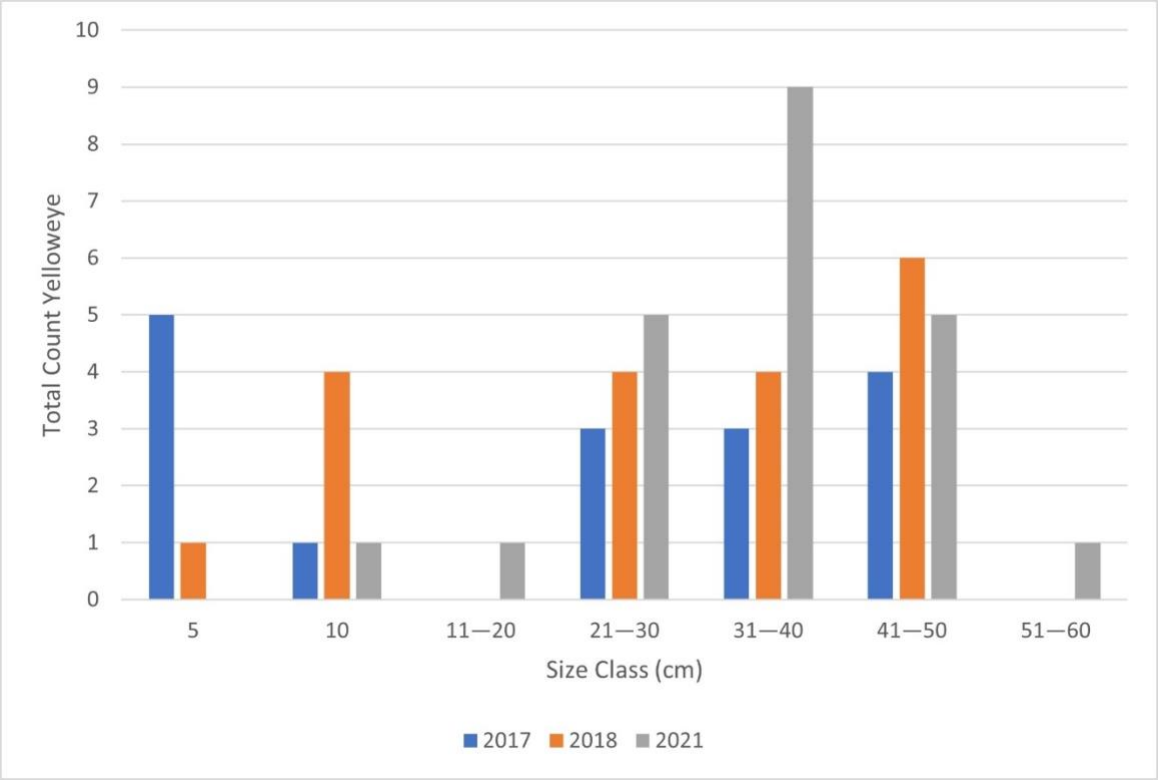


Figure 6. Counts of yelloweye rockfish (*Sebastes ruberrimus*) by size class (cm) measured from ROV video collected in 2017, 2018, and 2021.

Marine Debris and Anthropogenic Observations

Observations of marine debris were rare, and included one monofilament line and one longline.

Temporal Comparison of Foundation Invertebrates and Fish

North Point was surveyed by an ROV using quantitative methods in 2017, 2018, and 2021 (present study). The North Point area was also surveyed by the submersible *Delta* from 2001–2005, and these historic sampling efforts influenced selection of this site as a long-term monitoring site for present-day ROV surveys. Collecting data over time allows for interannual comparison of the abundance of foundation species on Cordell Bank. Foundation species are typically the dominant species in an ecosystem and are good indicators of local conditions. Within the invertebrate group, the foundation taxa on Cordell Bank include hydrocoral (*Stylaster californicus*), Cordell sponge (*Xestospongia edapha*), black edge sponge (*Stelletta clarella*), mound sponges, and the encrusting tunicate in the family Didemnidae. There has been

minimal change in the abundance (measured as average density per m² across transects) of *S. californicus* and the sponge taxa over time (Figure 7). However, the average density of the gray encrusting tunicate in the family Didemnidae significantly increased in 2021 (0.67 ± 0.2 per m²) from the densities documented in 2017 and 2018 (0.04 ± 0.02 per m² and 0.03 ± 0.02 per m², respectively).

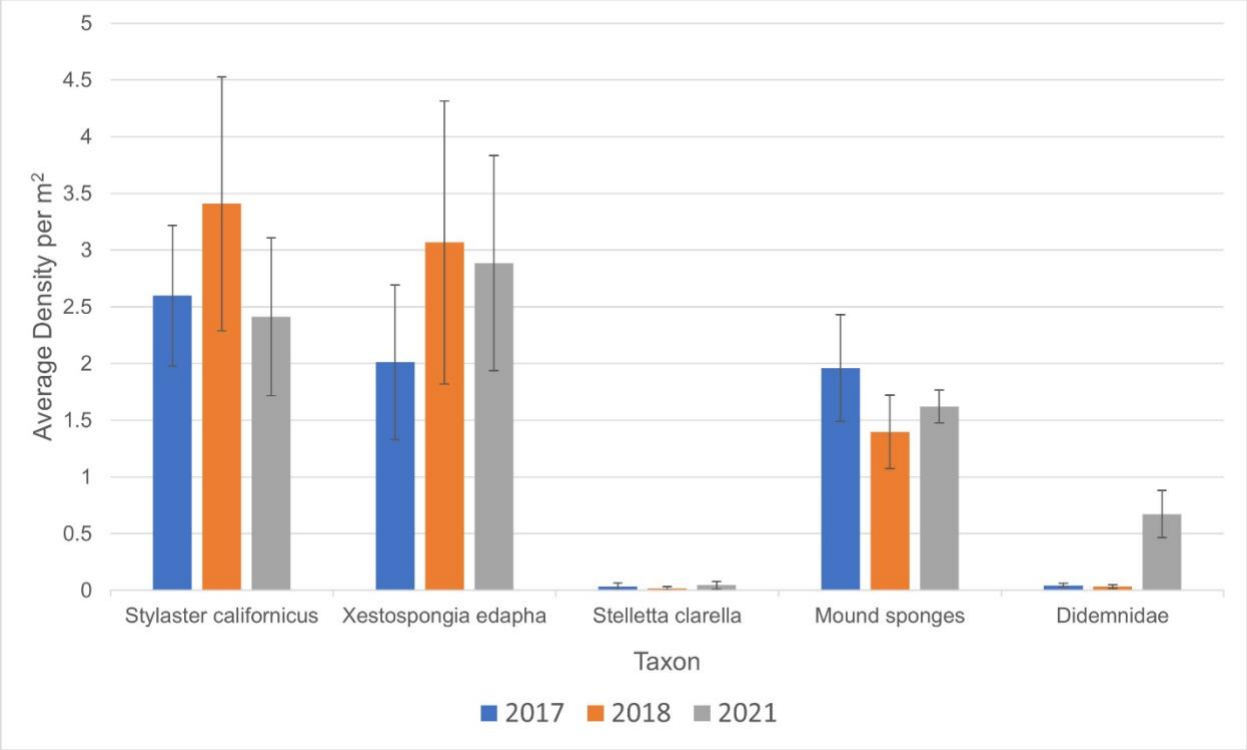


Figure 7. Average densities (per m²) of foundation macroinvertebrates enumerated from benthic surveys in 2017, 2018, and 2021 at the fixed sampling site North Point on Cordell Bank. Error bars are standard error of the mean density.

To monitor benthic fish on Cordell Bank, CBNMS is tracking focal species that are commonly observed: lingcod (*Ophiodon elongatus*), pygmy rockfish (*Sebastes wilsoni*), rosy rockfish (*S. rosaceus*), squarespot rockfish (*S. hopkinsi*), yelloweye rockfish (*S. ruberrimus*) and young-of-year rockfish (*Sebastes* spp.). Over time, densities of these species appear to be stable with no obvious signs of decline. Squarespot and young-of-year rockfish had greater abundances in 2021 compared to 2017 and 2018 (Figure 8).

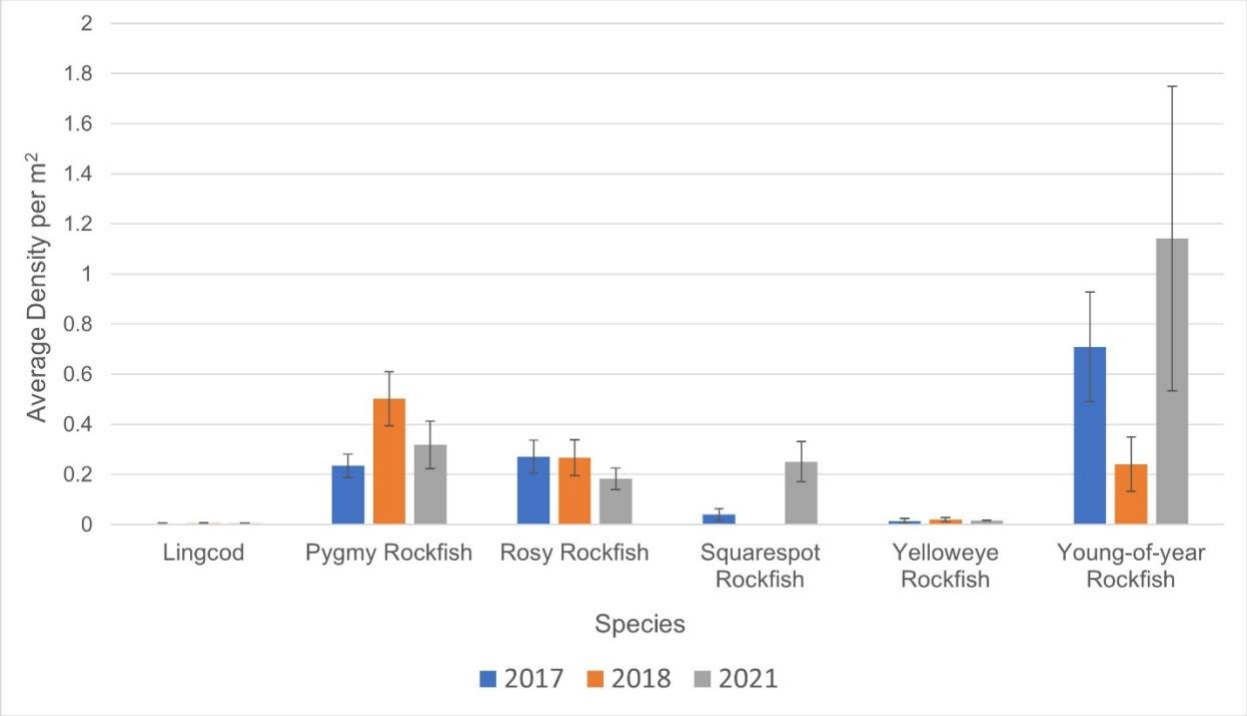
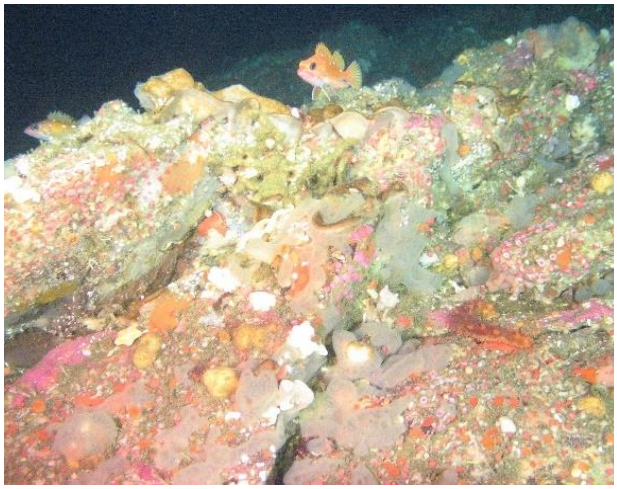


Figure 8. Average densities (per m^2) of foundation fish enumerated from benthic surveys in 2017, 2018, and 2021 at the fixed sampling site North Point on Cordell Bank. Error bars are standard error of the mean density.

Image Gallery: Dive Eight



Encrusting tunicates in the family Didemnidae were observed in higher densities than documented on cruises in 2017 and 2018. Photo: NOAA

Young-of-year rockfish were observed in high abundances and in higher densities than documented on cruises in 2017 and 2018. Photo: NOAA

The primary coral and sponge cover at North Point is the hydrocoral *Stylaster californicus* and Cordell sponge *Xestospongia edapha.* Photo: NOAA

A yellow *Mycale* spp. sponge provides a resting spot for a yellowtail rockfish (*Sebastes flavidus*). Photo: NOAA

Image Gallery: Coloration of Yelloweye Rockfish by Age Class


Juvenile: Dark red-orange body color with two horizontal bright white stripes on each side of the lateral line. The individuals pictured here are estimated to be ≤10 cm in length. Photos: NOAA


Subadult: Begin to lose the two horizontal white stripes and transition from red-orange to lighter orange body color. The individuals pictured here are approximately 15–25 cm in length. Photos: NOAA


Adult: Mature adults have a lighter orange body color. White stripes disappear and fin tips may turn black. The individuals pictured here are estimated to be >40 cm in length. Photos: NOAA

Chapter 5: Discussion

The results from this cruise met CBNMS objectives of characterizing deep-sea habitats and communities of corals, sponges, and groundfish, and furthers the work in the CBNMS long-term benthic science plan. Visual surveys in new and repeated areas allow for monitoring and documentation of species abundance and distribution, coral health, invasive species (i.e., tunicates), and anthropogenic disturbances to the seafloor.

Slope

Exploration on the slope at dive site FOB01 (the gooseneck) was the first visit to this area, which was previously open to trawling but recently designated as EFH in January 2020. The ROV surveys confirmed the presence of hard and mixed substrates that were predicted from multibeam mapping data collected in this area. The rocky areas were made up of extensive flat rock with overhanging shelfs and bands of jagged rocks the size of cobbles, which provided excellent habitat for fish, particularly high abundances of large blackgill rockfish (*S. melanostomus*). The flat rock was commonly draped in a mud veneer, and the density of cobbles varied in patches intermixed with mud. The visual survey was helpful for documenting the unique composition of rock substrates, which was not evident from predictive habitat models.

Although the habitat was favorable for fish, very few corals and sponges were found. The presence of mud on the hard substrate could inhibit the settlement of corals and sponges. Additionally, the depths of the gooseneck feature are not within the preferred range for many of the structure-forming corals and sponges known to be present in the sanctuary. The few corals that were observed were small in size. A limited number of small corals was also observed at a depth of 167–497 meters during a 2010 ROV survey on the slope southwest of Cordell Bank in similar rock habitat (Graiff et al., 2011).

The discovery of hundreds of dead pyrosomes on the seafloor was a new observation for the sanctuary. Currents appeared to determine the distribution of the pyrosomes, which often collected in clusters among rocks or were evenly dispersed as single individuals across expanses of mud bottom. Other invertebrates were observed preying on the dead pyrosomes. Large aggregations of pink urchins were commonly seen consuming pyrosomes, and pink urchins appeared to be the most abundant invertebrate seen throughout the dive. The sea stars *Stylasterias forreri* and *Rathbunaster californicus* also preyed on the dead pyrosomes.

The physical habitats and biological structure at the gooseneck are unique compared to other regions of the slope in CBNMS. It is unclear how past fishing efforts have impacted the community at this location, or if the habitat is less suitable to corals and sponges due to the mud-draped hard substrate. Future surveys at this site will provide insight on how community composition responds to the EFH designation and associated commercial bottom trawling closure.

Shelf

The two dives on the shelf were representative of other areas previously surveyed on the CBNMS shelf (i.e., mud bottom with sea pens and flatfish). The shelf tends to be fairly homogenous with low species richness. Although the sample size in the present study was small, comparing only two sites at one point in time, there did not appear to be large differences in the species composition, density, or health of the organisms in these two areas. Site 362 is in an area of higher trawl intensity, and fixed site 1 was closed to commercial bottom trawling starting in 2006 and reopened in January 2020. At both locations, multiple observations were made of marks in the mud that were not in the typical configurations of naturally formed mud/sand waves. The majority of the marks (n = 12) were documented at shelf 1, and one mark was seen at the end of the dive on line 362. All of these marks varied in length, depth, direction, and intensity of impact (scour) to the substrate, so they were most likely caused by anthropogenic disturbances. Without direct evidence, we can only speculate that different types of fishing gear, likely crab pots or bottom trawls, produced these marks.

The majority of the marks were shallow troughs with rounded top edges, and often were curved and short in direction and length. Sea pens observed near these marks were not damaged or dislodged. Overall, the footprint of these marks was small. It's possible that these marks were created by the deployment or retrieval of crab pots. Dungeness crab season closed on June 30, 2021 and the marks were observed in August 2021. The rounded sides of the troughs could indicate that the marks are older and have been smoothed by water movement.

Larger and deeper scour marks were seen at the end of the dive at shelf 1. There were signs of possible roller gear marks between two troughs, and one area had significant disturbance from something heavy being dragged through the mud. Sea pens near these marks were damaged and dislodged. Although not confirmed, these marks could have been created by bottom trawl gear. These were the first observations made in this area since it was opened to commercial bottom trawling in January 2020. Shelf site 1 is a fixed site, an area CBNMS selected to conduct repeated surveys over time to monitor the benthic community. Conducting these types of visual surveys in a variety of sanctuary habitats that experience different fishing efforts is important for providing the best data for successful management.

Bank

This study was the third quantitative survey completed at North Point. Although this represents just one location on Cordell Bank, repeated sampling at this site demonstrates the ability of CBNMS to monitor a site over time and assess change. Invertebrates and fish were stable in abundance and appeared healthy. Changes to the condition and health of species is of special interest. In particular, CBNMS focuses on corals and sponges because of their long-lived nature and ability to provide structure and habitat for other invertebrates and fish.

The upper reefs at this region of Cordell Bank are dominated by the bank's foundation species: *Stylaster* hydrocoral and multiple types of sponges. Their densities did not change drastically from 2017 and 2018 to 2021. The unknown species of gray encrusting tunicate (Didemnidae) was observed in higher abundances than in previous survey years. There were observations of Didemnidae growing on and over other invertebrates, but no direct evidence the tunicate is

smothering them. It is possible that the growth of this tunicate is seasonal. CBNMS will continue to monitor the presence and extent of this species.

Rockfish populations appear to be healthy. Large schools of young-of-year rockfish were observed among the diversity of other fish known to inhabit Cordell Bank. It appears that the yelloweye rockfish population at North Point is maturing. We observed more individuals in the subadult and adult coloration and body size categories, and no newly settled and young fish. Yelloweye rockfish have an extremely long lifespan, with some specimens aged up to 120 years. Yelloweye rockfish are also late maturing fish, becoming sexually mature at approximately 20 to 22 years of age (Love et al., 2002). As the population of yelloweye rockfish on Cordell Bank continues to grow and reach sexual maturity, there is good potential for continued recruitment in future years. This will continue to be monitored on future surveys at North Point and other sites on Cordell Bank.

Two other fixed sites have been identified on Cordell Bank: Northwest Ridge and Northeast Ridge. These sites were surveyed by an ROV in 2017 and 2014, respectively. Due to limited resources for benthic surveys, and in particular monitoring surveys, CBNMS has focused greater effort on North Point as a proof-of-concept study. Species abundance data up to 2018 were used in the development of the CBNMS condition report in 2021, but there was limited ability to interpret trends with the time series data available. Continued efforts should be made to monitor these sites over the next decade to ensure that data are available for the next condition report in approximately 2032.

In summary, conducting benthic ROV surveys like this one helps expand our understanding of the patterns in habitats and species diversity and richness in the sanctuary. To detect long-term change, future efforts will continue to survey fixed sites, as outlined in the CBNMS benthic monitoring plan. New areas of the sanctuary will also be included in future explorations, and continued characterization will build on the overall knowledge of community structure, such as species depth and habitat preferences. These types of data are vital for effective research and management of the unique benthic habitats in CBNMS.

Acknowledgements

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Appendix A:
Habitat Transect Maps per Dive

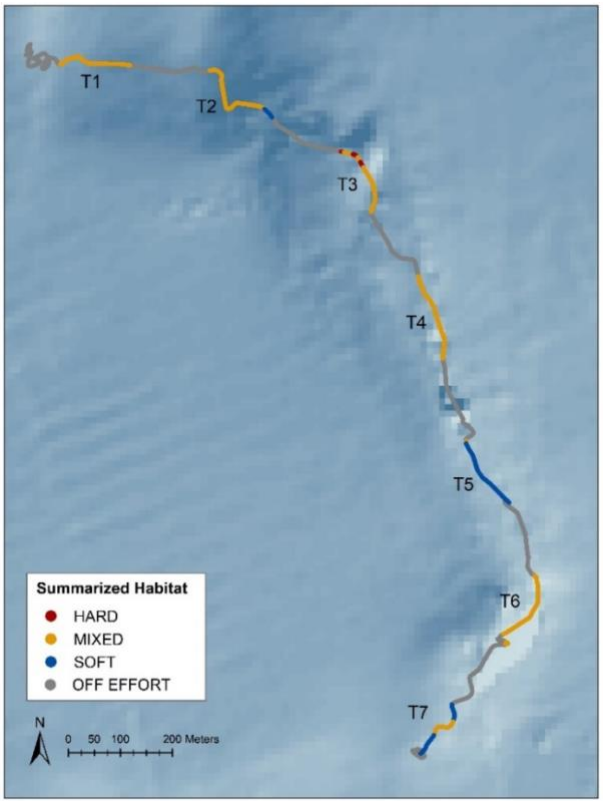

Figure App.1. Summarized habitat type (hard, mixed or soft) observed along seven ROV transect lines on dive 6, FOB01 (The Gooseneck).

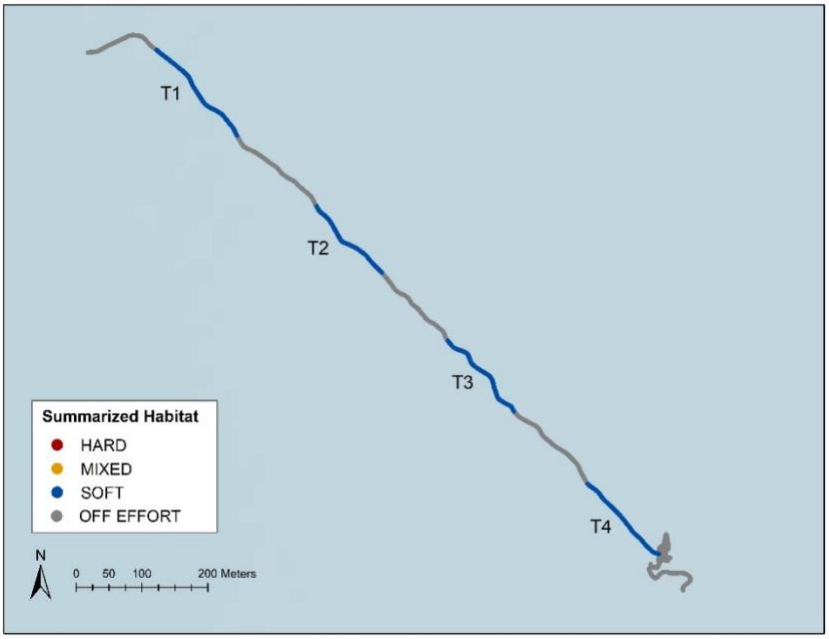

Figure App.2. Summarized habitat type observed along four ROV transect lines on dive 7, line 362. All habitat observed was classified as soft mud.

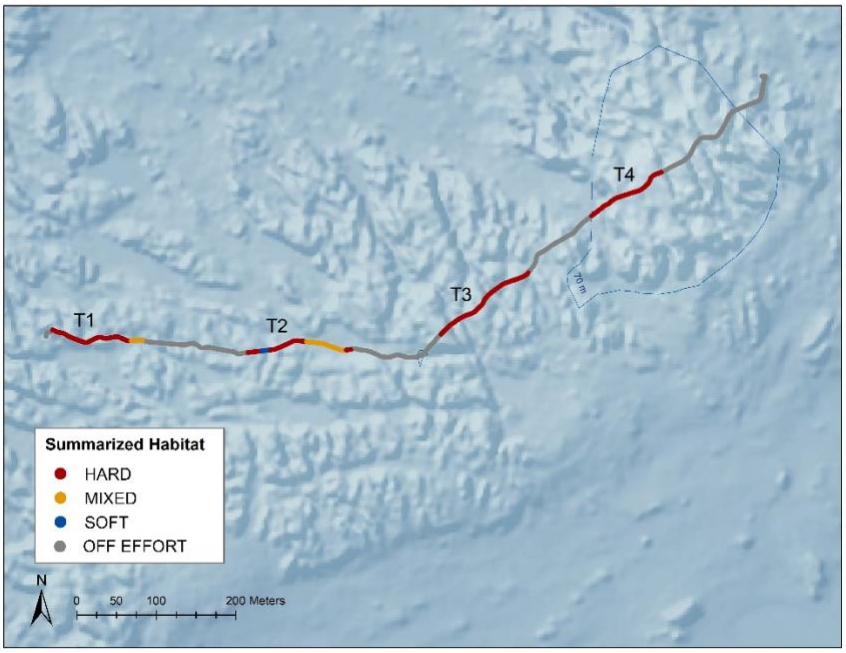

Figure App.3. Summarized habitat type (hard, mixed, soft) observed along four ROV transect lines on dive 8, North Point.

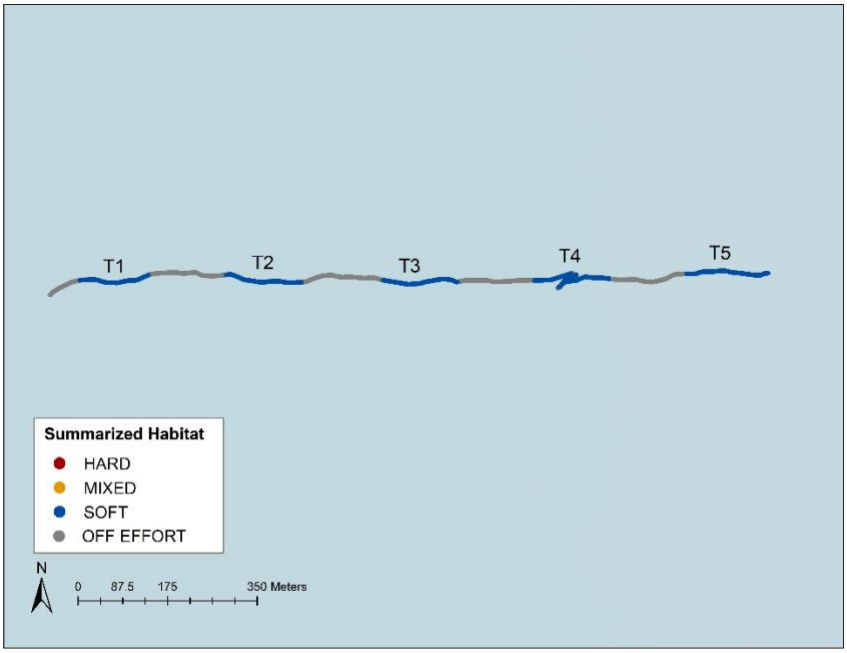

Figure App.4. Summarized habitat type observed along five ROV transect lines on dive 9, Shelf 1. All habitat observed was classified as soft mud.

Appendix B:
Invertebrate Species List per Dive

Table App. 1. Invertebrate species list observed on dive 6, FOB01 (The Gooseneck). Asterisks (*) denote species not observed on video transects, but from still images off transect.

Phylum	Scientific Name	Common Name/Description
Annelida	Polychaeta tube worm	Unknown tube worm, long white tubes
Arthropoda	*Munida quadrispina*	Squat lobster
Arthropoda	*Pandalus platyceros*	Spot prawn
Brachiopoda	*Laqueus californicus*	Brachiopod
Chordata	*Cnemidocarpa finmarkiensis*	Solitary heart tunicate
Chordata	Pyrosoma	Pyrosome
Cnidaria	Actiniaria	Unknown red anemone
Cnidaria	Cerianthidae	Burrowing anemone
Cnidaria	Hormathiidae	Anemone with orange tentacles and white base
Cnidaria	*Stomphia* sp.	Anemone (possible sp. Didemon)
Cnidaria	*Virgularia* sp.*	Sea pen
Echinodermata	*Apostichopus californicus*	California sea cucumber
Echinodermata	*Apostichopus leukothele**	White spined sea cucumber
Echinodermata	*Ceramaster* spp.	Cookie star
Echinodermata	*Florometra serratissima*	Crinoid
Echinodermata	*Henricia* spp.*	Blood star
Echinodermata	*Hippasteria* sp.	Spiny star
Echinodermata	*Luidia foliolata*	Sand star
Echinodermata	*Mediaster aequalis*	Vermillion sea star
Echinodermata	Ophiurina	Brittle stars
Echinodermata	*Poraniopsis* sp.	Spiny star
Echinodermata	*Psolus squamatus*	Sessile sea cucumber
Echinodermata	*Rathbunaster californicus*	California sun star
Echinodermata	*Strongylocentrotus fragilis*	Pink sea urchin
Echinodermata	*Stylasterias forreri*	Fish eating star
Mollusca	Buccinidae	Unknown whelk
Mollusca	*Octopus rubescens**	Red octopus
Mollusca	*Tritonia tetraquetra**	Tritonid nudibranch

Table App. 2. Invertebrate species list observed on dive 7, line 362. Asterisks (*) denote species not observed on video transects, but from still images off transect.

Phylum	Scientific Name	Common Name/Description
Chordata	Pyrosoma	Pyrosome
Cnidaria	Cerianthidae	Burrowing anemone
Cnidaria	*Metridium senile**	Plumose anemone
Echinodermata	*Brisaster* sp.	Heart urchin
Echinodermata	*Gorgonocephalus eucnemis*	Basket star
Echinodermata	*Luidia foliolata*	Sand star
Echinodermata	Ophiurina	Brittle stars
Mollusca	*Pleurobranchaea californica**	California sea slug

Table App. 3. Invertebrate species list observed on dive 9, Shelf 1. Asterisks (*) denote species not observed on video transects, but from still images off transect.

Phylum	Scientific Name	Common Name/Description
Chordata	Pyrosoma	Pyrosome
Cnidaria	Cerianthidae	Burrowing anemone
Cnidaria	*Metridium senile**	Plumose anemone
Echinodermata	*Brisaster* sp.	Heart urchin
Echinodermata	*Gorgonocephalus eucnemis*	Basket star
Echinodermata	*Luidia foliolata*	Sand star
Echinodermata	Ophiurina	Brittle stars
Mollusca	Buccinidae*	Unknown whelk
Mollusca	*Pleurobranchaea californica**	California sea slug

Table App. 4. Invertebrate species list observed on dive 8, North Point. Asterisks (*) denote species not observed on video transects, but from still images off transect.

Phylum	Scientific Name	Common Name/Description
Annelida	Sabellida*	Feather duster worms (Sabellidae) and serpulid worms (Serpulidae)
Arthropoda	*Loxorhynchus crispatus*	Decorator crab
Chordata	*Ascidia paratropa*	Solitary glass tunicate
Cnidaria	*Balanophyllia elegans*	Orange cup coral
Cnidaria	*Corynactis californica*	Strawberry anemone
Cnidaria	*Garveia annulate*	Orange hydroid
Cnidaria	*Paracyathus stearnsii*	Brown cup coral
Cnidaria	*Urticina piscivore*	Fish eating anemone
Echinodermata	*Apostichopus californicus*	California sea cucumber
Echinodermata	*Ceramaster* spp.	Cookie star
Echinodermata	*Florometra serratissima**	Crinoid
Echinodermata	*Henricia* spp.	Blood star
Echinodermata	*Mediaster aequalis*	Vermillion sea star
Echinodermata	Ophiurina	Brittle stars

Phylum	Scientific Name	Common Name/Description
Echinodermata	*Orthasterias koehleri*	Rainbow star
Echinodermata	*Patiria miniate*	Bat star
Echinodermata	*Poraniopsis inflata*	Spiny star
Echinodermata	*Pteraster tesselatus*	Cushion star
Echinodermata	*Solaster* sp.	Sun star
Echinodermata	*Stylasterias forreri*	Fish eating star
Mollusca	Buccinidae	Unknown whelk
Mollusca	*Calliostoma annulatum**	Blue-ring top snail
Mollusca	*Crassadoma gigantea*	Rock scallop
Mollusca	*Doris odhneri*	White sea lemon nudibranch
Mollusca	*Flabellinopsis iodinea*	Spanish shawl nudibranch
Porifera	*Acarnus Erithacus*	Red volcano sponge
Porifera	*Polymastia pachymastia**	Aggregated vase sponge
Porifera	Encrusting Porifera	Unidentified yellow, red, and orange encrusting sponge
Rhodophyta	Encrusting Corallinaceae	Encrusting coralline algae
Rhodophyta	*Maripelta rotata*	Purple circular shaped algae
Rhodophyta	*Polyneura latissima*	Most common red algae on Cordell Bank

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