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Characterizing megafaunal communities on ferromanganese and phosphorite-rich hardgrounds in the Southern California Borderland

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Characterizing megafaunal communities on ferromanganese and phosphorite-rich hardgrounds in the Southern California Borderland

A Thesis submitted in partial satisfaction of the requirements
for the degree Master of Science

in

Oceanography

by

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The Thesis of Devin Seiichi Vlach is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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ABSTRACT OF THE THESIS

Characterizing megafaunal communities on ferromanganese and phosphorite-rich hardgrounds in the Southern California Borderland

by

Devin Seiichi Vlach

Master of Science in Oceanography

University of California San Diego 2022

Professor Lisa A. Levin, Chair

The Southern California Borderland (SCB) is a tectonically complicated area offshore Southern California, comprised of a series of escarpments, banks, ridges and seamounts along the outer reaches beyond the continental shelf. To address threats from human activities, this study provides baseline information about the megafauna inhabiting the SCB hardgrounds, focusing on ferromanganese crusts and phosphorites, minerals considered for their resource potential. I analyzed composition, density, and diversity of megafaunal communities across 10 SCB sites using counting and statistical analyses of video transects recorded by remotely operated vehicles. In total, I counted 32,426 individuals representing 146 unique taxa over 41 transects. These transects covered depths ranging from 378-2765 m. Echinodermata contributed to 48% of the total abundance; Cnidaria 24%; Porifera 13%; Annelida 6%; Arthropoda 6%; Chordata 2%; Mollusca, Foraminifera, and Hemichordata contributed <1%. Megafauna communities showed heterogeneity, with density, diversity, and community composition varying across transects and sites. Mineral type had no influence on megafaunal density, but FeMn habitats had higher diversity and different taxonomic composition. Analysis suggests location, depth and oxygen were the most important variables explaining variance among megafaunal communities, with distinct communities formed at deeper depths and within the oxygen minimum zone. This study extends existing documentation of hardground-associated megafauna in the SCB to greater depths, revealing increasing representation of sponges and corals at depths below 1000 m. It also offers the first substrate-specific study, highlighting the variability seen within deep-sea megafaunal communities and establishing a baseline that can be used by policymakers to make more informed decisions.

Introduction.

The deep ocean is a vast, yet poorly explored environment. It is the largest habitat on Earth by volume and area, yet the deep ocean below 200 m is the least observed (Levin 2019). Even with limited investigation, impacts and changes to the deep-sea environment are evident. A 2017 report from the United Nations First Global Integrated Marine Assessment noted a serious decline in ocean health, with changes and losses in the structure, function, and benefits from marine ecosystems (U.N. 2017). In order to properly assess and manage ocean ecosystems, it is clear a better understanding of these systems and the communities that reside within them is needed.

The deep ocean is experiencing cumulative stressors from activities such as fishing, pollution, and climate change. Industrial-scale fishing expanding to deeper waters is largely unsustainable (Watson and Morato 2012). Deep sea fisheries have targeted low productivity, long-lived fish populations (Morato et al. 2006) using nonselective bottom trawls that may lead to inadvertent bycatch and clear-cutting of benthic habitat (Mengerink et al. 2014).

Deep-sea mining is an emerging industry that if carried out will have potential impacts to marine communities (Levin et al. 2016). Rising populations along with the transition towards renewable energy and technology have fueled the global demand for minerals, metals, and rare-earth elements (Balaram 2019). A 2018 report by the IPCC found that to limit global warming to 1.5 C, renewables are projected to supply 70-85% of electricity by 2050 (IPCC 2018). Production of battery metals such as graphite, lithium and cobalt are projected to increase by 500% to meet the growing energy demand (World Bank 2020). As mineral resources are exhausted on land, more attention is being given towards deep-sea minerals. Although mineral exploitation has not yet occurred in the deep sea, phosphorite (used for fertilizer) and ferromanganese crusts are among those hard substrates being considered for their mineral resource potential. These two marine minerals, phosphorite and ferromanganese crusts, naturally occur within the Southern California Borderland (Hein et al. 2016).

Characteristics of the Southern California Borderland

The Southern California Borderland (SCB) is a tectonically complicated area off Southern California, comprised of a series of escarpments, banks, and ridges, as well as numerous seamounts along the outer reaches beyond the continental shelf (Hein et al. 2000). This region is subject to large terrestrial inputs, metal fluxes from the continental shelf and slope hypoxic sediments, seasonal upwelling, high primary productivity, and a well-developed oxygen minimum zone (OMZ) (Hein et al. 2000). These characteristics allow for ferromanganese crusts and phosphorite to form in various locations throughout the SCB. Ferromanganese crusts, which are composed of Fe oxyhydroxide and Mn oxide, precipitate directly from surrounding seawater onto exposed rocks in deeper regions where sedimentation is lower (Hein et al. 2014). Marine phosphorite is found where Miocene sedimentary strata are exposed during early diagenetic formation (Hein et al. 2016). The majority of phosphorite samples obtained from the continental borderland have been from areas characterized by slow rates of sedimentation, with more than 95% of samples collected from depths between 100 – 1000 feet (Emery 1960).

At the present, previous work done in the SCB quantified megafaunal communities to a maximum depth of 900 m and did not consider the substrate when conducting surveys (Yoklavich et al. 2010). These studies focused on corals, sponges, and fishes. In July of 2016, E/V Nautilus explored this region as part of NA073 and NA075 with the goal of exploring the deeper regions off Southern California (Cormier et al. 2017). The megafaunal communities were found to differ greatly by location, depth, and benthic habitat characteristics (Cormier et al. 2017). The complex topography hosted a variety of megafauna communities, including sponges, soft corals, brittle stars, starfish, sea cucumbers, and benthic-dwelling fish (Cormier et al. 2017). Results from these surveys revealed that community composition patterns are similar to those observed on other California seamounts (McClain et al. 2009). Effort by NOAA fisheries along with support from its partners have seen an increase in the mapping of federal waters off Southern California. Prior to 2018, less than 15% of the seafloor in federal waters off Southern California had been mapped (NOAA 2018). Salgado et al. (2018) synthesized much of the deep-sea coral and sponge occurrences in relation to fisheries landings in the SCB. Benthic imaging was used to estimate diversity and abundance of deep-sea corals and sponges (Salgado et al. 2018). A total of 15 coral genera and six sponge morphotypes were identified that were broadly distributed across the SCB (Salgado et al. 2018). The majority (57.5%) of the images from these surveys were taken from the mesophotic depth zone between 45 and 150m, with the maximum depth studied at around 500m (Salgado et al. 2018).

Faunal association with marine minerals in other regions

The most detailed study of megafauna community-mineral associations was carried out by the International Seabed Authority (ISA) for cobalt-rich ferromanganese crusts hosted on seamounts in the central-west Pacific Ocean (ISA 2011). Video data were gathered from submersible and ROV dives carried out by the Hawaiian Underwater Research Laboratory on seamounts in the Hawaiian Archipelago between 1983 and 2003 (ISA 2011). The depths varied depending on the site, ranging from 200m to 1825m (ISA 2011). Composition varied between locations, with 209 species recorded on cobalt-rich sites, 271 from non-cobalt-rich sites, and 487 seen at both types of crust sites (ISA 2011). The majority of species found belonged to Cnidaria (287), Osteichthyes (252), Echinodermata (154), and Crustacea (106) (ISA 2011). Results showed no significant difference in invertebrate community composition on cobalt-rich sites and non cobalt-rich sites in the Hawaiian Archipelago (ISA 2011). The main determinant of community composition was depth, with three zones defined: 200-350m; 360-600m; and 750-1800m (ISA 2011). For the purpose of the ISA study, "cobalt-rich crusts" sites were determined based on whether the seamounts were in a region of likely commercial potential. Substrate type at each site was not determined in the analysis.

Rowden et al. (2013) described the benthic macrofauna and megafauna communities found on phosphorite nodules on the Chatham Rise in New Zealand. An ROV was used to conduct photographic transects and a box-corer was used to directly sample the seafloor. Multivariate statistics identified 12 distinct epifaunal communities and 5 infaunal communities, their taxa, and distribution (Rowden et al. 2013). Two epifaunal communities showed a close relationship with the distribution of high-density patches of phosphorite nodules (Rowden et al. 2013). These two communities were dominated by the stony coral *Goniocorella dumosa* (Rowden et al. 2013). Results from this study as well as previous surveys on the Chatham Rise indicate that the benthic communities found in the phosphorite site have not been found elsewhere on the Rise (Rowden et al. 2013).

Dawson (1984) summarized the benthic fauna on phosphorite nodules of the same study site on the Chatham Rise using photographic/video imagery and grabs in 1978 and 1981 using the RV *Valdivia* and RV *Sonne*. The study site was characterized by large echinoids (*Paramaretia* and *Spatangus*), asteroids (*Zoraster*, *Astropecten*, *Plutonaster*, *Mediaster*), conical sponges (*Hyalascus.*), crabs (*Carcinoplax victoriensis, Trichopeltarion fantascicum*), galatheids

(*Munida*), gastropods (*Cymatona* and *Fusitriton*), polychates, bivalves, isopods, amphipods, and cumaceans (Dawson 1984). Dawson's summary was based on observations made by Kudrass and von Rad (1984) from imagery taken by the RV *Sonne* survey.

To date, no studies have been done in the Southern California Borderland that quantify megafaunal occurrences on phosphorite and ferromanganese-rich hardgrounds. Acquiring information on community structure in these poorly explored regions provides a baseline that can be used by policymakers for informed decision-making.

Conservation criteria and management of the SCB

The California Borderland is a broad area comprised of a series of basins, ridges and islands that begins off the coast of Southern California and continues out to the extended continental slope. The Exclusive Economic Zone (EEZ), as described by the 1982 United Nations Law of the Sea, sets a zone that extends from 3 up to 200 nautical miles from the territorial sea baseline of a coastal nation (UNCLOS 1982). Both the 2020 NA124 and the 2021 FK210726 cruises to the SCB took place within the U.S. EEZ.

Management of federal waters within the EEZ is governed by several federal agencies. Activities related to hard mineral mining, conservation, and fishing are governed by the National Oceanic and Atmospheric Administration (NOAA). The Deep Seabed Hard Mineral Resource Act (DSHMRA), administered by NOAA, establishes a licensing and permit process for exploration and recovery of hard minerals for persons and entities under U.S. jurisdiction (DSHRMA 2002). Mining of mineral resources in the outer continental shelf is currently stewarded by the Bureau of Ocean and Energy Management (BOEM); however, to date there are no active leases in US waters for marine hard mineral mining. These agencies aim to protect the marine environment and the mineral resources, property at sea, and conservation of marine minerals (DSHRMA 2002).

Under U.S. law, the NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is responsible for managing marine fisheries within the U.S. EEZ (MSA 2006). NMFS works closely with regional fishery councils to manage fisheries in each respective region (MSA 2006).

Within the United States EEZ, the Pacific Fisheries Management Council (PFMC), with jurisdiction over the SCB, is one of eight regional fishery management councils established by Congress. The PFMC manages fisheries for about 119 species of salmon, groundfish, coastal pelagic species and highly migratory species along the West Coast of the United States. The Council and NMFS are required by law to identify and protect the Essential Fish Habitat (EFH) of species under their management plan. EFH is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (PFMC). The Council must also identify Habitat Areas of Particular Concern (HAPC), which represent high priority areas for conservation, management, or research and are necessary for healthy ecosystems and sustainable fisheries (MSA 2006). The Council offers criteria for determining HAPCs, which include: (i) The importance of the ecological function provided by the habitat, (ii) the extent to which the habitat is sensitive to human-induced environmental degradation, (iii) whether, and to what extent, development activities are, or will be, stressing the habitat type, (iv) the rarity of the habitat type (PFMC).

The Council can use discretionary authority under the Magnuson-Stevens Act to protect EFH that may be impacted by adverse activities. The Council has used this authority to designate seamounts as HAPC (Pacific Coast Groundfish FMP 2020). An amendment to the

Fishery Management Plan recognized deep-sea coral ecosystems as EFH, and under the Magnuson-Stevens Act, offered protection from bottom-fishing gear (MSA 2006). In 2010, the NOAA Deep-Sea Coral Research and Technology Program (DSCRTP) initiated a three-year study to better understand deep-sea corals and sponges (Yoklavich et al. 2011). Leg 3 of the expedition examined the Piggy Bank Seamount, located within the Channel Islands National Marine Sanctuary off Southern California (Yoklavich et al. 2011). Forty-eight, 15 minute transects were conducted across the seamount, with depths ranging from 275–900 m (Yoklavich et al. 2011). A total of 166 taxa of invertebrates and fishes were observed during the 48 quantitative transects (Yoklavich et al. 2011). Overall densities were 95-536 corals/1000 m^2; 224-969 sponges/1000 m^2; 77-185 fishes/1000 m^2 (Yoklavich et al. 2011). The most abundant coral included *Antipathes dendrochristos*, *Swiftia* spp., *Anthomastus ritteri*, *Lophelia pertusa*, *Desmophyllum dianthis*, and *Halipteris californica* (Yoklavich et al. 2011). The most abundant sponges were mound, foliose, upright flat, vase and barrel groups (Yoklavich et al. 2011). The most abundant fishes were bank rockfish in shallower depths and thornyhead rockfish in deeper depths (Yoklavich et al. 2011). Less than 1% of the corals and sponges had fishes that were less than one body length away; Those fishes included: thornyhead, bank rockfish, Dover sole, Pacific hagfish, eelpouts, and catshark egg cases (Yoklavich et al. 2011). This seamount is designated as essential fish habitat by NMFS and the PFMC.

Research Objectives.

The purpose of the study is to explore the relationship between marine mineral substrates and the megafauna associated with them in the SCB. Through analysis of video transects, I hope to (1) identify the major megafaunal taxa associated with hardground habitats of topographic highs (seamounts, ridges and banks) in the Southern California Borderland; (2) evaluate patterns of density and diversity of these taxa; (3) determine the occurrence and distribution of habitat-forming organisms e.g. corals, sponges; (4) determine whether megafaunal occurrence differs on phosphorite and ferromanganese crust substrates; and (5) evaluate how the distribution of megafauna relates to water depth, water temperature, water oxygen concentration, and proximity to shore. With this information, I aim to provide baseline understanding that can assist in management of the SCB, including the potential establishment of sites as protected areas through the Pacific Fisheries Management Council (PFMC) or other policy-making bodies.

Materials and Methods.

Study sites in the Southern California Borderland

From October 27 through November 6, 2020, a scientific team consisting of members from the Scripps Institution of Oceanography and the U.S. Geological Survey conducted benthic surveys of the Southern California Borderland aboard the E/V Nautilus as part of NA124. Biodiversity transects were obtained on seven dives, ranging in depth from 457m to 1685m. Dive sites included Patton Ridge Central, San Juan Seamount, Northeast Bank, Cortes Bank, Patton Ridge South, 40-Mile Bank, and San Clemente Escarpment (Table 1). A total of 26 transects were reviewed over these seven sites.

The following year, benthic surveys of the SCB continued from July 24 through August 6, 2021, aboard the R/V Falkor as part of FK210726. Eleven dives were completed as part of the FK210726 expedition over eight sites. 14 transects were reviewed from three of the eight sites visited during this cruise. These transects were selected to extend the depth range and number of transects conducted with identifiable phosphorites and FeMn crusts. These three sites include: San Juan Seamount, Little Joe Seamount, and Coronado Escarpment (Table 1).

The 41 transects reviewed for this study represent a suite of different rock and mineral types, water depths, temperatures, and oxygen concentrations (Table 1).

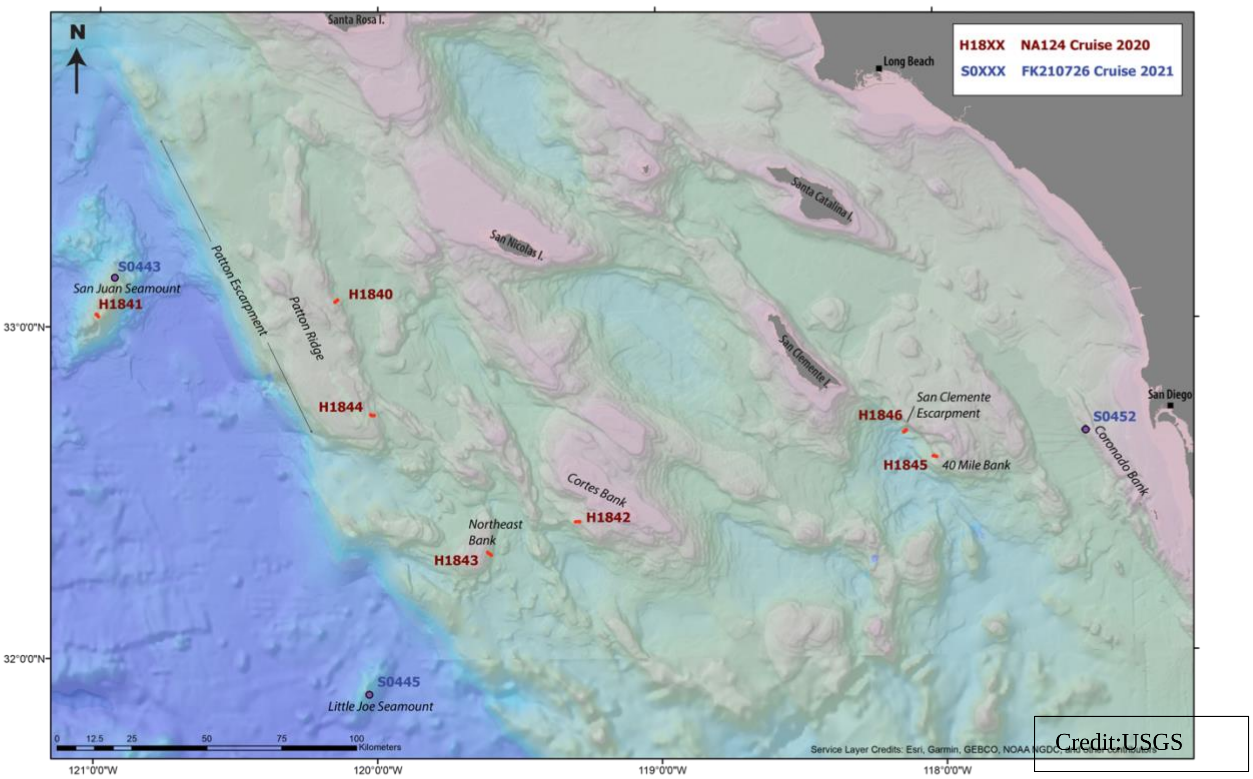

Figure 1. Map of the study area, dive sites, and topography.

Coronado Escarpment lies between the Loma Sea Valley and the San Diego Trough (Figure 1). It is a fairly flat area and shares a depth similar to those around the outer parts of the shelf (Emery et al. 1952). The bank is characterized by two flat peaks, separated by a saddle. Emery at al. (1952) found an abundance of phosphorite, believed to have been deposited during the Middle or early Miocene Epoch.

San Clemente Escarpment is formed on the flank of the southernmost of the Channel Islands (Figure 1). The northeastern flank forms a steep escarpment, with an average slope of 15° (Olmstead 1958). The Island is comprised primarily of volcanic rocks, though surveys have also found sedimentary rocks (Olmstead 1958).

40-Mile Bank (Figure 1) is characterized by mixed rock and sediment substrate. This site was targeted because historical dredging and photography have indicated phosphorite nodules present at 40 Mile Bank (Mero 1965). The concentration of phosphorites was found to lessen with increasing water depth, possibly due to increased sedimentation with lessening water currents at greater depths (Mero 1965).

Cortes bank (Figure 1) is a shallow bank, its position is such that it is exposed to equatorward-flowing California Current and poleward-flowing California Undercurrent (Pondella 2016). The strong bottom surges along with the unique trench-ridge topography creates vertical mixing and enhances upwelling (BLM 1979).

Northeast Bank is located within the continental margin (Figure 1), and is uniquely characterized by a smooth, gently domed summit containing volcanic sandstone and pelagic sediment (Paduan et al. 2009). Volcanic flows from the summit does not have pillow structures or glassy rinds, which indicate subaerial flows (Paduan et al. 2009).

Little Joe Seamount is a volcanic seamount that lies on the Pacific plate (Figure 1). As is characteristic with Southern California's volcanic seamounts, initial rock samples collected from Little Joe Seamount were mostly hawaiite and alkalic basalt (Davis et al. 2010). Further surveys done by USGS found evidence of FeMn encrustation on every rock sample collected (Hein et al. 2010). The thickness varied from 10-35mm, with some crusts up to 65mm thick (Hein et al. 2010).

The *Patton Escarpment* lies at the edge of the continental shelf offshore of Southern California (Figure 1). A study of ferromanganese crusts from the California continental margin and surrounding seamounts found the highest mean Mn concentration in crusts at Patton Escarpment with 25.1 wt% (Conrad et al. 2016).

San Juan Seamount lies off the continental margin (Figure 1) and was formed on oceanic crust (Paduan et al. 2009). It is the largest of the seven volcanic seamounts located on the Pacific plate, with a size of about 30 km wide and 70 km long (Davis et al. 2010). A unique morphological characteristic of the formation includes its guyot-like summit, comprised of a series of rounded ridges (Paduan et al. 2009). Bedded sand, gravel, and cobble deposits cover the seabed. (Paduan et al. 2009).

Table 1. Video transects conducted in the SCB from the NA124 and FK210726 cruises.

Cruise	Dive	Date	Site	Start Depth (m)	End Depth (m)	Primary Habitat	Substrate ID	Rep No.	Latitude	Longitude	Average Temp (°C)	Average O_2 (μM O_2/L)
FK210726	S0452	8/5/21	Coronado Escarpment	471	378	Mixed, Rock & Sediment	Phosphorite & other	5	32.6648	-117.4809	7.76	27.08
NA124	H1846	11/4/20	San Clemente Escarpment	1685	1366	Mixed, Rock & Sediment	FeMn(thin/patina)	4	32.6768	-118.1253	2.90	39.46
NA124	H1845	11/3/20	40-Mile Bank	869	660	Mixed, Rock & Sediment	Other Rock	3	32.5981	-118.0206	4.94	4.37
NA124	H1843	11/1/20	Cortes Bank	574	457	Mixed, Rock & Sediment	Phosphorite & other	3	32.4163	-119.2955	6.21	7.03
NA124	H1842	10/31/20	Northeast Bank	1214	628	Rocky	FeMn(thin/patina)	5	32.3207	-119.6045	4.63	9.69
FK210726	S0445	7/30/21	Little Joe Seamount	2765	2366	Mixed, Rock & Sediment	FeMn(thin/patina)	4	31.8973	-120.0315	1.79	105.67
NA124	H1840	10/29/20	Patton Ridge Central	741	538	Mixed, Rock & Sediment	Other Rock	3	33.0812	-120.1506	5.61	4.31
NA124	H1844	11/2/20	Patton Ridge South	722	560	Mixed, Rock & Sediment	Phosphorite & other	4	32.7383	-120.0208	5.43	3.91
NA124	H1841	10/30/20	San Juan Seamount Central	1120	595	Rocky	FeMn(thin/patina)	5	33.0338	-120.9990	4.70	9.33
FK210726	SO443	7/28/21	San Juan Seamount North	1443	1139	Rocky	FeMn(thin/patina)	5	33.1464	-120.9405	3.27	35.62

Data collection

Biodiversity video surveys and samples for NA124 were collected by the ROV Hercules. The ROV Hercules was equipped with a high-definition video camera configured with: Insite

Pacific, 6,000 msw rated, Zeus Plus with 10x zoom lens, Ikegami HDL-45A with zoom/pan/tilt/extend -1080i SMPTE 292M output format.

Conductivity/temperature/depth/oxygen (CTD-O_2) and salinity data readings were collected using the Sea-Bird FastCAT 49 CTD, Parascientific Digiquartz 8CB series pressure sensor, and Aanderaa 3830 oxygen sensor.

Biodiversity video surveys and samples for FK210726 were collected by the ROV SuBastian. The ROV SuBastian is equipped with a high-definition video camera configured with: Insite Pacific Mini Zeus HD, 1080i as well as a SULIS Subsea Z70 camera. Physical environmental variables such as conductivity, temperature, depth, oxygen, and salinity were collected using the Sea-Bird FastCAT SBE49 CTD, Paroscientific 8000 series pressure depth sensor, Aanderaa 3841 oxygen sensor, and PT100 temperature probe. On both cruises, scaling was determined using two green lasers, spaced 10 cm apart.

High-definition video was collected continuously throughout the course of the dive by ROVs Hercules and SuBastian. Three to five 100-m long video transects were analyzed from each dive (Table 1). During each transect, the ROV was piloted at a constant speed and was kept about 1 m off the seafloor. The camera angle was manually set by the pilot to give the best view of the bottom. At this angle, the bioboxes in the basket at the front of the ROV were no longer in view and the pilots had a clear image of the transect path. Start and stop points for each 100-m transect distance were determined using the ships onboard navigational tools. Oxygen, temperature, and salinity were collected throughout each transect.

Quantitative analysis of the video transects were performed by breaking each video transect into minute-long segments, and manually counting each species in each segment. For taxa-dense transects, individual species were counted, one at a time, for the duration of each minute-long segment. This process was repeated for each species counted.

We calculated the area of each transect using methods similar to those described by Curtis et al. (2015) in their 2012 expedition to Cobb Seamount. The width of each transect was estimated using the green scaling lasers projected by the ROV using Deep Sea Power & Light Micro Sea-Lasers, spaced 10 cm apart. The field of view (FOV) was defined as the horizontal line that transects the green lasers. Using an app that projects a ruler onto the media player, we can measure the pixel distance between the 10 cm lasers, as well as the pixels that run across the width of the FOV. Next, a scaling equation was used to calculate the actual width of the field of view.

If D_a is the actual laser scale distance in cm, D_i is the image laser-scale distance in pixels, W_a is the estimated FOV width in cm, and W_i is the image FOV width in pixels, then:

$$D_a/D_i = W_a/W_i$$

By rearranging the equation, we can solve for the estimated FOV width, W_a.

$$W_a = (D_a/D_i) * W_i$$

In our case, the actual laser scale distance, D_a was calculated at 10 cm, and the image laser-scale distance, D_i, was calculated at 20 pixels, and the image FOV width was calculated at 1070 pixels. The estimated FOV width in cm was calculated to be 535 cm, or 5.35 m. This width was assumed as an average for all transects. Next, the area of the transect was calculated by multiplying the length of 100 m by the 5.35 m width. Each transect was estimated to be 535 m^2.

Videos were reviewed in the laboratory after the conclusion of each cruise. Species identification was determined primarily based on morphology and known depth ranges (primarily for vertebrates). The observed megafauna were identified down to the lowest taxonomic level possible (from class to species level), using the Big Sur Ridge Field Guide (Burton et al 2017) and the NOAA OER Deepwater Benthic Animal Identification Guide 3 (NOAA) and with help from taxonomic experts. These taxonomic experts included: Dr. Christopher Mah (asteroids), Dr. Mary Wicksten (crustaceans), Dr. Estefania Rodriguez (anemones), Dr Steve Auscavitch (corals), Lonny Lundsten (general taxa), Dr. Abigail Powell (sponges), Ben Frable (vertebrates), and Dr. Charolette Seid (general taxa). Screenshots of uncertain taxa were taken from video transects and sent to these taxonomic experts for identification. Due to the difficult nature of analyzing deep-sea photos and video, there is some degree of uncertainty when it comes to the positive identification of species. This can be due to factors such as the lack of distinguishable features, distance from the camera, and individual orientation. Some megafaunal specimens that were collected by the ROV's manipulator either before or after the video transects through the ROV's manipulator. These specimens were sequenced and logged into the Scripps Institution of Oceanography Benthic Invertebrate Collection, courtesy of Greg Rouse and Charolette Seid. Some of these specimens were used to make positive identifications of animals observed on transects.

A taxonomic guide of the Southern California Borderland fauna (Supplementary File) was assembled from our taxonomic efforts using images from NA124 and FK210726. It provides images and identifications for most of the taxa observed and counted in video transects, but also includes some taxa found during the same dives, but outside of the transects.

Primary habitat and substrate identification

Habitat and substrate type identifications were made by Dr. Kira Mizell, of the U.S. Geological Survey. Primary habitat distinctions were made based on visual estimation of the amount of seafloor that was sediment covered. If more than 30% of the transect included substantial amounts of sediment to serve as significant habitat in addition to rocks and outcrops, it was marked as ‘Mixed, Rock+Sed’. The transects labeled ‘Rocky’ contained seafloor with less than 30% sediment. Transect labeled as ‘Sediment’ contained seafloor that was more than 90% sediment covered (Table 1).

Substrate rock type (e.g. FeMn, phosphorite, basalt, other) along the transects was identified during video review using rock shape (plate-like, lobed, angular, rounded etc.), surface texture (botryoidal, smooth, undulating, etc.), sediment cover, and outcrop morphology (Table 1). Transect substrate types were informed by transect video observation, rock identifications for samples collected along the same geologic feature during the same ROV dive as the video transect, as well as by identifications from previous rock collections reported in the literature.

Statistical analysis

Statistical analyses examined the influence of collection location, substrate type, depth, oxygen, and temperature on the density, diversity, and composition of the hardground megafauna. Diversity metrics and univariate analyses were conducted in R using the packages *vegan* and *car*. Graphs were plotted using the *ggplot2* package. Rarefaction curves were used to compare the diversity of samples of unequal sizes across sites within the SCB (Hurlbert 1971). These curves were plotted in R using the “rarefy” function. These curves illustrate the expected number of species as a function of the number of observed individuals increases.

Density data was standardized to the number of individuals per 1 m^2. The data was transformed using the log(x) function to achieve a normal distribution, so parametric tests could be used. A one-way analysis of variance (ANOVA) was used to determine if there were any statistically significant differences in densities between substrate, depth, oxygen, and temperature and an aposterior Tukey HSD test was used on significant ANOVA results. A t-test was used to determine if there was a statistically significant difference in densities between inshore and offshore sites.

Diversity of megafauna was characterized for dive sites and substrate types using univariate diversity measures including mean diversity, taxon richness (S), Shannon index ($H'_{[log10]}$), Pielou's evenness (J), and ES_{100} (Table 3).

Community composition data were fourth-root transformed prior to multidimensional scaling (MDS) analyses using Primer v.7. Compositional dissimilarities between transects were examined through a S17 Bray-Curtis dissimilarity matrix. The differences in composition as a function of substrate, depth, oxygen, and temperature were evaluated by conducting MDS, one-way ANOSIM and one-way SIMPER analyses. Differences in densities as a function of proximity to shore were evaluated using a two-sample t-test.

Results.

In total, we counted 32,426 individuals representing 146 taxa over 41 transects from both NA124 and FK210726. These transects covered depths ranging from 378-2765 m. Echinodermata contributed to 48% of the total abundance; Cnidaria 24%; Porifera 13%; Annelida 6%; Arthropoda 6%; Chordata 2%; Mollusca, Foraminifera, and Hemichordata contributed <1% of the total abundance. Phylum composition for each site can be found in Figure 2. Four of the top five most abundant taxa belonged to Echinodermata, which contributed to its high relative percentage. *Ophiacantha diplasia*, while only present in 6 of the 41 transects, contributed to 12% of the total abundance. Ophiuroid sp. 5, only present in 4 transects, contributed 6% of the total abundance. *Strongylocentrotus fragilis* contributed 7%; Brisingidae sp. contributed 6%; *Acanthogorgia* sp. contributed 10%. These 5 taxa represented 41% of the total abundance. Taxon lists and total counts from each transect can be found in Appendix 3.

Sites

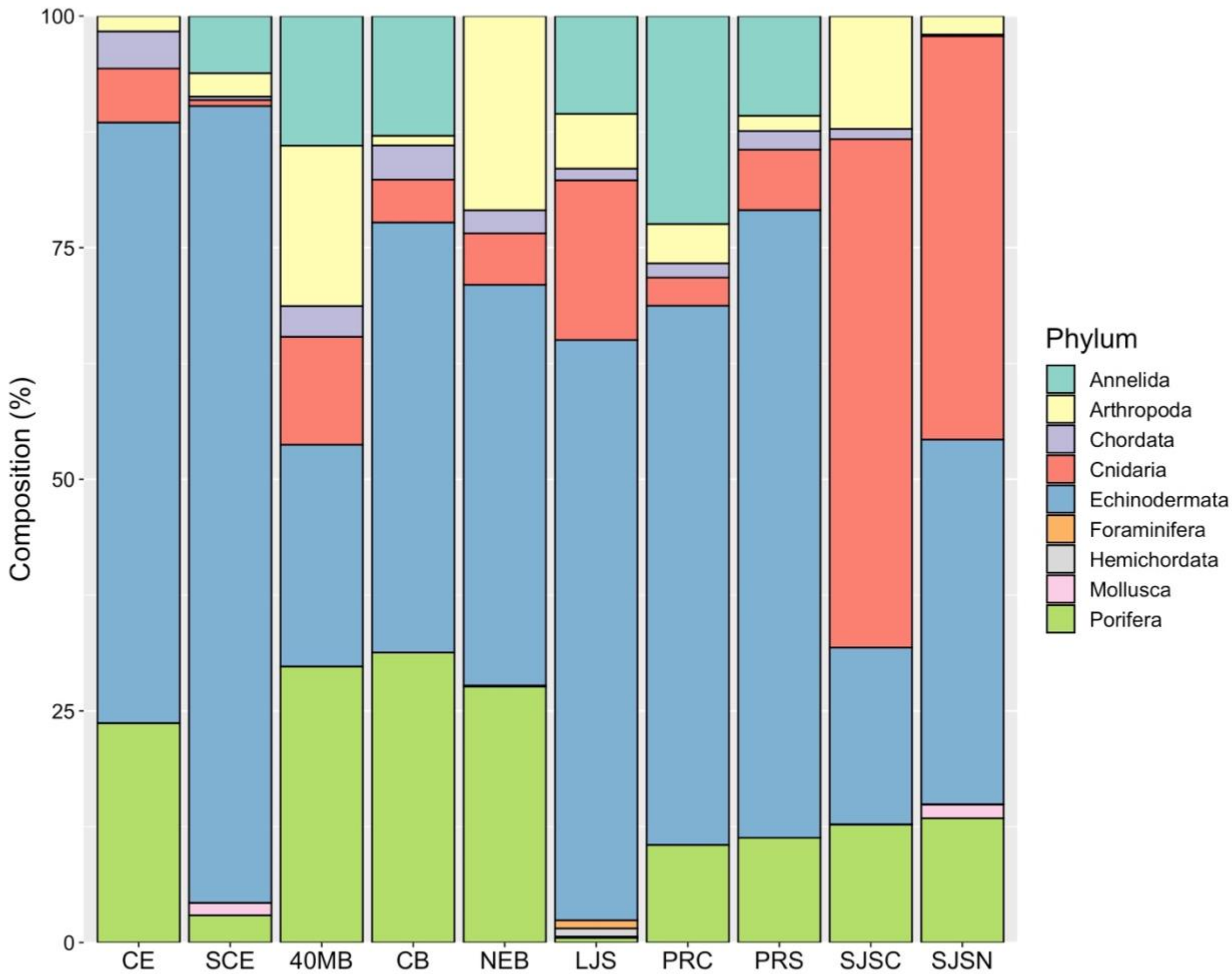

Figure 2. Southern California Borderland phylum composition at each site. CE (Coronado Escarpment); SCE (San Clemente Escarpment); 40MB (40-Mile Bank); CB (Cortes Bank); NEB (Northeast Bank); LJS (Little Joe Seamount); PRC (Patton Ridge Central); PRS (Patton Ridge South); SJSC (San Juan Seamount Central); SJSN (San Juan Seamount North).

Table 2. Total average density (ind. m^{-2}) and standard error from transects at each site and average density excluding ophiuroids.

Cruise	Site	Total avg. density (ind./m^2)	STD Error	Avg. density w/o ophiuroids (ind./m^2)	STD Error
FK210726	Coronado Escarpment	1.101	0.05	1.096	0.05
NA124	San Clemente Escarpment	1.152	0.36	0.244	0.06
NA124	40 Mile Bank	0.771	0.30	0.771	0.30
NA124	Cortes Bank	0.540	0.19	0.432	0.14
NA124	Northeast Bank	0.693	0.20	0.670	0.20
FK210726	Little Joe Seamount	0.372	0.04	0.325	0.03
NA124	San Juan Seamount Central	2.239	0.82	2.239	0.82
NA124	Patton Ridge South	1.803	0.56	0.844	0.21
NA124	San Juan Seamount Central	2.239	0.82	2.239	0.82
FK210726	San Juan Seamount North	2.846	0.48	1.925	0.64

Coronado Escarpment

Coronado Escarpment (Figure 3) contained the shallowest transects analyzed across both cruises, with transects ranging from depths of 471-378 m. The lower depth and higher oxygen levels introduced several unique fish species not observed on other sites. Species including *Merluccius productus*, *Parmaturus xaniurus*, *Hydrolagus colliei*, were observed throughout the dive, but not during transects. While there was a greater number of unique fish species, overall, the site was heavily dominated by few taxa. This is represented in the low diversity indices (Table 3). A total of 2945 individuals were counted across five transects. Transects were heavily dominated by the pink sea urchin *Strongylocentrotus fragilis*, which comprised 57% of the individuals counted. The five most abundant taxa included: the pink sea urchin *Strongylocentrotus fragilis*, at 57%, the carnivorous sponge *Asbestopluma* sp. at 21%, the asteroid *Goniasteridae* sp. 1 at 3%, the octocoral *Parastenella* sp. at 2%, and the sea pen *Anthoptilum* sp. at 2%.

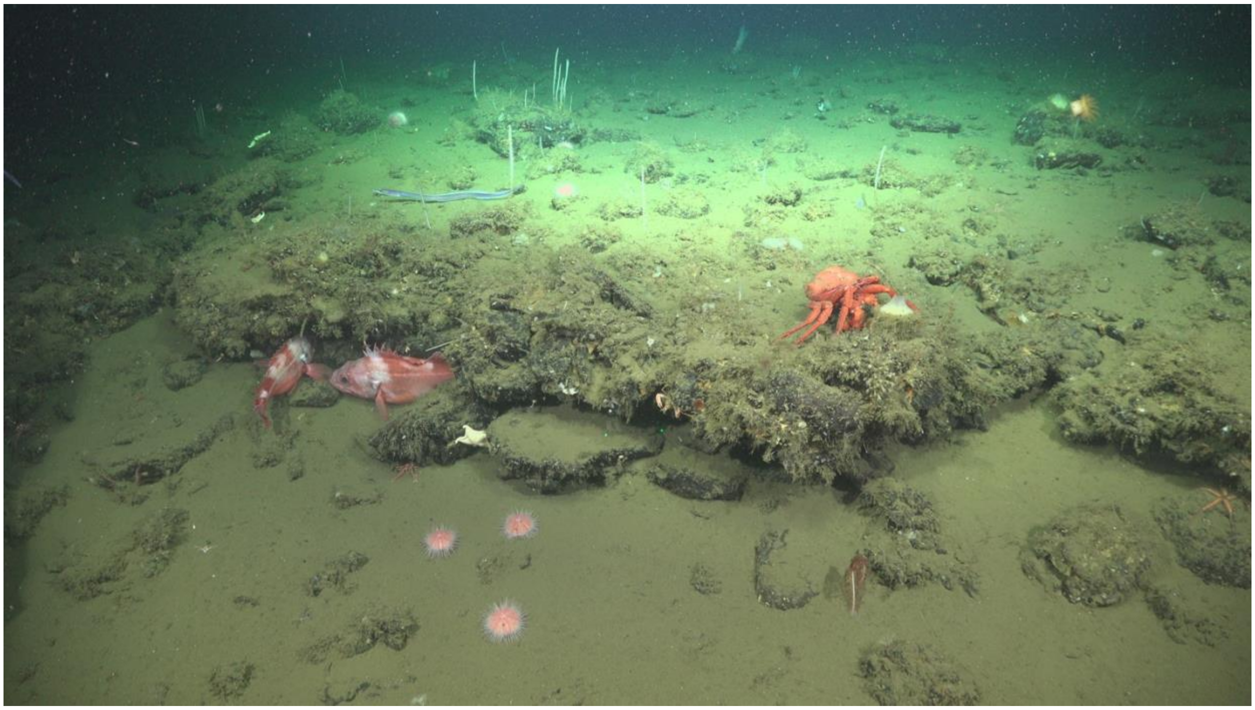

Figure 3. Characteristic taxa found at Coronado Escarpment including the blackgill rockfish *Sebastes melanostomus*, the carnivorous sponge *Asbestopluma* sp., the pink sea urchin *Strongylocentrotus fragilis*, and the king crab *Glyptolithodes cristatipes*.

San Clemente Escarpment

The habitat observed during transects at San Clemente Escarpment (Figure 4) was characterized by mixed rock and sediment, with the primary substrate being FeMn. 2466 individuals were counted across the four transects at San Clemente Escarpment, representing a density of 1.152 with a standard error of 0.36. The most characteristic taxon was ophiuroid sp. 5, which accounted for 79% of the total count. The next four taxon included: the polychaete *Swima* sp. nov. at 6%, the sea cucumber Synallactid sp. at 3%, the sponge *Vulcanellidae poecillastra* at 2%, and the urchin *Aspidodiadematidae* sp. at 1%.


Figure 4. Ophiuroid sp. 5 found at San Clemente Escarpment.

40-Mile Bank

The habitat observed during transects at 40-Mile Bank (Figure 5) was characterized by mixed rock and sediment substrate. A total of 1237 individuals were counted at 40-Mile Bank, representing a density of 0.771 ind. m^{-2} with a standard error of 0.30. The five most abundant taxa included: the sea cucumber *Pannychia* sp. at 17%, the sponge *Rhabdocalyptus* sp. at 17%, the annelid *Myxicola* sp. at 14%, squat lobsters at 7%, and benthic decapods at 6%.

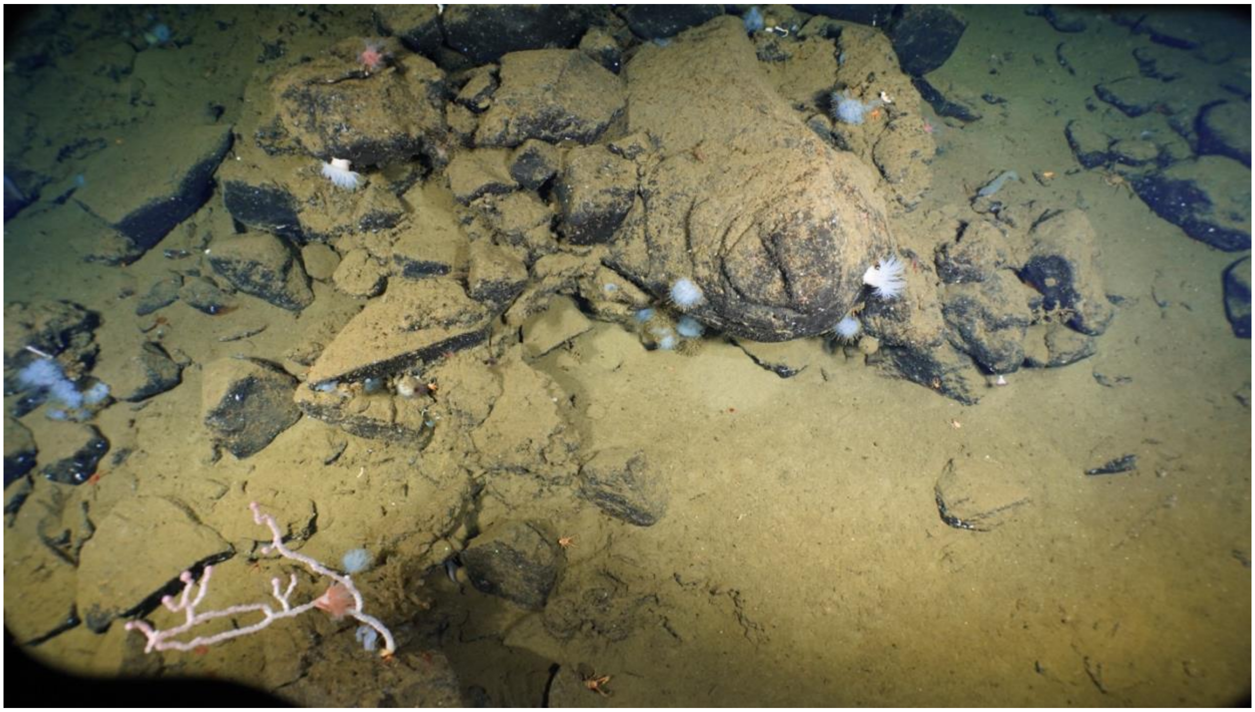

Figure 5. Characteristic fauna found at 40-Mile Bank, including the sea cucumber *Pannychia* sp., the sea anemone *Actiniaria* sp., the octocoral *Paragorgia* sp. and squat lobsters.

Cortes Bank

Cortes Bank (Figure 6) is a shallow seamount, its position is such that it is exposed to the equatorward-flowing California Current and poleward-flowing California Undercurrent (Pondella 2016). The strong bottom surges along with the unique trench-ridge topography creates vertical mixing and enhances upwelling (BLM 1979). The primary habitat contained a mixture of sediment and phosphorite rock. These physical properties seem to be reflected in the diversity indices, as Cortes Bank recorded some of the greater H' values compared with the other sites. While individual counts were low at 867, there was a greater diversity of taxa. The top five most abundant taxa were: the ophiuroid *Ophiacantha diplasia* at 20%, the annelid *Myxicola* sp. at 13%, the sponge hexactinellid sp. 5 at 11%, other hexactinellid spp. At 9%, and the asteroid Brisingidae sp. at 6%.

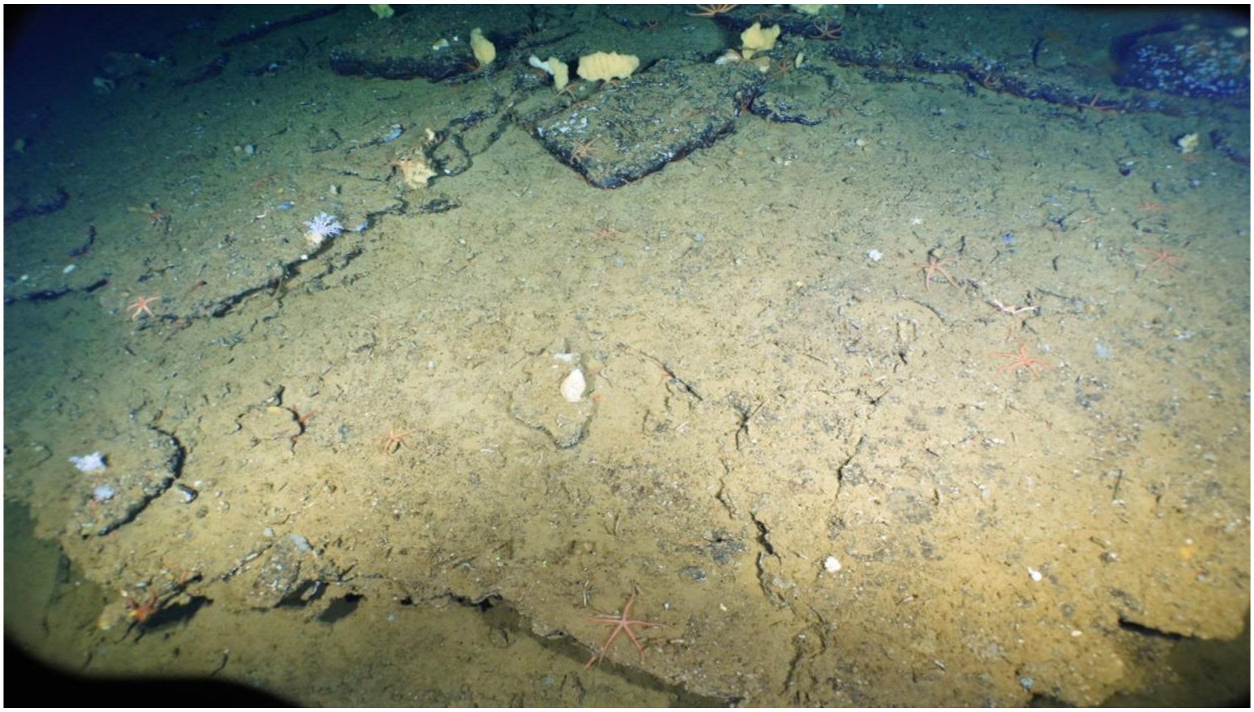
Figure 6. Characteristic fauna found at Cortes Bank including the ophiuroid *Ophiacantha diplasia*, hexactinellid "puffball" sponges and the sponge *Mycale* sp. – 460 m.

Northeast Bank

The habitat observed at Northeast Bank during transects was characterized by mixed sediment and rock substrate with thin, ferromanganese patina. The community here was notably less dense and diverse than other sites, with an average species count of 40 across 1854 total individuals and an average density of 0.771 ind. m^{-2} and standard error of 0.30. The community was comprised of characteristic taxa across the SCB, including the sea star Brisingidae sp., *Farrea* sp. (likely *F. occa*), squat lobsters, and benthic decapods. A unique feature of Northeast Bank was the sea cucumber community, where each transect contained one dominant species of sea cucumber per transect: *Benthodytes* sp., *Psolus* sp. (likely *P. squamatus*), *Pannychia* sp. (Figure 7). The five most abundant taxa included: the asteroid Brisingidae sp. at 28%, the sponge *Farrea* sp. at 18%, squat lobsters at 10%, benthic decapods at 9%, and the sea cucumber *Psolus* sp. at 3%.

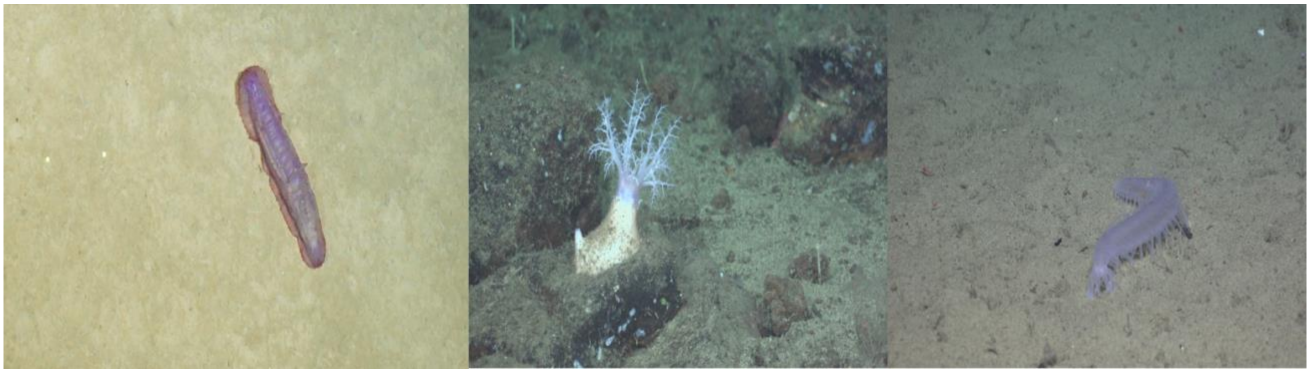
Figure 7. *Benthodytes* sp., *Psolus squamatus*, and *Pannychia* sp. found at Northeast Bank.

Little Joe Seamount

Little Joe Seamount (Figure 8) contained the deepest transects across both cruises, with transects ranging from depths of 2765 m to 2366 m. At this depth, every transect fell below the OMZ (defined in this paper as < 20 μmol O_2 L^{-1}), containing an average oxygen value of 105.67 μmol O_2 L^{-1} across the four transects. This site also contained the fewest total individuals counted at 795 across the four transects. The most abundant and characteristic taxon was the crinoid *Psathrometra fragilis*, at 15%. The next four taxa included: the crinoid *Antedonidae* sp. at 13%, the polychaete *Swima* sp. nov. at 10%, ophiuroid sp. 2 at 10%, and anemone sp. 1 at 6%.

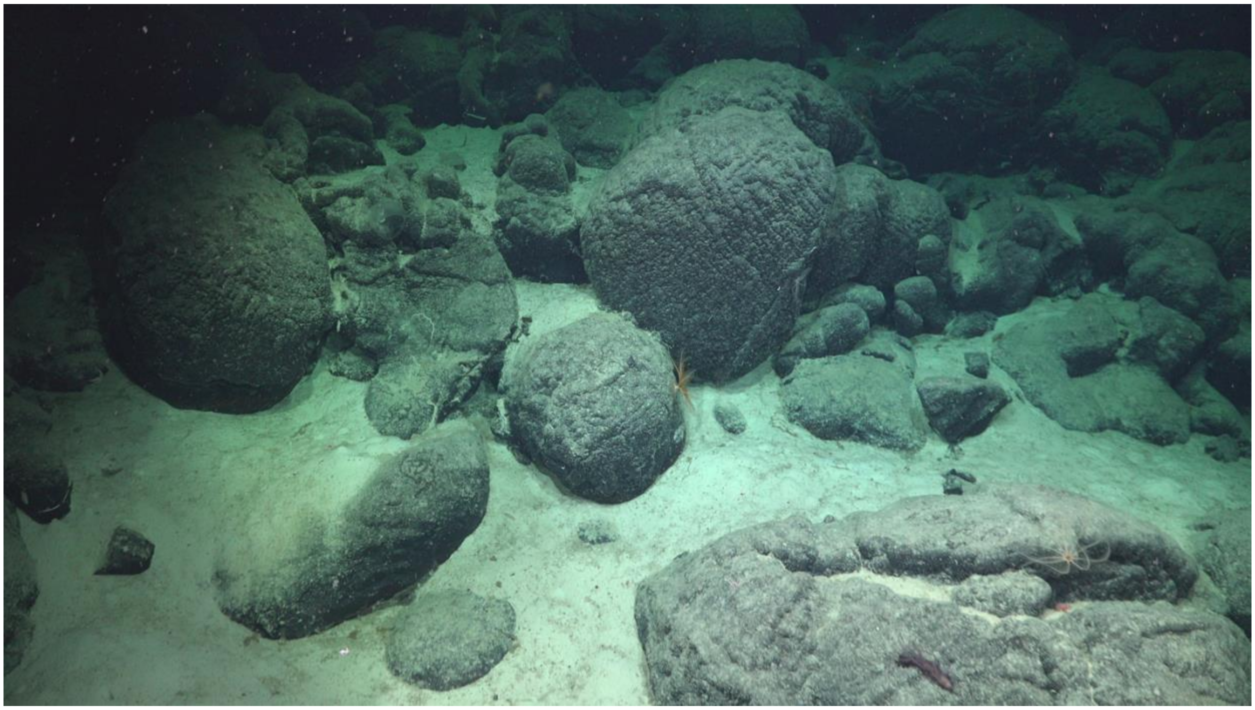
Figure 8. Characteristic crinoids *Psathyrometra fragilis* and *Antedonidae* sp. found at Little Joe Seamount – 2480 m.

Patton Ridge

Two dives took place at Patton Ridge. The first, Patton Ridge Central is characterized by a mixture of rock and sediment, with the primary substrate for this rock being basalt, sandstone, and sedimentary conglomerate. The benthos at Patton Escarpment is uniquely characterized by dense bands of the brittle star, *Ophiacantha diplasia* (Figures 9A,B), which was the most abundant species present on the transects, comprising 34% of the 4802 total individuals counted across the three transects, representing a density of 2.992 ind. m^{-2} with a standard error of 0.95. This brittle star band was only observed during the last transect of the dive, ranging from depths of 567-538 m, oxygen values ranging from 5.78-6.35 μmol O_2 L^{-1} and temperature values ranging from 5.98-6.03 °C. This band displayed zonation, where the brittle stars fell within distinct start and st$_o$p positions. The next four most dominant taxa included: the annelid *Myxicola* sp. at 23% of the total individuals counted, the pink sea urchin *Strongylocentrotus fragilis* at 12%, the sea cucumber *Pannychia* sp. at 8%, and the hexactinellid “puffball” sponge at 5%.

The habitat observed during transects during the second dive at Patton Ridge South was characterized by mixed rock and sediment, with the primary substrate being phosphorite. A total of 3859 individuals were counted across the four transects, representing a density of 1.803 ind. m^{-2} with a standard error of 0.56. Like Patton Ridge Central, the most abundant species at Patton Ridge South was the brittle star, *Ophiacantha diplasia*, comprising 53% of the total individuals counted. This band was observed during both Transect 3 and Transect 4, with depths ranging from 604-560 m, oxygen values ranging from 3.84-4.93 μmol O_2 L^{-1} , and temperature values ranging from 5.61-5.85 °C. The next four most abundant taxa include: the annelid *Myxicola* sp. at 11%, the asteroid Brisingidae sp. at 5%, the sea cucumber *Pannychia* sp. at 5% and the sponge *Farrea* sp. at 4%.

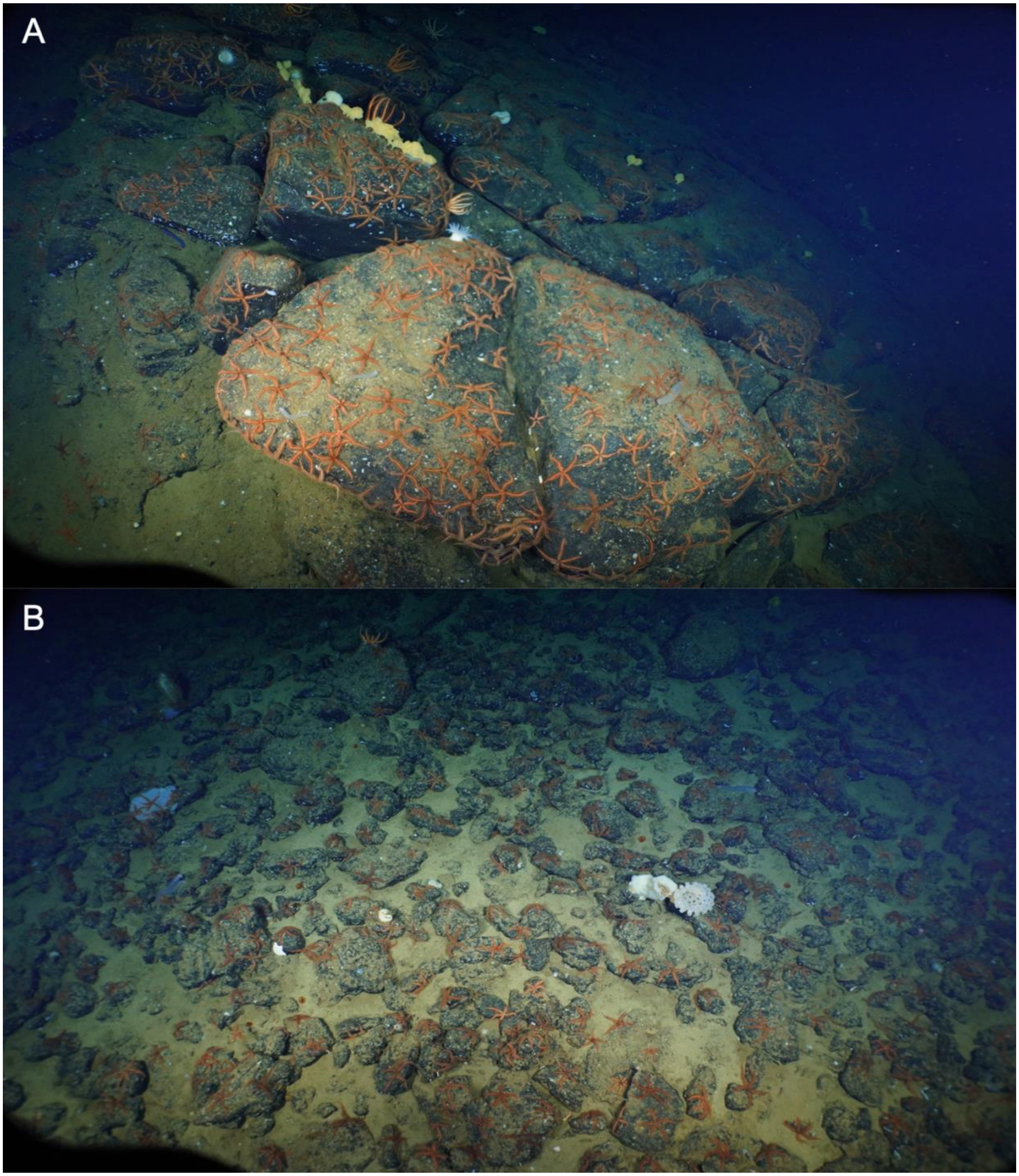

Figure 9. *Ophiacantha diplasia* observed at (A) Patton Escarpment Central - 560 m, and (B) Patton Escarpment South - 580 m.

San Juan Seamount

The habitat observed during all transects at San Juan Seamount was characterized by rocky substrate with thin, ferromanganese patina. A total of 5988 individuals were counted across the five transects at San Juan Seamount Central, representing a density of 2.239 ind. m^{-2}, with a standard error of 0.82. A total of 7613 individuals were counted across the five transects at San Juan Seamount North, representing a density of 2.846 ind. m^{-2} with a standard error of 0.48. The community at San Juan Seamount was uniquely characterized by its coral and sponge gardens, observed at both shallower and deeper depths (Figure 10A,B). This was observed on San Juan Seamount Central ranging from depths of 756-595 m and oxygen values of 4.02-3.59 μmol O_2 L^{-1} and on San Juan Seamount North ranging from depths of 1280-1138 m, and oxygen values from 34.90-34.87 μmol O_2 L^{-1}. The first two transects at San Juan Seamount Central displayed low densities at 0.13 and 0.36 ind. m^{-2} respectively, while transects 3,4, and 5 displayed higher density 3.52, 3.35, and 3.83 ind. m^{-2}. A similar trend was observed on San Juan Seamount North. The first two transects were dominated by several ophiuroid species, while transects 3,4, and 5 contained the coral and sponge garden. The five most abundant taxa at San Juan Seamount Central were: the coral Red *Swiftia* sp. at 25%, the asteroid Brisingidae sp. at 17%, benthic decapods at 11%, the corals *Parastenella* sp. at 9% and *Paragorgia* sp. at 9%. The most abundant taxa at San Juan Seamount North were: the coral *Acanthogorgia* sp. at 36%, ophiuroid sp. 2 at 19%, Ophiuroid sp. 4 at 6%, the carnivorous sponge *Asbestopluma* sp. at 6%, and ophiuroid sp. 3 at 5%.

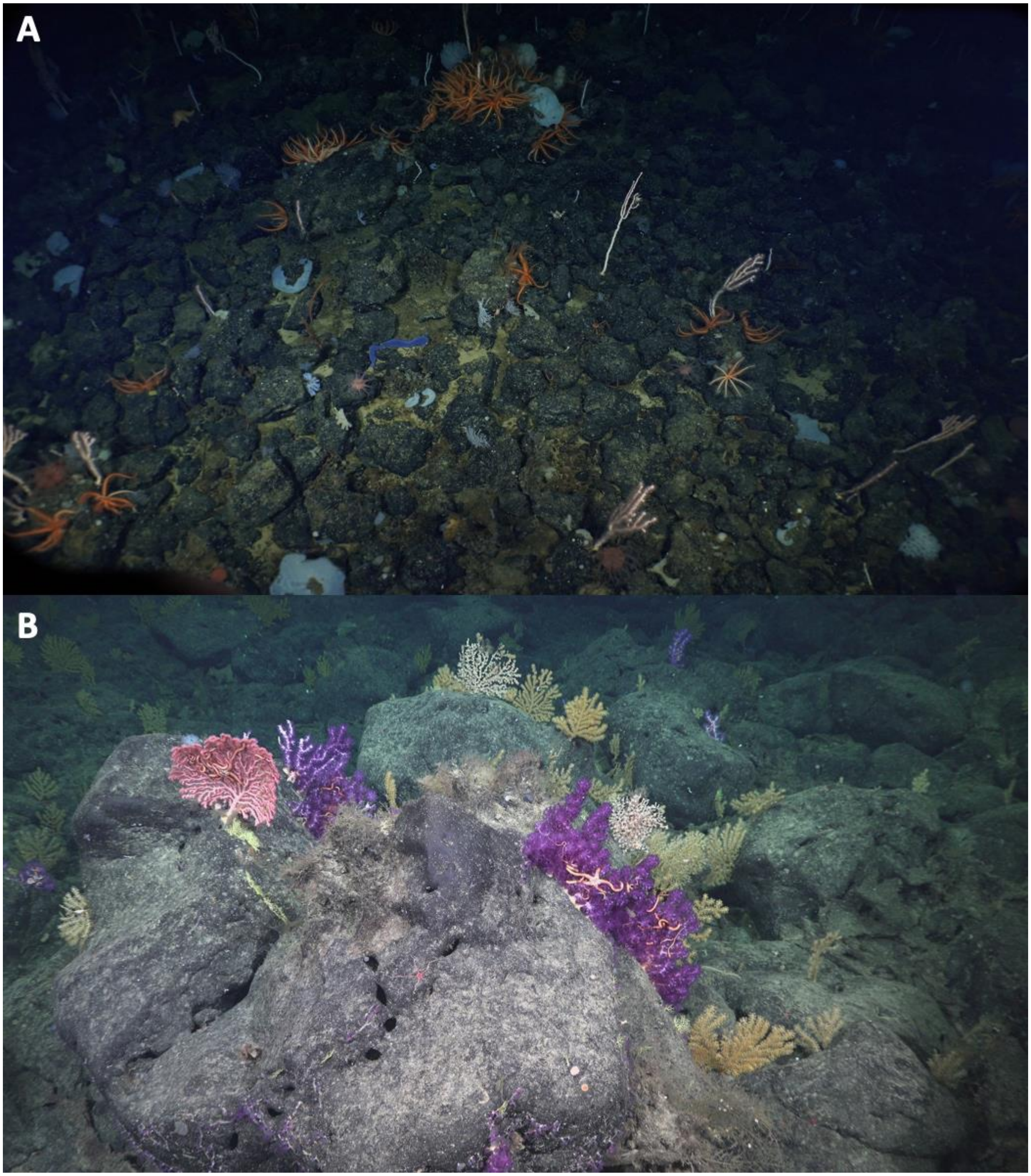

Figure 10. Coral and sponge gardens observed on San Juan Seamount (A) Central - Species present include *Paragorgia* sp., *Parastenella* sp., *Heteropolypus* sp., *Farrea* sp., and Brisingidae sp. (B) North - Species present include *Acanthogorgia* sp., *Paragorgia* sp., *Victorgorgia* sp., *Parastenella* sp., and *Zoanthidae* sp. - 1250 m.

Among-site comparisons

Density

Megafaunal density differed across sites (W = 0.945, p = 0.047). However, the only two sites exhibiting a statistically significant difference in densities were between San Juan Seamount North and Little Joe Seamount (t-test, p = 0.033), with density higher at the former site. Mean density was greatest on Patton Ridge (2.99 ± 0.95 ind. m^{-2}), due to the presence of the dense bands of *Ophiacantha diplasia* (Table 2; Figure 10A,B). To observe the effect ophiuroids had on density, they were temporarily removed from the analysis. Once removed, density was greatest on San Juan Seamount (2.24 ± 0.82 ind. m^{-2}) – the location of both coral and sponge gardens. Density (without ophiuroids) was lowest at San Clemente Escarpment (0.24 ± 0.06 ind. m^{-2}) and Little Joe Seamount (0.33 ± 0.03 ind. m^{-2}), the two deepest sites in this study (Table 2).

Community Composition

The greatest dissimilarities in community composition occurred across locations (ANOSIM, Global R = 0.748, p = 0.001) (Figure 15A). Echinodermata was the dominant phylum across sites except for on San Juan Seamount, which had a greater abundance of Cnidaria (Figure 2). These cnidarians were comprised primarily of octocorals. Three sites seemed to contribute most to the variation in community composition: Coronado Escarpment, San Clemente Escarpment, and Little Joe Seamount. These sites, which include the shallowest and the two deepest sites, respectively, exhibited extreme dissimilarities between each other and the communities at other sites.

Taxa contributing to these differences (SIMPER, Average dissimilarity = 88.10) include the pink sea urchin *Strongylocentrotus fragilis*, and the carnivorous sponge *Asbestopluma* sp., which were present on Coronado Escarpment, but nearly absent at Little Joe Seamount. The crinoids *Psathyrometra fragilis* and *Antedonidae* sp., and the polychaete *Swima* sp. nov. were present at Little Joe Seamount but absent at every other site.

Diversity

The greatest number of unique taxa observed (i.e., taxa only seen at a single site) was at San Juan Seamount North, Patton Ridge South, and Little Joe Seamount. Taxon diversity (H') appears to align with taxon evenness (J'), as the sites with the greatest diversity, 40-Mile Bank, Little Joe Seamount, and Cortes Bank, also had the greatest evenness (Table 3). Rarefaction richness across sites (Figure 11) was greatest on Little Joe Seamount, 40 Mile Bank, and Northeast Bank (Table 3). These sites also contained some of the lowest observed densities. Rarefaction richness was smallest on San Clemente Escarpment, Coronado Escarpment, and Patton Ridge South (Table 3). These sites were heavily dominated by few a species such as ophiuroids or sea urchins.

Table 3. Average richness (S), diversity (H') (calculated in log(10)), evenness (J'), and ES100 for transects at each site studied in the Southern California Borderland.

Cruise	Site	S	H'	STD Error	J'	STD Error	ES_{100}
FK210726	Coronado Escarpment	26.80	1.82	0.16	0.55	0.05	15.44
NA124	San Clemente Escarpment	19.75	1.44	0.50	0.48	0.16	11.29
NA124	40 Mile Bank	29.67	3.06	0.27	0.90	0.08	25.22
NA124	Cortes Bank	25.00	2.79	0.30	0.88	0.03	22.92
NA124	Northeast Bank	23.20	2.49	0.15	0.81	0.06	23.36
FK210726	Little Joe Seamount	28.50	3.01	0.11	0.90	0.01	27.08
NA124	Patton Ridge Central	28.00	2.09	0.41	0.62	0.11	14.71
NA124	Patton Ridge South	31.75	2.30	0.53	0.67	0.16	20.05
NA124	San Juan Seamount Central	24.20	2.38	0.14	0.77	0.07	17.26
FK210726	San Juan Seamount North	38.20	2.22	0.12	0.61	0.03	19.98

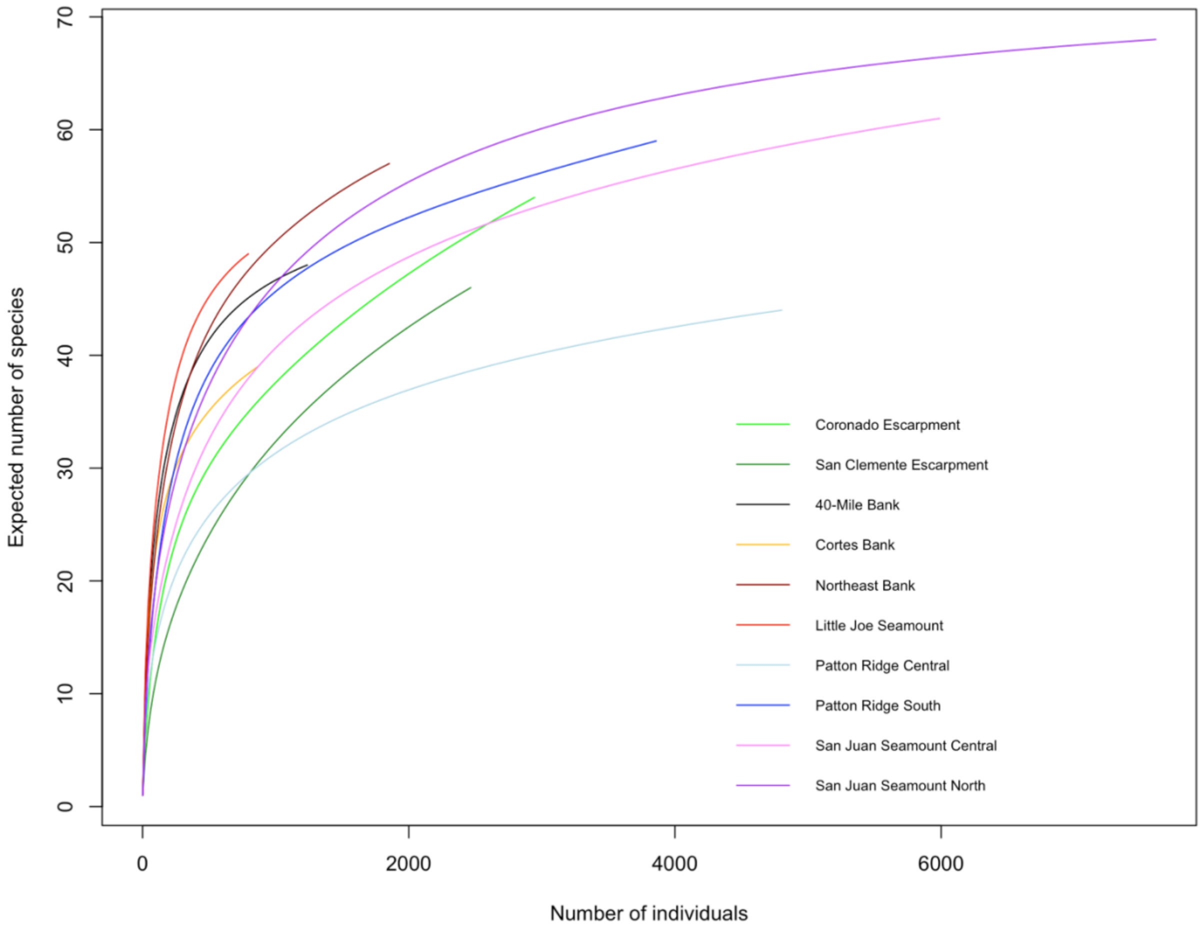

Figure 11. Rarefaction (ES) plots for megafauna observed at each site

Substrate type

Density

The average megafaunal density on FeMn (1.46 ± 1.49 ind. m^{-2}) and phosphorite (1.51 ± 0.86 ind. m^{-2}) substrates was about 15% less than other rock substrate (1.73± 1.43 ind. m^{-2}) (Figure 14A). However, the densities on FeMn, phosphorite, and other rock types were highly variable and not statistically different from one another (W=0.975, p = 0.4819).

Community Composition

There was a weak but significant difference in community composition across substrate types (ANOSIM, Global R = 0.197, p = 0.005) (Figure 15B). The communities on FeMn substrates were dominated by both Echinodermata (44%) and Cnidaria (32%). The most dominant group on phosphorite substrates was Echinodermata (73%), followed by Porifera (16%) (Figure 16A).

The communities on FeMn substrates showed some differences from those on other rocks substrates, but had overlap (ANOSIM, R = 0.193, p = 0.034). Taxa contributing to these differences (SIMPER, Average dissimilarity = 76.66) include the annelid *Myxicola* sp., the sea cucumber *Pannychia* sp., the asteroid Brisingidae sp., the hexactinellid “puffball” sponge, and the crab *Chorilia lonipes*, all of which were more abundant on Other Rock substrates. The communities on phosphorite substrates were significantly different from those on other rock substrates (ANOSIM, R = 0.48, p = 0.003). The taxa contributing to the differences on phosphorite and other rock substrates (SIMPER, Average dissimilarity = 74.81) include the pink sea urchin *Strongylocentrotus fragilis*, the carnivorous sponge *Asbestopluma* sp., and the brittle star *Ophiacantha diplasia*, which were more abundant on phosphorite substrates. The annelid *Myxicola* sp. and the sea cucumber *Pannychia* sp. were more abundant on Other Rock. There was a statistically greater difference between communities on FeMn and phosphorite substrates (ANOSIM, R = 0.426, p = 0.001). The primary taxa contributing to this difference (SIMPER, Average dissimilarity = 82.36) include the pink sea urchin *Strongylocentrotus* fragilis, the carnivorous sponge *Asbestopluma* sp., the sea pen *Anthoptilum grandiflorum*, and the hexactinellid “puffball” sponge, all of which were more abundant on phosphorite substrates. The sponge *Farrea* sp. was more abundant on FeMn substrates.

Diversity

Rarefaction richness across substrates (Figure 12) was greatest on FeMn crusts (ES_{100} = 27.67), and Phosphorite/Other Rock (ES_{100} = 27.18). Rarefaction richness was lowest on Phosphorites (ES_{100} = 18.97) and increased on FeMn/Other Rock (ES_{100} = 22.65) and Other Rock (ES_{100} = 23.07). ES_{50} richness was not statistically different across substrate types (ANOVA, $p>0.05$).

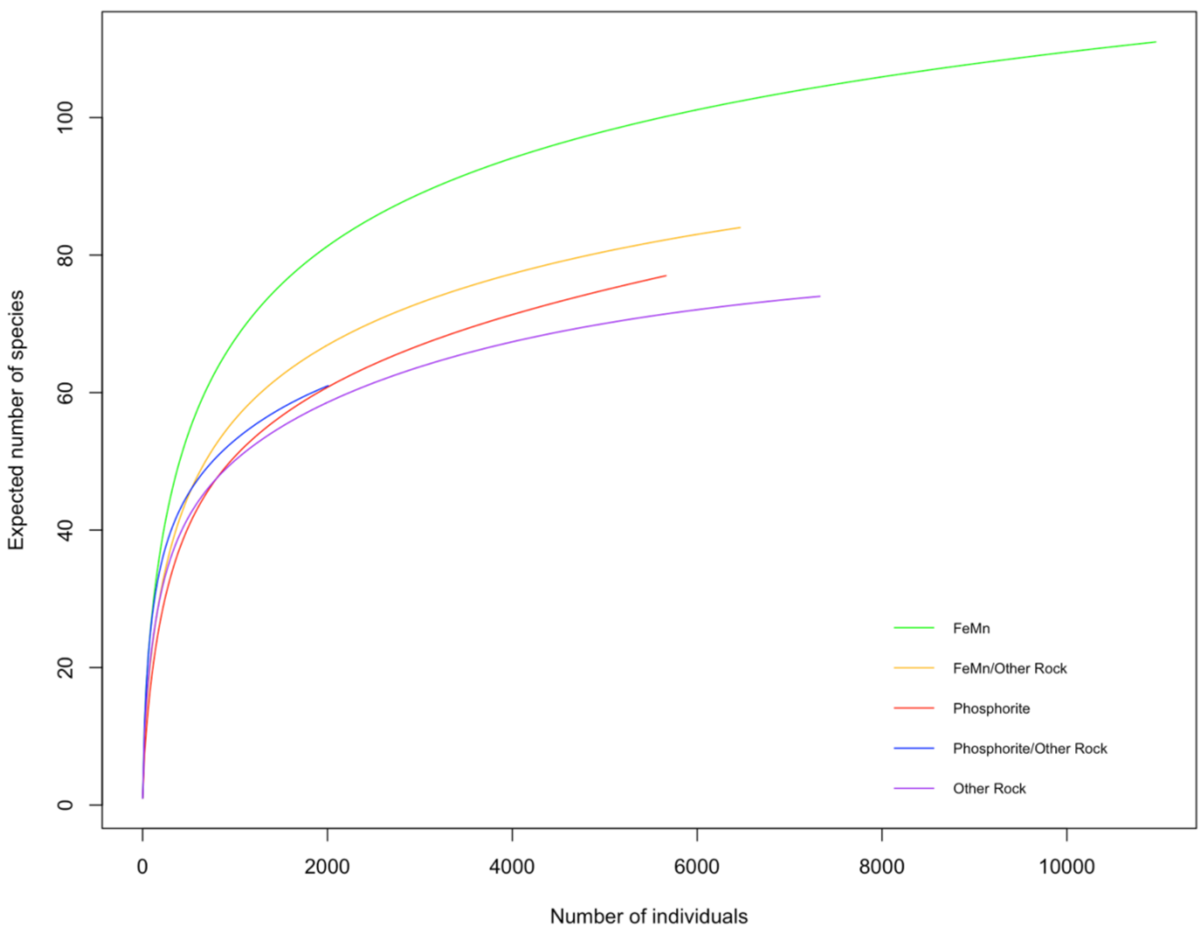

Figure 12. Rarefaction (ES) plots for megafauna observed across substrate type.

Depth

Density

The average megafaunal density showed little variation between depth ranges of 0-600 m (1.33 ± 1.18 ind. m^{-2}), 600-1000 m (1.67 ± 1.30 ind. m^{-2}), and 1000-2800 m (1.37 ± 1.32 ind. m^{-2}) (Figure 14B.). There was no statistical difference among megafauna densities in these depth zones (W = 0.969, p = 0.309).

Community Composition

Community composition varied significantly across all depth zones (ANOSIM, Global R = 0.475, p = 0.01) (Figure 15C). The community within the depth range of 0-600 m was heavily dominated by Echinodermata (65%), followed by Porifera (19%). The community within 600-1000 m was more evenly split between Echinodermata (38%), Cnidaria (27%), and Porifera (15%). Community composition within the depth range of 1000-2800 m also was split between Echinodermata (51%), Cnidaria (32%), and Porifera (10%) (Figure 16B).

The taxa contributing to differences between depths of 0-600 m and 600-1000 m (SIMPER, Average dissimilarity = 70.92) include the pink sea urchin *Strongylocentrotus fragilis*, and the brittle star *Ophiacantha diplasia,* both of which more abundant at depths of 0-600 m. The sponge *Farrea* sp., the asteroid Brisingidae sp., and the annelid *Myxicola* sp. were more abundant between 600-1000 m. The taxa contributing to differences between depths of 0-600 m and 1000-2800 m (SIMPER, Average dissimilarity = 83.91) include the pink sea urchin *Strongylocentrotus fragilis,* the carnivorous sponge *Asbestopluma* sp., the brittle star *Ophiacantha diplasia*, and the hexactinellid “puffball” sponge, all of which were more abundant at depths of 0-600 m. Ophiuroid sp. 5 was more abundant between 1000-2800 m. The taxa contributing to differences between depths of 600-1000 m and 1000-2800 m (SIMPER, Average dissimilarity = 78.03) include the asteroid Brisingidae sp., the sea cucumber *Pannychia* sp., the sponge *Farrea* sp., and the annelid *Myxicola* sp., all of which were more abundant between 600-1000 m. The octocoral *Acanthogorgia* sp. was more between 1000-2800 m.

Oxygen

Density

The average megafaunal density showed little variation among various oxygen concentration categories 0-6 μmol O_2 L^{-1} (1.73 ± 1.28 ind. m^{-2}), 6-22 μmol O_2 L^{-1} (1.37 ± 1.76 ind. m^{-2}), 22-40 μmol O_2 L^{-1} (1.37 ± 1.05 ind. m^{-2}), and 40-110 μmol O_2 L^{-1} (1.15 ± 1.43 ind. m^{-2}) (Figure 14C). There was no statistically significant difference in megafaunal densities as a function of these 4 oxygen categories (W = 0.970, p = 0.336).

Community Composition

There were differences in megafaunal community composition across the four oxygen concentration categories (ANOSIM, Global R = 0.507, p-value = 0.001) (Figure 15D). The community within the 0-6 μmol O_2 L^{-1} oxygen range was more evenly distributed between Echinodermata (39%), Cnidaria (26%) and Porifera (15%). At 6-22 μmol L^{-1} , the community shifted more toward Echinodermata (64%), followed by Porifera (17%) and Annelida (11%). At 22-40 μmol O_2 L^{-1}, the community was split between Echinodermata (45%), and Cnidaria (33%). The community within the oxygen range of 40-110 μmol O_2 L^{-1} was heavily dominated by Echinodermata (79%) (Figure 16C).

All communities except for 0-6 vs 6-22 μmol O_2 L^{-1} and 6-22 μmol O_2 L^{-1} vs 22-40 μmol O_2 L^{-1} (ANOSIM, p > 0.05) were statistically different. The communities on opposite ends of the oxygen spectrum (0-6 μmol O_2 L^{-1} vs 40-110 μmol O_2 L^{-1}) showed the most variability (ANOSIM, R = 0.954, p = 0.001). The taxa contributing to these differences (SIMPER, Average dissimilarity = 85.45) include ophiuroid sp. 5 and the crinoid *Antedonidae* sp. both of which were more abundant at ranges of 40-110 μmol O_2 L^{-1} . The asteroid Brisingidae sp., the sea cucumber *Pannychia* sp., and the sponge *Farrea* sp. were more abundant between 0-6 μmol O_2 L^{-1} . The next greatest variability in community composition occurred between the ranges of 22-40 μmol O_2 L^{-1} and 40-110 μmol O_2 L^{-1} (ANOSIM, R = 0.869, p = 0.002). The taxa contributing to the differences (SIMPER, Average dissimilarity = 80.66) include ophiuroid sp. 2, the crinoid *Antedonidae* sp., and the crinoid *Psathyrometra* fragilis, which were more abundant between 40-110 μmol O_2 L^{-1} . The pink sea urchin *Strongylocentrotus fragilis* and the carnivorous sponge *Asbestopluma* sp. were more abundant between 22-40 μmol O_2 L^{-1}. Communities within 0-6 μmol O_2 L^{-1} and 22-40 μmol O_2 L^{-1} showed significant differences in their composition (ANOSIM, R = 0.501, p = 0.001). Taxa contributing to these differences (SIMPER, Average dissimilarity = 76.89) include the asteroid Brisingidae sp., the sea cucumber *Pannychia* sp., and the annelid *Myxicola* sp., which were more abundant between 0-6 μmol L^{-1} . The pink sea urchin *Strongylocentrotus fragilis* and the carnivorous sponge *Asbestopluma* sp. were more abundant between 22-40 μmol O_2 L^{-1}. Communities within 22-40 μmol O_2 L^{-1} and 40-110 μmol O_2 L^{-1} showed significant differences, but had some overlap (ANOSIM, R = 0.318, p = 0.003). The taxa contributing to these differences (SIMPER, Average dissimilarity = 80.66) include ophiuroid sp. 2, the crinoid *Antedonidae* sp., and the crinoid *Psathyrometra fragilis* were more abundant between 40-110 μmol O_2 L^{-1}. The pink sea urchin *Strongylocentrotus fragilis* and the carnivorous sponge *Asbestopluma* sp. were more abundant between 22-40 μmol O_2 L^{-1}.

Diversity

Oxygen appears not to exert strong control on megafaunal diversity. Surprisingly, the highest diversity was observed at sites with very low oxygen (e.g., 40-mle bank, Patton Ridge, Cortes Bank) and with very high oxygen (Little Joe seamount), with lowest diversity (San Clemente Escarpment) at intermediate oxygen levels where bands of brittle stars predominate (Figure 13).

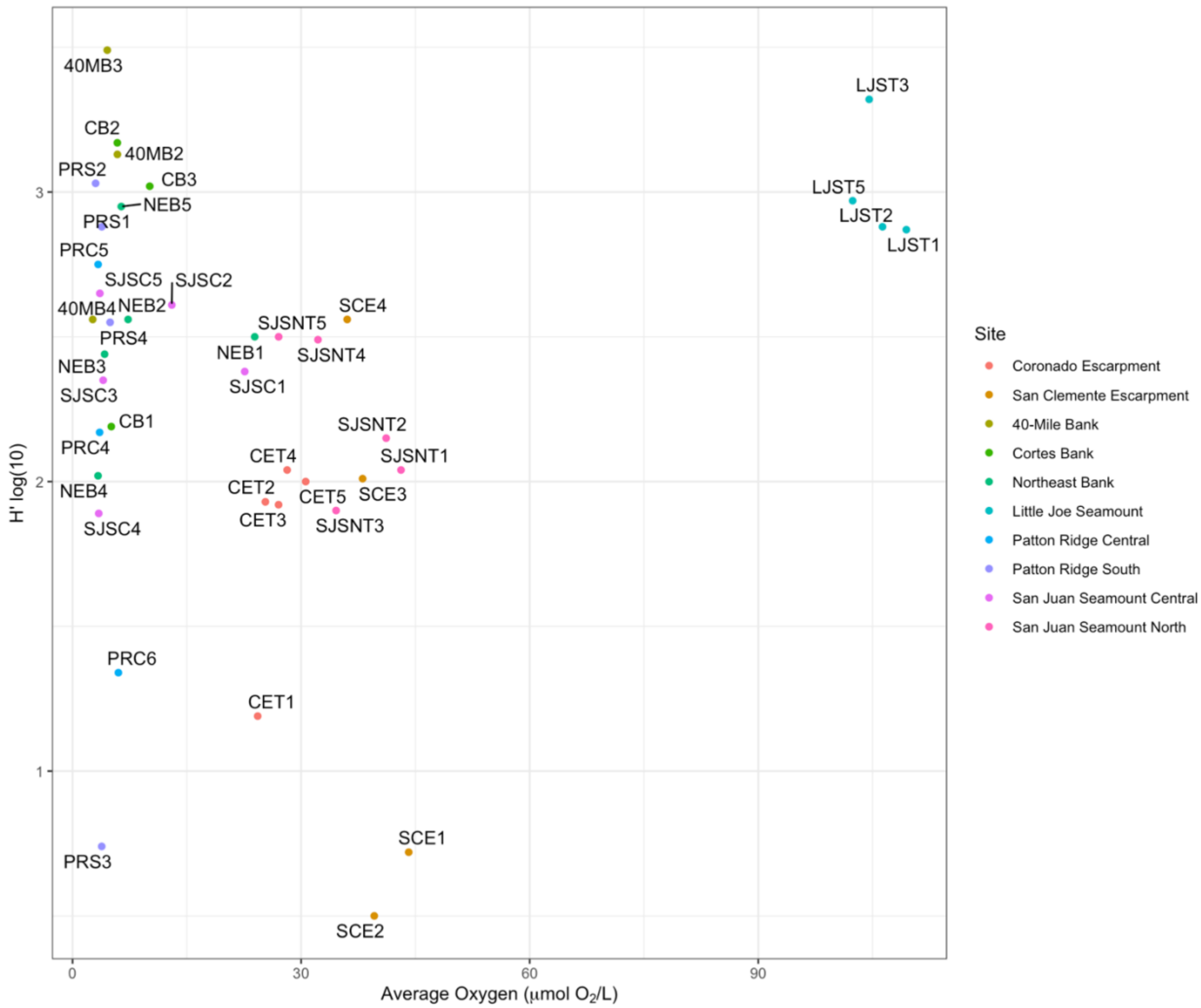

Figure 13. Individual transect diversity (H') as a function of oxygen concentration.

Temperature

Density

Average megafaunal densities were lowest at temperatures ranging from 1-3 °C (0.84 ± 0.64 ind. m^{-2}) and greatest between 5-6 °C (2.38 ± 1.18 ind. m^{-2}) (Figure 14D.). However, these average densities were not statistically different from one another (W = 0.979, p = 0.646).

Community Composition

Communities showed differences with some overlap in their composition due to temperature (ANOSIM, Global R = 0.495, p = 0.001) (Figure 15E). Communities within 1-3 °C range were heavily dominated by Echinodermata (81%). Within 3-5 °C, communities were more evenly distributed between Echinodermata (36%), Cnidaria (36%), and Porifera (15%). Similarly, communities within 5-6 °C displayed a more even split between Echinodermata (41%), Cnidaria (29%), and Porifera (14%). Communities within 6-9 °C were more dominated by Echinodermata (64%) and Porifera (20% (Figure 16D).

The greatest difference in community composition occurred between temperature ranges of 1-3 °C and 5-6 °C (ANOSIM, R = 0.873, p = 0.001). The taxa contributing to these differences (SIMPER, Average dissimilarity = 85.67) include the asteroid Brisingidae sp. and the annelid *Myxicola* sp., which were more abundant between 5-6 °C. Ophiuroid sp. 5, the sponge *Farrea* sp., and the polychaete *Swima* sp. nov. were more abundant between 1-3 °C. Groups within temperature ranges of 1-3 °C and 6-9 °C displayed the next greatest difference (ANOSIM, R = 0.785, p = 0.001). The taxa contributing to these differences (SIMPER, Average dissimilarity = 88.01) include ophiuroid sp. 5 and the polychaete *Swima* sp. nov., which were more abundant between 1-3 °C. The pink sea urchin *Strongylocentrotus fragilis*, the carnivorous sponge *Asbestopluma* sp., and the hexactinellid "puffball" sponge were more abundant between

6-9 °C. Groups within temperature ranges of 1-3 °C and 3-5 °C displayed significant differences (ANOSIM, R = 0.615, p = 0.001). The taxa contributing to these differences (SIMPER, average dissimilarity = 80.66) include ophiuroid sp. 5 and the polychaete *Swima* sp. nov., which were more abundant between 1-3 °C. The sponge *Farrea* sp., ophiuroid sp. 2, and the urchin *Araeosoma* sp were more abundant between 3-5 °C. Groups within temperature ranges of 3-5 °C and 6-9 °C displayed significant differences (ANOSIM, R = 0.479, p = 0.001). Taxa contributing to these differences (SIMPER, Average dissimilarity = 77.63) include the pink sea urchin *Strongylocentrotus fragilis*, the brittle star *Ophiacantha diplasia* and the carnivorous sponge *Asbestopluma* sp., which were more abundant between 6-9 °C. The sponge *Farrea* sp., benthic decapods, and squat lobsters were more abundant between 3-5 °C. Groups within temperature ranges of 5-6 °C and 6-9 °C displayed significant differences with some overlap (ANOSIM, R = 0.355, p = 0.002). Taxa contributing to these differences (SIMPER, Average dissimilarity = 68.61) include the pink sea urchin *Strongylocentrotus fragilis* and the brittle star *Ophiacantha diplasia*, which were more abundant between 6-9 °C. The sponge *Farrea* sp., the asteroid Brisingidae sp., and the annelid Myxicola sp. were more abundant between 5-6 °C. Groups within temperature ranges of 3-5 °C and 5-6 °C displayed significant differences (ANOSIM, R = 0.355, p = 0.002). The taxa contributing to these differences (SIMPER, Average dissimilarity = 67.59) include the asteroid Brisingidae sp., the annelid *Myxicola* sp., the sea cucumber *Pannychia* sp., and the octocoral *Paragorgia* sp., which were more abundant between 5-6 °C. The octocoral *Acanthogorgia* sp. was more abundant between 3-5 °C.

Proximity to shore

Density

The average megafaunal densities across inshore dive sites was lower for inshore sites (1.03 ± 0.47 ind. m^{-2}) than for offshore sites (1.66 ± 1.43 ind. m^{-2} (Figure 14E.). The mean densities were statistically different ($t = -2.094$, $df = 37.983$, $p = 0.043$).

Community Composition

Communities showed a significant, albeit small difference in composition due to proximity (ANOSIM, Global $R = 0.203$, $p = 0.013$) (Figure 15F). There was a greater abundance of Cnidaria offshore and Chordata inshore (Figure 16E). The taxa contributing to the differences (SIMPER, Average dissimilarity = 76.59) include the pink sea urchin *Strongylocentrotus fragilis*, ophiuroid sp. 5, and the carnivorous sponge *Asbestopluma* sp., which were more abundant inshore. The asteroid Brisingidae sp. and the sponge *Farrea* sp. were more abundant offshore.

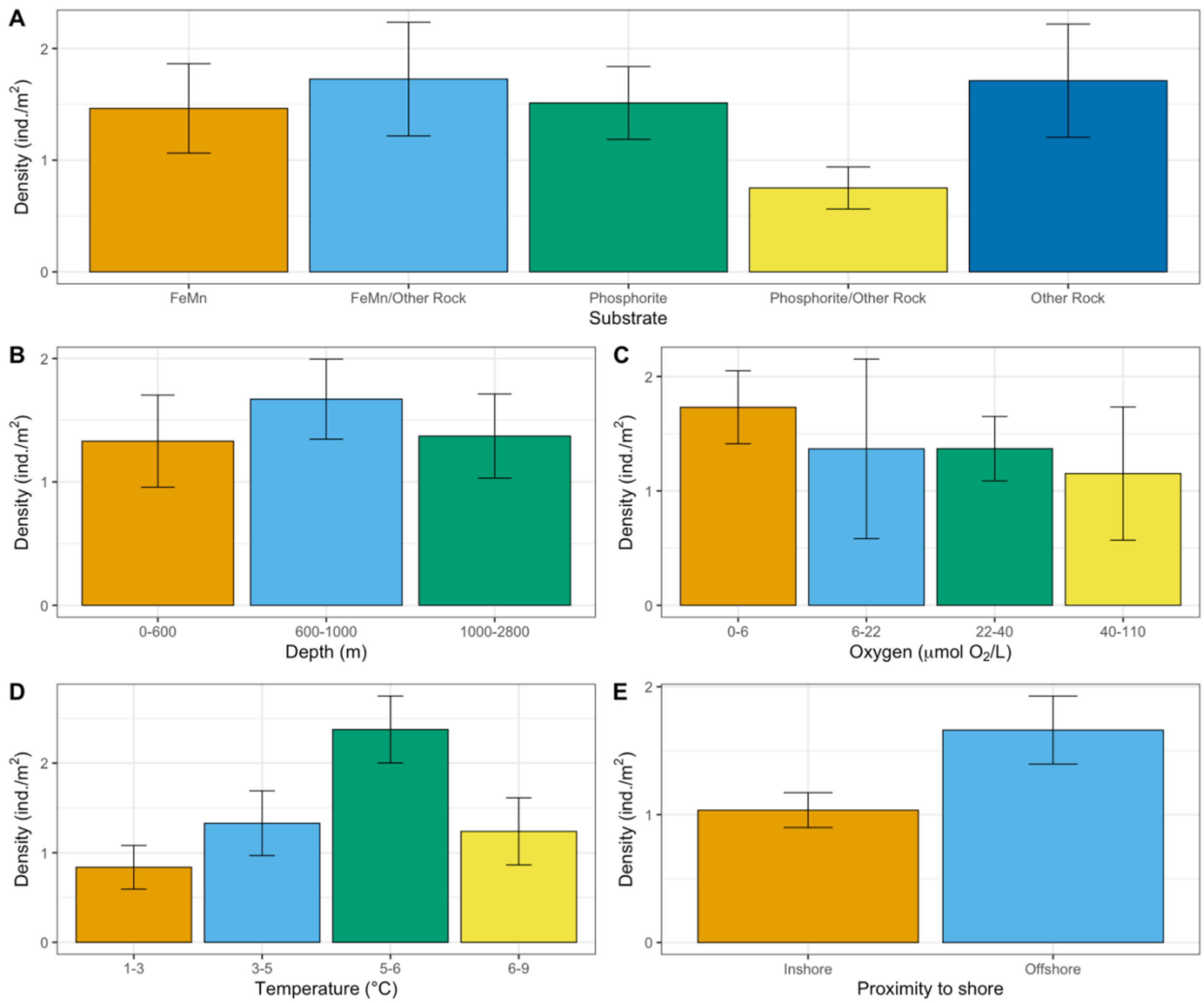

Figure 14. Average ± standard error density of megafauna communities across (A) various substrate types identified during NA124 and FK210726 transects, (B) depth ranges, (C) oxygen ranges, (D) temperature ranges, (E) dive sites' proximity to shore.

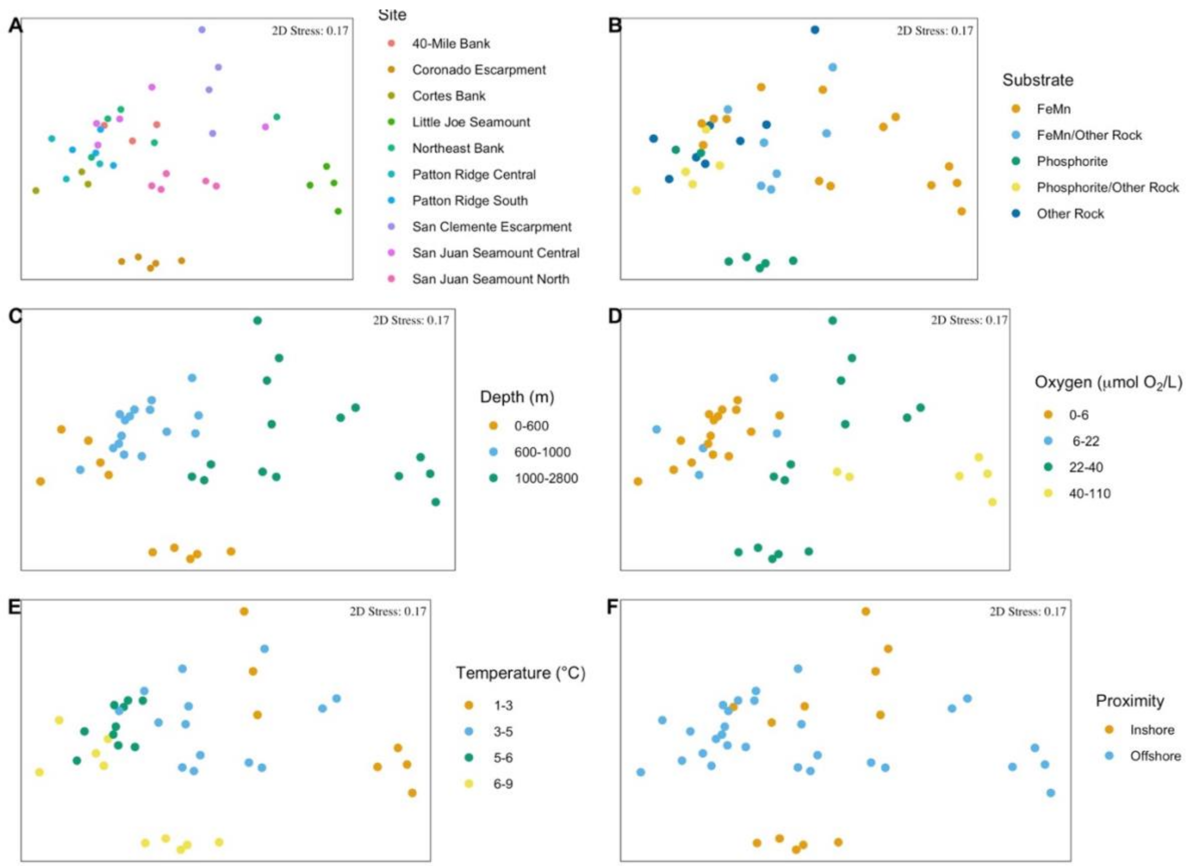

Figure 15. Multi-dimensional scaling analysis of megafaunal community composition across (A) Sites (B) Substrate types (C) Depth zones (D) Oxygen concentration zones (E) Temperature ranges (F) Proximity to shore.

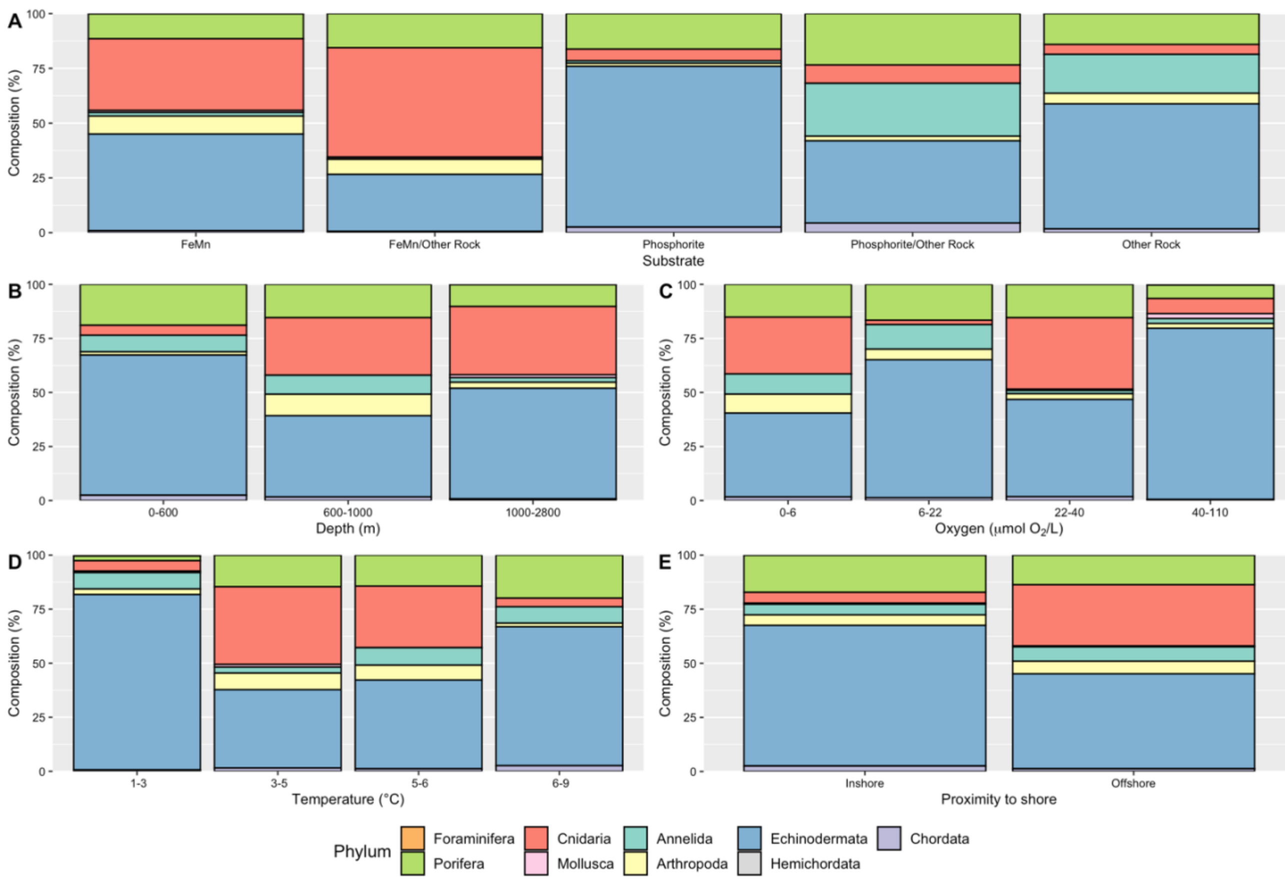

Figure 16. Percent composition of megafauna phyla across (A) various substrate types identified during NA124 and FK210726 transects, (B) depth zones, (C) oxygen concentration zones, (D) temperature ranges, (E) dive sites' proximity to shore.

Sponges, corals, and fishes

Our results shared similar trends with other studies conducted in the SCB examining corals, sponges, and fishes (Figure 17). *Lophelia pertussa* and other stony coral were most abundant down to depths of around 300 m but were nearly absent at deeper depths (Yoklavich et al. 2010). Sea pens (*Anthoptilum grandiflorum*, *Umbellula sp.*, *Halipteris* sp., and *Narella* sp.) were most common at shallower sites at depths between 500-700 m. The fish at these shallower sites were dominated by rockfish including *Sebastes zacentrus*, *Sebastes aurora*, and *Sebastes* sp.. As depth increased, the composition of both corals and sponges changed. There was a greater abundance of fan-like gorgonians (*Acanthogorgia* sp., *Paragorgia* sp., *Parastenella* sp., and *Victorgorgia* sp.), stick-like gorgonians (*Swiftia* sp.), and mushroom corals (*Heteropolypus* sp.) at deeper sites. There was less variance in sponge representation and abundance through depth and across sites (Figure 16B).

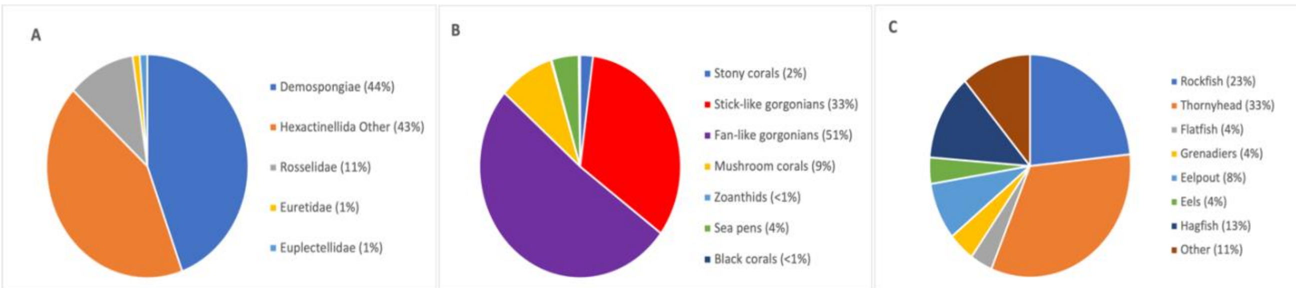

Figure 17. Proportional representation of (A) sponges (B) corals (C) fishes observed during NA124 and FK210726 transects.

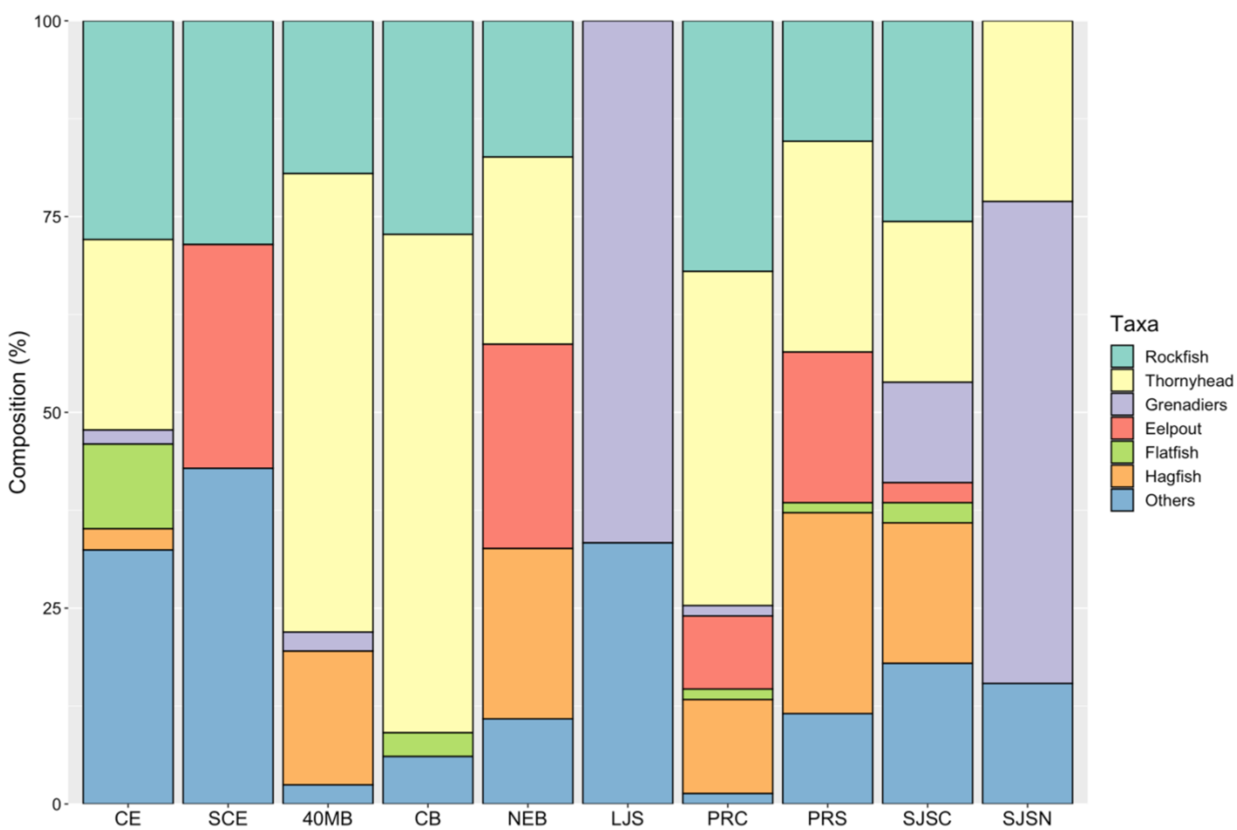

Figure 18. Southern California Borderland demersal fish percent composition at each site. CE (Coronado Escarpment); SCE (San Clemente Escarpment); 40MB (40-Mile Bank); CB (Cortes Bank); NEB (Northeast Bank); LJS (Little Joe Seamount); PRC (Patton Ridge Central); PRS (Patton Ridge South); SJSC (San Juan Seamount Central); SJSN (San Juan Seamount North).

Discussion.

Clear megafaunal and demersal fish community heterogeneity was observed within the Southern California Borderland. Density, diversity, and community composition varied across transects and sites (Table 3). During a single dive (e.g., San Juan Seamount), we could observe near-barren areas with low megafaunal density and diversity, dense ophiuroid beds, and diverse coral and sponge gardens.

In a global context, megafaunal diversity in our study area is lower than those found in mineral-rich abyssal habitats worldwide. Megafauna surveys within the UK-1 exploration contract area in the eastern CCZ (depths of 3900-4400 m) recorded Shannon's Diversity (H') values ranging from 3.20-3.27, Pielou's evenness (J') values ranging from 0.69-0.73 and ES_{100} values ranging from 28.47-31.94 (Amon et al. 2016). Megafaunal abundance, diversity, and community composition were also relatively homogenous between transects and sites (Amon et al. 2016), in contrast to the heterogeneity seen in this study (Table 3). Megafaunal diversity was greater in the SCB than those found on the Chilean margin on both hard and soft substrates at similar depths (Sellanes et al. 2009). Below, we examine the relationship between megafaunal communities in the SCB and several potential drivers of this variance.

Environmental drivers

There was no evidence that depth, oxygen, or temperature were potential drivers of megafaunal densities. However, megafaunal density at offshore sites was statistically greater than at inshore sites ($t = -2.094$, $df = 37.983$, $p = 0.043$) (Figure 14E). Density data were log-transformed prior to analyses, which removed the skew from high density areas such as Patton

Ridge. The lack of inshore sites could possibly explain the variance in densities. Due to cruise logistics, 40-Mile Bank and Coronado Escarpment were the only two inshore sites that could be sampled. It is possible that other inshore sites have higher megafaunal densities.

Notably, substrate, depth, oxygen, temperature, and proximity were all potential drivers of community composition (Figure 15). There were no clear differences in community composition due to substrate. However, there was a higher abundance of corals on FeMn crusts compared with phosphorites or other substrates. Both coral and sponge gardens were observed on San Juan Seamount, which contained FeMn-coated rocks on every transect. Several unique coral species were also observed on San Juan Seamount, including the octocoral *Victorgorgia* sp. and the black coral *Lillipathes* sp.. Similar studies at the Rio Grande Rise in the Southwest Atlantic examined the effects of substrate on megafaunal richness and composition from depths of 600 – 2000 m (Corrêa et al. 2022). They found FeMn to be a potential driver of benthic megafaunal structure, and that habitats formed by FeMn deposits contained distinct communities (Corrêa et al. 2022). VME indicator species including the sponges *Sarostegia oculate* and *Aphrocallistes* cf. *Beatrix* had a high affinity for FeMn crusts in the Rio Grande Rise (Corrêa et al. 2022). However, the exact nature of this relationship is still being explored. Rarefaction analysis suggests diversity and species richness are greatest on FeMn substrates and lower on phosphorites in the SCB (Figure 12). However, FeMn substrates were observed on San Juan Seamount and Little Joe Seamount, two of the deeper sites that also contained diverse coral and sponge gardens. This would suggest richness and diversity could be linked to location, depth, and proximity to shore, rather than substrate type.

Communities within the OMZ showed much less variability among transects and sites in terms of composition, whereas communities outside the OMZ had highly variable composition

(Figure 15D). Echinodermata was the most abundant phylum across all oxygen ranges but exhibited the lowest abundance at low-oxygen sites (0–6 μmol O_2 L^{-1}) (Figure 16C). Typically, crustaceans and echinoderms are more sensitive to hypoxia, and display lower oxygen thresholds than annelids, molluscs, and cnidarians (Levin et al. 2009). Echinodermata was the most abundant phylum between 40-110 μmol O_2 L^{-1} , but this oxygen range primarily represents Little Joe Seamount, and results could be due to depth effects such as a decline in food availability rather than oxygen. Corals (primarily octocorals) seemed much more tolerant of low-oxygen conditions, and their abundance seemed to be more site-specific. The coral and sponge gardens on San Juan Seamount were found both within (4.02-3.59 μmol O_2 L^{-1}) and below (34.90-34.87 μmol O_2 L^{-1}) the OMZ.

There was high variability in diversity (H') across oxygen levels. Nearly one third of the transects fell within suboxic conditions (defined in this paper as < 5 μmol O_2 L^{-1}) (Figure 13). This contradicts the current paradigm that megafaunal diversity diminishes under suboxic conditions (Levin 2003). Variations in these communities can also be explained by water mass characteristics including flow regime, circulation patterns, and organic matter supply (Puerta et al. 2020). Currents may affect the distribution of food particles, prevent fouling from sediment, and influence larval dispersion (Huff et al. 2013). This area of study lies within the Southern California Bight, and is influenced by the cold, nutrient-rich waters from the California Current, warm waters from the California Countercurrent, and the nutrient-rich California Undercurrent at depth.

Changes in community composition and density were observed across depth ranges. The two most distinct clusters in community composition were found at Coronado Escarpment and Little Joe Seamount, the shallowest and deepest sites, respectively (Figure 15C). These two sites also reflect large-scale diversity trends found in deep-sea benthic communities. For many taxa, there is a parabolic pattern in species diversity with respect to depth, with a peak at depths of around 2,000 m (Rex 1981 and Levin et al. 2001). This pattern has been explained by biological interactions, the species area hypothesis, and hump-shaped energy productivity (Ramirez-Llodra et al. 2010). Density in the SCB tended to decrease with increasing depth. When brittle stars were removed from the analysis, density was greatest at San Juan Seamount, which experienced oxygen levels as low as 3.44 μmol O_2 L^{-1}, well within the OMZ. San Clemente and Little Joe Seamount, our two deepest sites that fell below the OMZ, had the lowest density and sponges were nearly absent at both (Figure 2). Food availability could explain the decline in density with depth seen in the SCB megafaunal communities. Less than 1% of surface primary production reaches the sea floor, and POC exponentially decreases with depth (Herndl & Reinthaler 2013, Martin et al. 1987). With less food availability, we would expect to see lower megafaunal densities.

Edge effects – Ophiacantha diplasia

Echinodermata accounted for 48% of the total megafauna abundance in this study. Although the ophiuroid *Ophiacantha diplasia* was only observed on 6 of the 41 transects, it accounted for 12% of the total abundance. High-density beds of these ophiuroids were observed on Patton Ridge, forming distinct bands with an upper and lower boundary.

High densities of megafauna have been documented occurring near the upper and lower boundaries of the OMZ (Levin 2003). It is believed that this effect is due to the interaction of rich organic matter with release from oxygen limitation (Levin 2003). This phenomenon has been referred to as a boundary or edge effect, but it has been observed both at and within the

OMZ. Previous studies have found ophiuroids with densities greater than 50 ind. m^{-2} at approximately 22.3 μmol O_2 L^{-1} in Central California (Thompson et al. 1985), and in Southern California with densities around 16 ind. m^{-2} at approximately 17 μmol O_2 L^{-1} (Smith & Hamilton 1983). This effect has also been observed to vary with location and taxa (Levin 2003).

On Patton Ridge Central, a high-density band of *Ophiacantha diplasia* was only observed during the shallowest transect, with depths ranging from 567-538 m and oxygen values from 5.78-6.35 μmol O_2 L^{-1} (Figure 9A). The ophiuroids present on this transect had an average density of around 3.00 ind. m^{-2}, but were observed only during the latter half of the 100-m transect, suggesting a greater density than listed by at least a factor of two. The transect prior to it shared a similar substrate, depth, and temperature, but had a significantly lower oxygen value (average value of 3.36 vs 6.02 μmol O_2 L^{-1}). The average oxygen values differed by approximately 57% between the two transects. Similar trends were found on Patton Ridge South, with ophiuroids appearing at increased oxygen levels.

High-density bands of *Ophiacantha diplasia* were observed during the two shallowest dives on Patton Ridge South, with depths ranging from 604-560 m and oxygen values from 3.84-4.93 μmol O_2 L^{-1} (Figure 9B). The ophiuroids had a similar density as those on Patton Ridge Central (3 ind. m^{-2}) and were also observed halfway throughout the 100 m^2 transect. The transect prior to it shared a similar substrate, depth, and temperature, but had an average oxygen value of approximately 32% less. This suggests that oxygen may be a potential driver for the occurrence of these dense bands of *Ophiacantha diplasia*.

Implications for conservation and management

Deep-sea benthic megafauna are typically long-lived and slow growing, making them particularly vulnerable to disturbances (Clark et al. 2016). Activities such as bottom-trawling and deep sea-bed mining pose direct threats to these benthic communities (Mengerink et al. 2014 and Levin et al. 2016). We observed several unique taxa as well as coral and sponge gardens associated with FeMn substrates, which have been targeted for mining exploration elsewhere. Both phosphorite (another mineral targeted for mining) and FeMn substrates hosted megafaunal communities that were statistically different from one another, as well as from other rock substrates.

The area of study lies within U.S. federal waters, and as such management falls under the jurisdiction of U.S. federal agencies such as NOAA Fisheries. Every site in this study has been designated as Essential Fish Habitat (EFH) by NOAA Fisheries and the Pacific Fisheries Management Council (PFMC), meaning steps have been taken to minimize the impact fisheries have on EFH. In addition, certain sites within the SCB, including San Juan Seamount, have been identified as HAPCs (Figure 19) and have been designated as particularly important to ecosystem function, sensitive to human activities, stressed by development or are rare (NOAA 2021). These protections cover impacts to EFH through gear modifications, closed areas, and overall reductions of fishing efforts (PCGFMP 2020).

To date, there has been no interest in commercial-scale mining within deep waters of the U.S. EEZ. However, there are study sites within the SCB that contain minerals of interest. San Juan Seamount contained FeMn-coated rocks on every transect and was the site of both coral and sponge gardens, which are known vulnerable marine ecosystem indicators. Coronado Escarpment, which contained phosphorite on every rock sampled, was the site with the largest abundance of observed fish. These areas are protected from impacts due to fishing efforts, but there are currently no protections measures in place against other potential human activities. H.R. 5797 was a bill introduced to the U.S. Congress in 2016, that has not passed, that would have established the California Seamounts and Ridges National Marine Conservation Area. This bill would have protected specific seamounts, ridges, and banks in federal waters off the coast of California (H.R. 5797 2016). Certain seamounts including San Juan Seamount would have been protected from activities such as oil and gas development, deep sea-mining, aquaculture, and damaging fishing practices (H.R. 5797 2016).

The high-density areas, unique taxa, and coral and sponge gardens we observed supports the paradigm that seamounts, escarpments, banks, and ridges are biodiversity hotspots. As deep-seabed mining, oil and gas development, and other fishing practices continue, the potential impacts to benthic communities must be considered. Based on these findings, we suggest biodiversity surveys should be completed in areas of interest prior to decision making about activities that may cause harm to the communities associated with them.

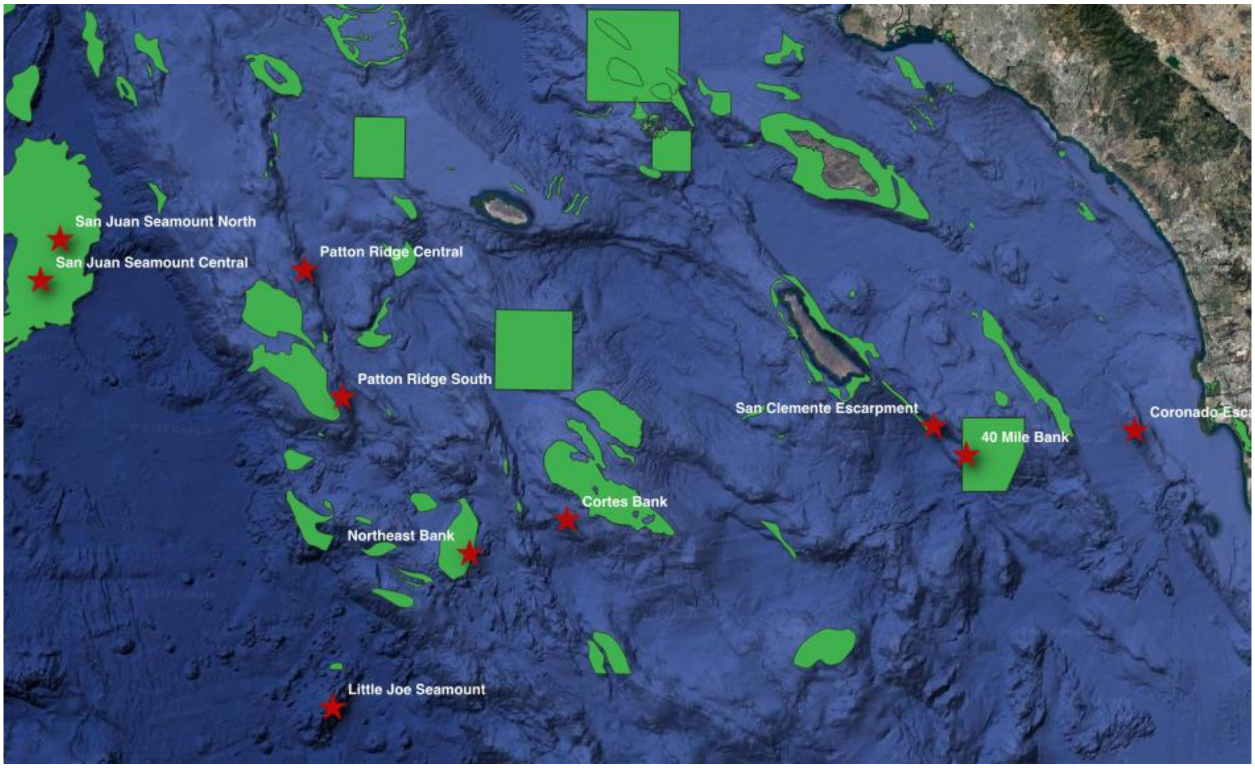

Figure 19. Map of the study area and dive sites (red stars), with Habitat Areas of Particular Concern highlighted in green.

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Supplementary File.

Supplementary File 1: Vlach_SCB_megafauna_guide.pdf

Appendices.

Appendix 1: Environmental data collected from biodiversity transects conducted from NA124 and FK210726

Cruise	Dive	Date	Site	Start Depth (m)	End Depth (m)	Type	Rep No.	Average Depth (m)	Avgerage Temp (C)	Average Salinity (ppt)	Average O_2 (μM)	Delta Depth (m)	Delta O_2 (μM)
FK210726	S0452	8/5/21	Coronado Escarpment	471	466	Transect	1	469	7.45	34.63	24.3	5	0.33
FK210726	S0452	8/5/21	Coronado Escarpment	462	456	Transect	2	459	7.61	34.64	25.31	6	1.03
FK210726	S0452	8/5/21	Coronado Escarpment	450	447	Transect	3	449	7.7	34.63	27.04	3	0.65
FK210726	S0452	8/5/21	Coronado Escarpment	442	428	Transect	4	435	7.83	34.64	28.17	14	2.29
FK210726	S0452	8/5/21	Coronado Escarpment	404	378	Transect	5	391	8.22	34.66	30.6	26	0.53
NA124	H1846	11/4/20	San Clemente Escarpment	1685	1673	Transect	1	1682	2.75	34.57	44.12	16	3.57
NA124	H1846	11/4/20	San Clemente Escarpment	1670	1613	Transect	2	1645	2.89	34.56	39.60	53	1.15
NA124	H1846	11/4/20	San Clemente Escarpment	1507	1441	Transect	3	1478	2.94	34.56	38.07	68	1.71
NA124	H1846	11/4/20	San Clemente Escarpment	1433	1365	Transect	4	1404	3.02	34.55	36.05	68	2.86
NA124	H1845	11/3/20	40 Mile Bank	869	826	Transect	2	859	4.64	34.43	5.89	45	1.58
NA124	H1845	11/3/20	40 Mile Bank	828	780	Transect	3	793	4.82	34.41	4.56	81	1.96
NA124	H1845	11/3/20	40 Mile Bank	685	660	Transect	4	673	5.36	34.37	2.65	27	0.38
NA124	H1843	11/1/20	Cortes Bank	574	569	Transect	1	571	6.00	34.31	5.09	2	0.64
NA124	H1843	11/1/20	Cortes Bank	515	505	Transect	2	508	6.10	34.30	5.88	15	1.40
NA124	H1843	11/1/20	Cortes Bank	469	457	Transect	3	463	6.54	34.27	10.13	11	0.86
NA124	H1842	10/31/20	Northeast Bank	1214	1161	Transect	1	1198	3.49	34.51	23.91	55	5.37
NA124	H1842	10/31/20	Northeast Bank	944	878	Transect	2	903	4.52	34.43	7.29	66	2.50
NA124	H1842	10/31/20	Northeast Bank	820	749	Transect	3	791	4.95	34.39	4.21	67	0.99
NA124	H1842	10/31/20	Northeast Bank	693	628	Transect	4	662	5.56	34.34	3.35	65	0.56
NA124	H1842	10/31/20	Northeast Bank	546	517	Transect	5	532	6.29	34.30	6.40	29	0.74
FK210726	S0445	7/30/21	Little Joe Seamount	2765	2705	Transect	1	2735	1.79	35.04	109.43	60	2.16
FK210726	S0445	7/30/21	Little Joe Seamount	2597	2549	Transect	2	2573	1.77	35.05	106.30	48	2.06
FK210726	S0445	7/30/21	Little Joe Seamount	2525	2469	Transect	3	2497	1.78	35.04	104.55	56	0.3
FK210726	S0445	7/30/21	Little Joe Seamount	2378	2375	Transect	5	2376	1.81	35.04	102.38	46	2.01
NA124	H1840	10/29/20	Patton Ridge Central	741	689	Transect	4	716	5.28	34.37	3.56	50	0.94
NA124	H1840	10/29/20	Patton Ridge Central	687	615	Transect	5	655	5.53	34.34	3.36	70	0.78
NA124	H1840	10/29/20	Patton Ridge Central	567	538	Transect	6	550	6.02	34.29	6.02	29	0.67
NA124	H1844	11/2/20	Patton Ridge South	722	672	Transect	1	703	4.96	34.39	3.84	49	1.40
NA124	H1844	11/2/20	Patton Ridge South	659	635	Transect	2	645	5.29	34.35	3.03	25	0.46
NA124	H1844	11/2/20	Patton Ridge South	604	572	Transect	3	589	5.62	34.31	3.83	32	0.44
NA124	H1844	11/2/20	Patton Ridge South	561	560	Transect	4	561	5.84	34.30	4.93	3	0.65
NA124	H1841	10/30/20	San Juan Seamount Central	1120	1038	Transect	1	1105	3.45	34.50	22.60	40	1.30
NA124	H1841	10/30/20	San Juan Seamount Central	953	944	Transect	2	950	4.02	34.46	13.03	6	2.15
NA124	H1841	10/30/20	San Juan Seamount Central	756	692	Transect	3	725	5.07	34.38	4.02	67	1.21
NA124	H1841	10/30/20	San Juan Seamount Central	690	632	Transect	4	667	5.29	34.36	3.44	53	0.73
NA124	H1841	10/30/20	San Juan Seamount Central	627	595	Transect	5	608	5.68	34.31	3.59	24	0.66
FK210726	S0443	7/28/21	San Juan Seamount North	1442	1392	Transect	1	1417	3.10	34.93	43.11	50	4.28
FK210726	S0443	7/28/21	San Juan Seamount North	1383	1313	Transect	2	1348	3.04	34.92	41.16	70	2.05
FK210726	S0443	7/28/21	San Juan Seamount North	1280	1245	Transect	3	1261	3.27	34.90	34.59	35	0.61
FK210726	S0443	7/28/21	San Juan Seamount North	1242	1212	Transect	4	1227	3.34	34.89	32.21	30	3.17
FK210726	S0443	7/28/21	San Juan Seamount North	1175	1138	Transect	5	1157	3.60	34.87	27.05	37	1.95

Appendix 2: Habitat and substrate ID

Cruise	Dive	Date	Site	Start Depth (m)	End Depth (m)	Type	Rep No.	Primary Habitat	Substrate ID
FK210726	S0452	8/5/21	Coronado Escarpment	471	466	Transect	1	Mixed, Rock+Sed	Phosphorite
FK210726	S0452	8/5/21	Coronado Escarpment	462	456	Transect	2	Mixed, Rock+Sed	Phosphorite
FK210726	S0452	8/5/21	Coronado Escarpment	450	447	Transect	3	Mixed, Rock+Sed	Phosphorite
FK210726	S0452	8/5/21	Coronado Escarpment	442	428	Transect	4	Mixed, Rock+Sed	Phosphorite
FK210726	S0452	8/5/21	Coronado Escarpment	404	378	Transect	5	Mixed, Rock+Sed	Phosphorite
NA124	H1846	11/4/20	San Clemente Escarpment	1685	1673	Transect	1	Mixed, Rock+Sed	FeMn (thin/patina)+other
NA124	H1846	11/4/20	San Clemente Escarpment	1670	1613	Transect	2	Mixed, Rock+Sed	Other rock (basalt)
NA124	H1846	11/4/20	San Clemente Escarpment	1507	1441	Transect	3	Mixed, Rock+Sed	FeMn (thin/patina)
NA124	H1846	11/4/20	San Clemente Escarpment	1433	1365	Transect	4	Mixed, Rock+Sed	FeMn (thin/patina)+other
NA124	H1845	11/3/20	40 Mile Bank	869	826	Transect	2	Mixed, Rock+Sed	Other Rock
NA124	H1845	11/3/20	40 Mile Bank	828	780	Transect	3	Mixed, Rock+Sed	Other Rock
NA124	H1845	11/3/20	40 Mile Bank	685	660	Transect	4	Mixed, Rock+Sed	Other Rock
NA124	H1843	11/1/20	Cortes Bank	574	569	Transect	1	Mixed, Rock+Sed	Phosphorite+other
NA124	H1843	11/1/20	Cortes Bank	515	505	Transect	2	Mixed, Rock+Sed	Phosphorite+other
NA124	H1843	11/1/20	Cortes Bank	469	457	Transect	3	Mixed, Rock+Sed	Phosphorite+other
NA124	H1842	10/31/20	Northeast Bank	1214	1161	Transect	1	Mixed, Rock+Sed	FeMn (thin/patina)
NA124	H1842	10/31/20	Northeast Bank	944	878	Transect	2	Rocky	FeMn (thin/patina)+other
NA124	H1842	10/31/20	Northeast Bank	820	749	Transect	3	Mixed, Rock+Sed	FeMn (thin/patina)+other
NA124	H1842	10/31/20	Northeast Bank	693	628	Transect	4	Rocky	FeMn (thin/patina)
NA124	H1842	10/31/20	Northeast Bank	546	517	Transect	5	Rocky	Other Rock
FK210726	S0445	7/30/21	Little Joe Seamount	2765	2705	Transect	1	Mixed, Rock+Sed	FeMn (thin/patina)
FK210726	S0445	7/30/21	Little Joe Seamount	2597	2549	Transect	2	Mixed, Rock+Sed	FeMn (thin/patina)
FK210726	S0445	7/30/21	Little Joe Seamount	2525	2469	Transect	3	Mixed, Rock+Sed	FeMn (thin/patina)
FK210726	S0445	7/30/21	Little Joe Seamount	2378	2375	Transect	5	Rocky	FeMn (thin/patina)
NA124	H1840	10/29/20	Patton Ridge Central	741	689	Transect	4	Mixed, Rock+Sed	Other Rock
NA124	H1840	10/29/20	Patton Ridge Central	687	615	Transect	5	Rocky	Other Rock
NA124	H1840	10/29/20	Patton Ridge Central	567	538	Transect	6	Mixed, Rock+Sed	Other Rock
NA124	H1844	11/2/20	Patton Ridge South	722	672	Transect	1	Mixed, Rock+Sed	Phosphorite+other
NA124	H1844	11/2/20	Patton Ridge South	659	635	Transect	2	Mixed, Rock+Sed	Phosphorite+other
NA124	H1844	11/2/20	Patton Ridge South	604	572	Transect	3	Rocky	Phosphorite
NA124	H1844	11/2/20	Patton Ridge South	561	560	Transect	4	Rocky	Phosphorite
NA124	H1841	10/30/20	San Juan Seamount Central	1120	1038	Transect	1	Mixed, Rock+Sed	FeMn (thin/patina)
NA124	H1841	10/30/20	San Juan Seamount Central	953	944	Transect	2	Rocky	FeMn (thin/patina)
NA124	H1841	10/30/20	San Juan Seamount Central	756	692	Transect	3	Rocky	FeMn (thin/patina)
NA124	H1841	10/30/20	San Juan Seamount Central	690	632	Transect	4	Rocky	FeMn (thin/patina)
NA124	H1841	10/30/20	San Juan Seamount Central	627	595	Transect	5	Rocky	FeMn (thin/patina)
FK210726	S0443	7/28/21	San Juan Seamount North	1442	1392	Transect	1	Rocky	FeMn (thin/patina)
FK210726	S0443	7/28/21	San Juan Seamount North	1383	1313	Transect	2	Rocky	FeMn (thin/patina)
FK210726	S0443	7/28/21	San Juan Seamount North	1280	1245	Transect	3	Rocky	FeMn (thin/patina)+other
FK210726	S0443	7/28/21	San Juan Seamount North	1242	1212	Transect	4	Rocky	FeMn (thin/patina)+other
FK210726	S0443	7/28/21	San Juan Seamount North	1175	1138	Transect	5	Rocky	FeMn (thin/patina)+other

Appendix 3: Complete megafaunal counts from the NA124 and FK210726 cruises

Appendix 3.1: Total counts from Coronado Escarpment

Taxa	CET1	CET2	CET3	CET4	CET5
Xenophyophore sp.	0	0	0	0	0
Demospongiae sp.	1	3	0	6	1
Puffball sponge	5	4	3	6	29
Rhizaxinella gadus	1	0	0	0	0
Asbestopluma sp.	44	172	150	224	26
Mycale sp.	0	0	0	0	0
Thenea sp.	0	0	0	0	1
Other Hexactinellidae sp.	2	0	7	5	0
Hexactinellidae sp. 1	0	0	0	0	0
Hexactinellidae sp. 4	0	0	0	0	0
Hexactinelidae sp. 5	0	0	0	0	0
Rosselidae sp.	0	0	0	2	0
Farrea sp.	0	0	0	0	0
Farrea truncata complex	0	0	0	0	0
Euretidae sp.	0	0	0	0	0
Aphrocallistes vastus	0	0	0	0	0
Heterochone calyx	0	1	0	0	0
Sclerothamnopsis compressa	0	1	0	0	0
Staurocalyptus sp.	1	1	0	0	0
Rhabdocalyptus sp.	0	0	0	0	0
Chonelasma sp.	1	0	0	0	0
Hyalonema sp.	0	0	0	0	0
Euplectellidae sp.	0	0	0	0	0
Saccocalyx pedunculata	0	0	0	0	0
Encrusting sponge	0	0	0	0	0
Poecillastra sp.	0	0	0	0	0
Ctenophore sp.	0	0	0	0	0
Jellyfish sp. 2	0	0	0	0	0
LRJ	6	20	2	0	0
Solmissus incisa	0	0	0	0	0
Siphonophora sp.	0	0	0	0	0
Dromalia sp.	0	0	0	0	0
Red *Swiftia* sp.	0	0	0	0	0
Victorgorgia sp.	0	0	0	0	0
Paragorgia sp.	0	0	0	3	0
Acanthogorgia sp.	0	0	0	0	0
Parastanella sp.	2	14	4	25	25
Heteropolypus sp.	0	0	0	0	0

Plexaurid sp.	0	0	0	0	0
Zoanthidae sp.	0	0	0	0	0
Sea Pen	0	0	0	0	0
Anthoptilum sp.	21	13	10	23	1
Umbellula sp.	0	0	0	0	0
Halipteris sp.	0	0	0	0	0
Narella sp.	0	0	0	0	0
Cup coral	0	0	0	0	1
Corallimorphus sp.	0	0	0	0	0
Lillipathes sp.	0	0	0	0	0
Actinaria sp.	0	0	0	1	0
Actinerus sp.	0	0	0	0	0
Purple actinaria	0	0	0	0	0
Metridoidea sp.	0	0	0	0	1
Urticina sp.	0	0	0	0	0
Hormathiidae sp.	0	0	0	0	0
Liponema brevicore	0	0	0	0	0
Cerianthidae sp.	0	0	0	0	0
Actinaria sp. 1	0	0	0	0	0
Actinaria sp. 2	0	0	0	0	0
Actinoscyphia aurelia	0	0	0	0	0
Acesta sp.	0	0	0	0	0
Grimpoteuthis sp.	0	0	0	0	0
Tritonia sp.	0	0	0	0	0
Heliocranchia sp.	0	0	0	0	0
Laetmonice sp.	0	0	0	0	0
Myxicola sp.	0	0	0	0	0
Swima sp. nov.	0	0	0	0	0
Daddy long leg isopod	0	0	0	0	0
Pelagic shrimp	1	2	0	0	0
Benthic decapod	0	0	0	0	2
Sternostylus sp.	0	0	0	0	0
Pantopoda sp.	0	0	0	0	0
Chorilia lonipes	0	0	0	1	0
Arthropod sp. 1	0	0	0	0	0
Arthropod sp. 4	0	0	0	0	0
Glyptolithodes cristatipes	2	0	0	3	6
Chionecetes tanneri	0	0	0	0	0
Paralomis sp.	0	0	0	0	0

Squat lobster	0	7	6	1	17
Paguroidea sp.	0	0	0	1	0
Hermit crab	0	0	0	0	0
Asteroid sp. 1	0	0	0	0	0
Asteroid sp. 4	0	0	0	0	0
Goniasteridae sp. 1	0	24	11	18	29
White asteroid	4	6	13	12	5
Bumpy asteroid	0	0	0	0	3
Asteridae sp.	2	0	1	0	1
Benthopectinidae sp.	4	0	0	0	0
Porianopsis sp.	1	1	0	0	0
Pteraster sp.	6	1	1	6	6
Hymenaster sp.	0	0	0	0	0
Ceramaster sp.	5	9	4	3	1
Valvatida sp.	0	0	0	0	0
Myxoderma sp.	0	0	0	0	0
Goniasteridae sp.	0	0	0	0	0
Hippasteria sp.	0	0	1	0	0
Sunstar sp.	0	0	0	0	0
Ophiuroid sp.	0	0	0	4	10
Ophiacantha diplasia	0	0	0	0	0
Ophiuroid sp. 1	0	0	0	0	0
Ophiuroid sp. 2	0	0	0	0	0
Ophiuroid sp. 3	0	0	0	0	0
Ophiuroid sp. 4	0	0	0	0	0
Ophiuroid sp. 5	0	0	0	0	0
Asteronyx sp.	0	6	2	17	3
Gorgonocephalus eucnemis	0	0	0	0	0
Freyellidae sp.	0	0	0	0	0
Brisingidae sp.	0	0	0	0	0
Zenometridae sp.	0	0	0	0	0
Antedonidae sp.	0	0	0	0	1
Psathyrometra fragilis	0	0	0	0	0
Hyocrinus sp.	0	0	0	0	0
Araesoma sp.	0	0	0	0	0
Holasteroida sp.	0	0	0	0	1
Aspidodiadematidae sp.	0	0	0	0	0
Strongylocentrotus fragilis	484	319	249	261	363
Scotoplanes sp.	0	0	0	0	0

Peniagone sp.	0	0	0	0	0
Elipidiidae sp.	0	0	0	0	0
Pannychia sp.	1	0	0	0	0
Deiamatidae sp. 1	0	0	0	0	0
Deiamatidae sp. 2	0	0	0	0	0
Synallactida sp.	0	0	0	0	0
Psolus sp.	0	0	0	1	9
Benthodytes sp.	0	0	0	0	0
Enteropneust sp.	0	0	0	0	0
Tunicate sp.	1	0	0	0	0
Pyrosome sp.	0	1	0	3	2
Facciolella sp.	1	6	6	0	1
Lycodes sp.	0	1	0	0	0
Parmaturus xaniurus	0	0	0	0	0
Skate sp.	0	0	1	0	0
Other fish sp.	2	9	5	1	2
Sebastes zacentrus	1	0	0	0	0
Sebastes spp.	4	2	4	1	6
Sebastes melanostomus	0	1	7	2	20
Sebastes aurora	0	0	0	0	0
Sebastolobus alascanus	2	3	3	2	0
Sebastolobus altivelis	0	0	0	0	0
Liparidae sp.	0	0	0	0	0
Zoarcidae sp.	0	0	0	0	0
Bathysaurus sp.	1	0	0	0	0
Flatfish sp.	1	0	7	2	2
Eptatretus stoutii	0	0	1	0	2
Grenadier sp.	0	0	2	0	0
Cyclops fish	0	0	0	0	0
Myctophid sp.	0	0	0	0	0

Appendix 3.2: Total counts from San Clemente Escarpment

Taxa	**SCET1**	**SCET2**	**SCET3**	**SCET4**
Xenophyophore sp.	0	2	4	1
Demospongiae sp.	0	0	0	0
Puffball sponge	3	0	0	0
Rhizaxinella gadus	0	0	0	0
Asbestopluma sp.	0	0	0	0
Mycale sp.	0	0	0	0

Thenea sp.	0	0	0	0
Other Hexactinellidae sp.	6	0	0	0
Hexactinellidae sp. 1	0	0	0	0
Hexactinellidae sp. 4	0	0	0	0
Hexactinelidae sp. 5	1	0	0	0
Rosselidae sp.	0	0	0	0
Farrea sp.	1	0	7	4
Farrea truncata complex	0	0	0	0
Euretidae sp.	1	0	0	3
Aphrocallistes vastus	0	0	0	0
Heterochone calyx	0	0	0	0
Sclerothamnopsis compressa	0	0	0	0
Staurocalyptus sp.	1	1	1	0
Rhabdocalyptus sp.	0	0	0	0
Chonelasma sp.	1	0	0	0
Hyalonema sp.	0	0	0	0
Euplectellidae sp.	0	1	0	0
Saccocalyx pedunculata	0	0	0	0
Encrusting sponge	0	0	0	0
Poecillastra sp.	28	3	9	1
Ctenophore sp.	0	1	0	0
Jellyfish sp. 2	0	0	0	0
LRJ	0	0	0	0
Solmissus incisa	0	0	0	0
Siphonophora sp.	0	0	0	0
Dromalia sp.	0	0	0	1
Red *Swiftia* sp.	0	0	1	0
Victorgorgia sp.	0	0	0	0
Paragorgia sp.	0	0	0	0
Acanthogorgia sp.	1	0	0	0
Parastanella sp.	0	0	0	0
Heteropolypus sp.	0	0	0	0
Plexaurid sp.	0	0	0	0
Zoanthidae sp.	0	0	0	0
Sea Pen	0	0	1	0
Anthoptilum sp.	0	0	0	0
Umbellula sp.	0	1	0	0
Halipteris sp.	0	0	0	0

Narella sp.	0	0	5	0
Cup coral	0	0	0	0
Corallimorphus sp.	0	0	0	0
Lillipathes sp.	0	0	0	0
Actinaria sp.	1	0	0	0
Actinerus sp.	0	0	0	0
Purple actinaria	0	0	0	0
Metridoidea sp.	0	0	0	0
Urticina sp.	0	0	0	0
Hormathiidae sp.	0	0	0	0
Liponema brevicore	0	0	0	0
Cerianthidae sp.	0	0	0	0
Actinaria sp. 1	0	0	0	0
Actinaria sp. 2	0	0	0	0
Actinoscyphia aurelia	0	2	1	1
Acesta sp.	10	0	11	12
Grimpoteuthis sp.	0	0	0	0
Tritonia sp.	0	0	0	0
Heliocranchia sp.	0	0	0	0
Laetmonice sp.	0	0	0	0
Myxicola sp.	0	4	0	0
Swima sp. nov.	15	38	95	0
Daddy long leg isopod	0	0	0	0
Pelagic shrimp	1	0	0	0
Benthic decapod	2	0	5	17
Sternostylus sp.	0	0	0	0
Pantopoda sp.	0	0	1	0
Chorilia lonipes	0	0	0	1
Arthropod sp. 1	0	0	0	0
Arthropod sp. 4	0	0	0	0
Glyptolithodes cristatipes	0	0	0	0
Chionecetes tanneri	0	0	0	0
Paralomis sp.	0	0	1	6
Squat lobster	4	9	12	3
Paguroidea sp.	0	0	0	0
Hermit crab	0	0	0	0
Asteroid sp. 1	0	0	0	0
Asteroid sp. 4	2	0	0	0
Goniasteridae sp. 1	0	0	0	0

White asteroid	0	0	0	0
Bumpy asteroid	0	0	0	0
Asteridae sp.	0	0	0	0
Benthopectinidae sp.	0	1	0	0
Porianopsis sp.	0	0	0	0
Pteraster sp.	2	0	0	0
Hymenaster sp.	0	0	0	0
Ceramaster sp.	2	0	5	0
Valvatida sp.	0	0	0	0
Myxoderma sp.	0	0	0	0
Goniasteridae sp.	0	0	0	0
Hippasteria sp.	0	0	0	0
Sunstar sp.	0	0	0	0
Ophiuroid sp.	0	0	0	0
Ophiacantha diplasia	0	0	0	0
Ophiuroid sp. 1	0	0	0	0
Ophiuroid sp. 2	0	0	0	0
Ophiuroid sp. 3	0	0	0	0
Ophiuroid sp. 4	0	0	1	0
Ophiuroid sp. 5	867	808	263	4
Asteronyx sp.	0	0	0	0
Gorgonocephalus eucnemis	0	0	0	0
Freyellidae sp.	0	0	0	0
Brisingidae sp.	0	0	0	0
Zenometridae sp.	0	0	0	0
Antedonidae sp.	0	0	0	0
Psathyrometra fragilis	0	0	0	0
Hyocrinus sp.	0	0	0	2
Araesoma sp.	0	0	0	0
Holasteroida sp.	0	0	0	0
Aspidodiadematidae sp.	0	0	22	14
Strongylocentrotus fragilis	16	0	5	0
Scotoplanes sp.	5	0	0	0
Peniagone sp.	0	0	0	0
Elipidiidae sp.	0	0	0	0
Pannychia sp.	0	7	2	1
Deiamatidae sp. 1	0	0	0	0
Deiamatidae sp. 2	0	0	0	0
Synallactida sp.	1	0	36	48

Psolus sp.	0	0	1	0
Benthodytes sp.	0	0	0	0
Enteropneust sp.	0	0	0	0
Tunicate sp.	0	0	0	2
Pyrosome sp.	0	0	0	0
Facciolella sp.	0	0	1	0
Lycodes sp.	0	0	0	0
Parmaturus xaniurus	0	0	0	0
Skate sp.	0	0	0	0
Other fish sp.	0	0	0	0
Sebastes zacentrus	0	0	0	2
Sebastes spp.	0	0	0	0
Sebastes melanostomus	0	0	0	0
Sebastes aurora	0	0	0	0
Sebastolobus alascanus	0	0	0	0
Sebastolobus altivelis	0	0	0	0
Liparidae sp.	0	1	0	1
Zoarcidae sp.	0	0	2	0
Bathysaurus sp.	0	0	0	0
Flatfish sp.	0	0	0	0
Eptatretus stoutii	0	0	0	0
Grenadier sp.	0	0	0	0
Cyclops fish	0	0	0	0
Myctophid sp.	0	0	0	0

Appendix 3.3: Total counts from 40-Mile Bank

Taxa	40MBT2	40MBT3	40MBT4
Xenophyophore sp.	0	0	0
Demospongiae sp.	0	0	18
Puffball sponge	6	20	0
Rhizaxinella gadus	0	0	0
Asbestopluma sp.	0	0	0
Mycale sp.	0	0	0
Thenea sp.	0	0	0
Other Hexactinellidae sp.	3	9	4
Hexactinellidae sp. 1	0	0	0
Hexactinellidae sp. 4	0	0	0
Hexactinelidae sp. 5	0	2	0
Rosselidae sp.	0	0	0

Farrea sp.	5	26	16
Farrea truncata complex	0	0	0
Euretidae sp.	0	0	0
Aphrocallistes vastus	0	0	0
Heterochone calyx	0	3	12
Sclerothamnopsis compressa	0	0	10
Staurocalyptus sp.	1	2	3
Rhabdocalyptus sp.	0	0	206
Chonelasma sp.	0	1	0
Hyalonema sp.	3	0	0
Euplectellidae sp.	0	0	0
Saccocalyx pedunculata	0	0	0
Encrusting sponge	1	3	0
Poecillastra sp.	2	12	0
Ctenophore sp.	2	0	0
Jellyfish sp. 2	0	5	0
LRJ	0	0	0
Solmissus incisa	0	0	0
Siphonophora sp.	0	1	1
Dromalia sp.	0	0	5
Red *Swiftia* sp.	0	0	3
Victorgorgia sp.	0	0	0
Paragorgia sp.	0	1	1
Acanthogorgia sp.	0	31	0
Parastanella sp.	0	0	0
Heteropolypus sp.	0	0	21
Plexaurid sp.	0	0	0
Zoanthidae sp.	0	0	0
Sea Pen	0	0	0
Anthoptilum sp.	0	0	0
Umbellula sp.	0	0	0
Halipteris sp.	0	0	0
Narella sp.	5	10	6
Cup coral	0	0	0
Corallimorphus sp.	0	0	0
Lillipathes sp.	0	0	0
Actinaria sp.	17	19	0
Actinerus sp.	0	0	0

Purple actinaria	0	0	0
Metridoidea sp.	2	5	0
Urticina sp.	0	0	0
Hormathiidae sp.	0	0	0
Liponema brevicore	0	0	0
Cerianthidae sp.	5	3	0
Actinaria sp. 1	0	0	0
Actinaria sp. 2	0	0	0
Actinoscyphia aurelia	0	1	0
Acesta sp.	0	1	0
Grimpoteuthis sp.	0	0	0
Tritonia sp.	0	0	0
Heliocranchia sp.	0	0	0
Laetmonice sp.	0	0	0
Myxicola sp.	0	20	153
Swima sp. nov.	0	0	0
Daddy long leg isopod	0	0	0
Pelagic shrimp	12	5	0
Benthic decapod	41	32	5
Sternostylus sp.	0	0	0
Pantopoda sp.	0	0	0
Chorilia lonipes	9	11	6
Arthropod sp. 1	0	0	0
Arthropod sp. 4	0	0	0
Glyptolithodes cristatipes	0	0	0
Chionecetes tanneri	0	0	0
Paralomis sp.	4	1	4
Squat lobster	36	40	8
Paguroidea sp.	0	0	0
Hermit crab	0	0	0
Asteroid sp. 1	0	1	6
Asteroid sp. 4	3	6	1
Goniasteridae sp. 1	0	0	0
White asteroid	0	0	0
Bumpy asteroid	0	0	0
Asteridae sp.	0	0	0
Benthopectinidae sp.	0	0	0
Porianopsis sp.	0	0	0
Pteraster sp.	0	0	0

Hymenaster sp.	0	0	0
Ceramaster sp.	0	5	0
Valvatida sp.	0	0	0
Myxoderma sp.	0	0	0
Goniasteridae sp.	0	0	0
Hippasteria sp.	0	0	0
Sunstar sp.	0	0	0
Ophiuroid sp.	0	0	0
Ophiacantha diplasia	0	0	0
Ophiuroid sp. 1	0	0	0
Ophiuroid sp. 2	0	0	0
Ophiuroid sp. 3	0	0	0
Ophiuroid sp. 4	0	0	0
Ophiuroid sp. 5	0	0	0
Asteronyx sp.	0	0	0
Gorgonocephalus eucnemis	1	0	0
Freyellidae sp.	0	0	0
Brisingidae sp.	0	0	4
Zenometridae sp.	0	0	0
Antedonidae sp.	0	0	0
Psathyrometra fragilis	0	0	0
Hyocrinus sp.	0	0	0
Araesoma sp.	1	1	2
Holasteroida sp.	0	0	0
Aspidodiadematidae sp.	0	0	0
Strongylocentrotus fragilis	0	0	0
Scotoplanes sp.	0	0	3
Peniagone sp.	0	0	0
Elipidiidae sp.	0	0	0
Pannychia sp.	9	36	171
Deiamatidae sp. 1	0	0	0
Deiamatidae sp. 2	0	0	0
Synallactida sp.	0	0	0
Psolus sp.	0	0	46
Benthodytes sp.	0	0	0
Enteropneust sp.	0	0	0
Tunicate sp.	0	0	0
Pyrosome sp.	0	0	0
Facciolella sp.	0	0	0

Lycodes sp.	0	0	0
Parmaturus xaniurus	0	0	0
Skate sp.	0	0	0
Other fish sp.	0	0	0
Sebastes zacentrus	2	2	4
Sebastes spp.	0	0	0
Sebastes melanostomus	0	0	0
Sebastes aurora	0	0	0
Sebastolobus alascanus	15	4	2
Sebastolobus altivelis	1	0	2
Liparidae sp.	1	0	0
Zoarcidae sp.	0	0	0
Bathysaurus sp.	0	0	0
Flatfish sp.	0	0	0
Eptatretus stoutii	2	2	3
Grenadier sp.	0	0	1
Cyclops fish	0	0	0
Myctophid sp.	0	0	0

Appendix 3.4: Total counts from Cortes Bank

Taxa	CBT1	CBT2	CBT3
Xenophyophore sp.	0	0	0
Demospongiae sp.	0	0	0
Puffball sponge	28	4	15
Rhizaxinella gadus	0	0	0
Asbestopluma sp.	0	1	8
Mycale sp.	0	7	0
Thenea sp.	0	0	0
Other Hexactinellidae sp.	4	36	34
Hexactinellidae sp. 1	0	0	0
Hexactinellidae sp. 4	0	0	1
Hexactinelidae sp. 5	0	43	51
Rosselidae sp.	0	0	0
Farrea sp.	0	2	2
Farrea truncata complex	0	0	0
Euretidae sp.	0	0	0
Aphrocallistes vastus	0	0	0
Heterochone calyx	3	1	1

Sclerothamnopsis compressa	0	0	0
Staurocalyptus sp.	0	18	7
Rhabdocalyptus sp.	0	2	2
Chonelasma sp.	0	0	0
Hyalonema sp.	0	0	0
Euplectellidae sp.	0	0	0
Saccocalyx pedunculata	0	0	0
Encrusting sponge	0	0	0
Poecillastra sp.	1	0	0
Ctenophore sp.	0	2	0
Jellyfish sp. 2	0	0	0
LRJ	0	0	0
Solmissus incisa	0	0	0
Siphonophora sp.	0	0	0
Dromalia sp.	0	0	0
Red *Swiftia* sp.	0	0	0
Victorgorgia sp.	0	0	0
Paragorgia sp.	1	2	0
Acanthogorgia sp.	0	0	0
Parastanella sp.	0	0	0
Heteropolypus sp.	0	8	1
Plexaurid sp.	0	0	0
Zoanthidae sp.	0	0	0
Sea Pen	0	0	0
Anthoptilum sp.	0	0	0
Umbellula sp.	0	0	0
Halipteris sp.	0	0	0
Narella sp.	0	0	0
Cup coral	0	0	0
Corallimorphus sp.	0	0	0
Lillipathes sp.	0	0	0
Actinaria sp.	0	8	2
Actinerus sp.	0	0	0
Purple actinaria	0	0	0
Metridoidea sp.	0	10	1
Urticina sp.	0	0	0
Hormathiidae sp.	0	0	0
Liponema brevicore	0	0	0

Cerianthidae sp.	2	0	0
Actinaria sp. 1	0	0	0
Actinaria sp. 2	0	3	0
Actinoscyphia aurelia	0	0	0
Acesta sp.	0	0	0
Grimpoteuthis sp.	0	0	0
Tritonia sp.	0	0	0
Heliocranchia sp.	0	0	0
Laetmonice sp.	0	0	0
Myxicola sp.	0	88	24
Swima sp. nov.	0	0	0
Daddy long leg isopod	0	0	0
Pelagic shrimp	0	0	0
Benthic decapod	0	0	0
Sternostylus sp.	0	0	0
Pantopoda sp.	0	0	0
Chorilia lonipes	1	8	0
Arthropod sp. 1	0	0	0
Arthropod sp. 4	0	0	0
Glyptolithodes cristatipes	0	0	0
Chionecetes tanneri	0	0	0
Paralomis sp.	0	0	0
Squat lobster	0	0	0
Paguroidea sp.	0	0	0
Hermit crab	0	0	0
Asteroid sp. 1	0	3	5
Asteroid sp. 4	0	0	0
Goniasteridae sp. 1	0	0	0
White asteroid	0	0	0
Bumpy asteroid	0	0	0
Asteridae sp.	0	0	0
Benthopectinidae sp.	0	7	22
Porianopsis sp.	0	0	20
Pteraster sp.	3	9	3
Hymenaster sp.	0	0	0
Ceramaster sp.	0	2	11
Valvatida sp.	0	0	0
Myxoderma sp.	2	2	3
Goniasteridae sp.	0	0	0

Hippasteria sp.	1	1	0
Sunstar sp.	0	1	0
Ophiuroid sp.	0	0	0
Ophiacantha diplasia	1	57	115
Ophiuroid sp. 1	0	0	0
Ophiuroid sp. 2	0	0	0
Ophiuroid sp. 3	0	0	0
Ophiuroid sp. 4	0	0	0
Ophiuroid sp. 5	0	0	0
Asteronyx sp.	0	0	0
Gorgonocephalus eucnemis	0	0	0
Freyellidae sp.	0	0	0
Brisingidae sp.	5	37	9
Zenometridae sp.	0	0	0
Antedonidae sp.	0	0	0
Psathyrometra fragilis	0	0	0
Hyocrinus sp.	0	0	0
Araesoma sp.	0	0	0
Holasteroida sp.	0	0	0
Aspidodiadematidae sp.	0	0	0
Strongylocentrotus fragilis	0	0	2
Scotoplanes sp.	0	0	0
Peniagone sp.	0	0	0
Elipidiidae sp.	0	0	0
Pannychia sp.	33	2	5
Deiamatidae sp. 1	0	0	0
Deiamatidae sp. 2	0	0	0
Synallactida sp.	0	0	1
Psolus sp.	2	10	28
Benthodytes sp.	0	0	0
Enteropneust sp.	0	0	0
Tunicate sp.	0	0	0
Pyrosome sp.	0	0	0
Facciolella sp.	0	0	0
Lycodes sp.	0	0	0
Parmaturus xaniurus	0	1	0
Skate sp.	0	0	0
Other fish sp.	0	0	0
Sebastes zacentrus	0	3	6

Sebastes spp.	0	0	0
Sebastes melanostomus	0	0	0
Sebastes aurora	0	0	0
Sebastolobus alascanus	1	12	8
Sebastolobus altivelis	0	0	0
Liparidae sp.	0	0	0
Zoarcidae sp.	0	0	0
Bathysaurus sp.	0	0	0
Flatfish sp.	0	1	0
Eptatretus stoutii	0	0	0
Grenadier sp.	0	0	0
Cyclops fish	0	0	0
Myctophid sp.	0	0	1

Appendix 3.5: Total counts from Northeast Bank

Taxa	NEBT1	NEBT2	NEBT3	NEBT4	NEBT5
Xenophyophore sp.	0	0	0	0	0
Demospongiae sp.	0	0	0	0	2
Puffball sponge	0	5	0	0	3
Rhizaxinella gadus	0	0	0	0	0
Asbestopluma sp.	0	0	0	0	34
Mycale sp.	0	0	0	0	0
Thenea sp.	0	0	0	0	0
Other Hexactinellidae sp.	0	0	0	1	1
Hexactinellidae sp. 1	0	0	0	1	0
Hexactinellidae sp. 4	0	0	0	0	0
Hexactinelidae sp. 5	0	0	1	0	0
Rosselidae sp.	0	1	0	0	5
Farrea sp.	4	34	89	185	16
Farrea truncata complex	0	0	0	0	0
Euretidae sp.	0	0	2	0	3
Aphrocallistes vastus	0	0	0	0	2
Heterochone calyx	0	1	3	1	1
Sclerothamnopsis compressa	0	0	1	22	29
Staurocalyptus sp.	0	3	4	14	9
Rhabdocalyptus sp.	0	0	0	7	2
Chonelasma sp.	0	0	0	0	0
Hyalonema sp.	0	0	0	0	0

Euplectellidae sp.	0	0	1	0	0
Saccocalyx pedunculata	0	2	3	1	0
Encrusting sponge	0	8	0	0	5
Poecillastra sp.	0	0	1	0	5
Ctenophore sp.	0	0	0	0	0
Jellyfish sp. 2	0	0	0	0	0
LRJ	1	0	0	0	0
Solmissus incisa	0	0	0	0	0
Siphonophora sp.	0	0	0	0	0
Dromalia sp.	0	0	1	5	0
Red *Swiftia* sp.	0	0	1	0	0
Victorgorgia sp.	0	0	0	0	0
Paragorgia sp.	0	0	2	3	10
Acanthogorgia sp.	0	0	0	0	0
Parastanella sp.	0	0	0	0	0
Heteropolypus sp.	0	1	5	4	14
Plexaurid sp.	0	0	0	0	0
Zoanthidae sp.	0	0	0	0	0
Sea Pen	0	0	0	0	0
Anthoptilum sp.	0	0	0	0	0
Umbellula sp.	0	0	0	0	0
Halipteris sp.	0	0	0	7	0
Narella sp.	0	0	9	8	0
Cup coral	0	0	0	0	0
Corallimorphus sp.	0	0	0	0	0
Lillipathes sp.	0	0	0	0	0
Actinaria sp.	0	2	0	1	11
Actinerus sp.	0	0	0	0	0
Purple actinaria	0	0	0	0	0
Metridoidea sp.	1	0	0	0	3
Urticina sp.	0	0	0	0	0
Hormathiidae sp.	0	1	0	0	0
Liponema brevicore	0	3	0	0	0
Cerianthidae sp.	0	0	0	0	0
Actinaria sp. 1	0	0	0	0	0
Actinaria sp. 2	4	6	0	0	0
Actinoscyphia aurelia	0	0	0	0	0
Acesta sp.	0	0	0	0	0
Grimpoteuthis sp.	0	0	0	0	0

Tritonia sp.	0	0	0	2	0
Heliocranchia sp.	0	0	0	0	0
Laetmonice sp.	0	0	0	0	0
Myxicola sp.	0	0	0	0	0
Swima sp. nov.	0	0	0	0	0
Daddy long leg isopod	0	0	0	0	0
Pelagic shrimp	10	0	0	0	0
Benthic decapod	9	85	63	4	1
Sternostylus sp.	0	0	0	0	0
Pantopoda sp.	0	0	0	0	0
Chorilia lonipes	0	4	0	4	20
Arthropod sp. 1	0	0	0	0	0
Arthropod sp. 4	0	0	0	0	0
Glyptolithodes cristatipes	0	0	0	0	0
Chionecetes tanneri	0	0	0	0	1
Paralomis sp.	0	0	1	1	0
Squat lobster	4	3	140	39	0
Paguroidea sp.	0	0	0	0	0
Hermit crab	0	0	0	0	0
Asteroid sp. 1	0	0	9	0	0
Asteroid sp. 4	0	0	0	14	8
Goniasteridae sp. 1	0	0	0	0	0
White asteroid	0	0	0	0	0
Bumpy asteroid	0	0	0	0	0
Asteridae sp.	0	0	0	0	0
Benthopectinidae sp.	0	0	0	0	0
Porianopsis sp.	0	0	0	0	1
Pteraster sp.	0	0	0	0	0
Hymenaster sp.	0	0	0	0	0
Ceramaster sp.	0	0	3	0	0
Valvatida sp.	0	0	0	0	0
Myxoderma sp.	0	0	0	0	0
Goniasteridae sp.	0	0	0	0	0
Hippasteria sp.	0	0	0	0	0
Sunstar sp.	0	0	0	0	0
Ophiuroid sp.	0	0	0	0	61
Ophiacantha diplasia	0	0	0	0	0
Ophiuroid sp. 1	0	0	0	0	0
Ophiuroid sp. 2	0	0	0	0	0

Ophiuroid sp. 3	0	0	0	0	0
Ophiuroid sp. 4	0	0	0	0	0
Ophiuroid sp. 5	0	0	0	0	0
Asteronyx sp.	0	0	0	0	0
Gorgonocephalus eucnemis	0	0	0	0	0
Freyellidae sp.	0	0	0	0	0
Brisingidae sp.	0	18	15	354	133
Zenometridae sp.	0	0	0	0	0
Antedonidae sp.	0	1	0	0	0
Psathyrometra fragilis	0	0	0	0	0
Hyocrinus sp.	0	0	0	0	0
Araesoma sp.	1	55	0	0	0
Holasteroida sp.	0	0	0	0	0
Aspidodiadematidae sp.	0	1	3	0	0
Strongylocentrotus fragilis	0	0	0	0	0
Scotoplanes sp.	0	0	0	0	0
Peniagone sp.	0	0	0	0	0
Elipidiidae sp.	0	0	0	0	0
Pannychia sp.	0	0	23	1	20
Deiamatidae sp. 1	0	0	0	0	0
Deiamatidae sp. 2	0	0	0	0	0
Synallactida sp.	0	0	0	0	0
Psolus sp.	0	23	0	39	0
Benthodytes sp.	19	0	0	0	0
Enteropneust sp.	0	0	0	0	0
Tunicate sp.	0	0	0	0	0
Pyrosome sp.	0	0	0	0	0
Facciolella sp.	0	1	0	0	0
Lycodes sp.	0	0	0	0	0
Parmaturus xaniurus	0	0	0	0	0
Skate sp.	0	0	0	0	0
Other fish sp.	2	0	0	0	0
Sebastes zacentrus	0	0	0	3	5
Sebastes spp.	0	0	0	0	0
Sebastes melanostomus	0	0	0	0	0
Sebastes aurora	0	0	0	0	0
Sebastolobus alascanus	4	3	1	1	1
Sebastolobus altivelis	0	0	1	0	0
Liparidae sp.	2	0	0	0	0

Zoarcidae sp.	0	0	12	0	0
Bathysaurus sp.	0	0	0	0	0
Flatfish sp.	0	0	0	0	0
Eptatretus stoutii	0	1	3	2	4
Grenadier sp.	0	0	0	0	0
Cyclops fish	0	0	0	0	0
Myctophid sp.	0	0	0	0	0

Appendix 3.6: Total counts from Little Joe Seamount

Taxa	LJST1	LJST2	LJST3	LJST5
Xenophyophore sp.	1	0	4	2
Demospongiae sp.	0	0	0	0
Puffball sponge	0	0	0	0
Rhizaxinella gadus	0	0	0	0
Asbestopluma sp.	0	0	4	0
Mycale sp.	0	0	0	0
Thenea sp.	0	0	0	0
Other Hexactinellidae sp.	0	0	0	0
Hexactinellidae sp. 1	0	0	0	0
Hexactinellidae sp. 4	0	0	0	0
Hexactinelidae sp. 5	0	0	0	0
Rosselidae sp.	0	0	0	0
Farrea sp.	0	0	0	0
Farrea truncata complex	0	0	0	0
Euretidae sp.	0	0	0	0
Aphrocallistes vastus	0	0	0	0
Heterochone calyx	0	0	0	0
Sclerothamnopsis compressa	0	0	0	0
Staurocalyptus sp.	0	0	0	0
Rhabdocalyptus sp.	0	0	0	0
Chonelasma sp.	0	0	0	0
Hyalonema sp.	0	0	0	0
Euplectellidae sp.	0	0	0	0
Saccocalyx pedunculata	0	0	0	0
Encrusting sponge	0	0	0	0
Poecillastra sp.	0	0	0	0
Ctenophore sp.	0	0	0	0
Jellyfish sp. 2	0	0	0	0

LRJ	0	0	0	0
Solmissus incisa	0	0	0	0
Siphonophora sp.	0	0	0	0
Dromalia sp.	0	0	0	0
Red *Swiftia* sp.	0	0	0	0
Victorgorgia sp.	0	0	0	0
Paragorgia sp.	0	0	0	0
Acanthogorgia sp.	0	0	0	0
Parastanella sp.	0	0	0	0
Heteropolypus sp.	1	1	1	0
Plexaurid sp.	0	0	0	0
Zoanthidae sp.	0	2	0	0
Sea Pen	0	0	0	0
Anthoptilum sp.	0	0	0	1
Umbellula sp.	0	0	1	0
Halipteris sp.	0	0	0	0
Narella sp.	7	10	10	2
Cup coral	0	0	2	33
Corallimorphus sp.	0	0	0	0
Lillipathes sp.	0	0	0	0
Actinaria sp.	0	0	2	0
Actinerus sp.	0	0	0	0
Purple actinaria	0	0	0	0
Metridoidea sp.	0	5	1	0
Urticina sp.	0	0	0	0
Hormathiidae sp.	0	0	0	0
Liponema brevicore	0	0	2	1
Cerianthidae sp.	0	0	0	0
Actinaria sp. 1	0	0	33	16
Actinaria sp. 2	0	0	2	4
Actinoscyphia aurelia	0	0	0	0
Acesta sp.	0	0	0	0
Grimpoteuthis sp.	0	0	1	0
Tritonia sp.	0	0	0	0
Heliocranchia sp.	0	0	0	0
Laetmonice sp.	1	1	0	0
Myxicola sp.	0	0	0	0
Swima sp. nov.	53	14	14	1
Daddy long leg isopod	0	0	0	1

Pelagic shrimp	3	9	2	2
Benthic decapod	3	0	4	2
Sternostylus sp.	0	0	0	0
Pantopoda sp.	1	0	1	0
Chorilia lonipes	0	0	0	0
Arthropod sp. 1	0	0	0	0
Arthropod sp. 4	0	0	0	0
Glyptolithodes cristatipes	0	0	0	0
Chionecetes tanneri	0	0	0	0
Paralomis sp.	0	0	0	0
Squat lobster	2	0	1	4
Paguroidea sp.	2	6	0	0
Hermit crab	0	0	3	1
Asteroid sp. 1	0	0	0	0
Asteroid sp. 4	0	0	0	0
Goniasteridae sp. 1	0	0	0	0
White asteroid	0	0	0	0
Bumpy asteroid	0	0	0	0
Asteridae sp.	5	13	1	0
Benthopectinidae sp.	0	0	0	0
Porianopsis sp.	2	0	0	0
Pteraster sp.	0	2	1	1
Hymenaster sp.	0	0	6	1
Ceramaster sp.	5	0	0	0
Valvatida sp.	4	0	0	0
Myxoderma sp.	0	0	0	0
Goniasteridae sp.	29	8	2	1
Hippasteria sp.	0	0	0	0
Sunstar sp.	0	0	0	0
Ophiuroid sp.	0	0	0	0
Ophiacantha diplasia	0	0	0	0
Ophiuroid sp. 1	4	2	0	1
Ophiuroid sp. 2	1	3	46	32
Ophiuroid sp. 3	0	6	0	0
Ophiuroid sp. 4	2	0	0	2
Ophiuroid sp. 5	0	0	0	0
Asteronyx sp.	0	0	0	0
Gorgonocephalus eucnemis	0	0	0	0
Freyellidae sp.	1	0	0	0

Brisingidae sp.	0	0	0	0
Zenometridae sp.	0	0	0	0
Antedonidae sp.	5	31	34	37
Psathyrometra fragilis	4	85	20	12
Hyocrinus sp.	2	4	7	2
Araesoma sp.	0	0	0	0
Holasteroida sp.	2	4	4	3
Aspidodiadematidae sp.	0	0	0	0
Strongylocentrotus fragilis	0	0	0	0
Scotoplanes sp.	0	0	0	0
Peniagone sp.	0	1	0	0
Elipidiidae sp.	0	2	4	0
Pannychia sp.	0	0	0	0
Deiamatidae sp. 1	7	10	6	2
Deiamatidae sp. 2	0	0	2	0
Synallactida sp.	2	1	1	17
Psolus sp.	0	0	0	0
Benthodytes sp.	1	4	1	0
Enteropneust sp.	0	0	5	2
Tunicate sp.	0	3	3	1
Pyrosome sp.	0	0	0	0
Facciolella sp.	0	0	0	0
Lycodes sp.	0	0	0	0
Parmaturus xaniurus	0	0	0	0
Skate sp.	0	0	0	0
Other fish sp.	0	1	0	0
Sebastes zacentrus	0	0	0	0
Sebastes spp.	0	0	0	0
Sebastes melanostomus	0	0	0	0
Sebastes aurora	0	0	0	0
Sebastolobus alascanus	0	0	0	0
Sebastolobus altivelis	0	0	0	0
Liparidae sp.	0	0	0	0
Zoarcidae sp.	0	0	0	0
Bathysaurus sp.	0	0	0	0
Flatfish sp.	0	0	0	0
Eptatretus stoutii	0	0	0	0
Grenadier sp.	0	1	0	1
Cyclops fish	0	0	0	0

Myctophid sp.	0	0	0	0

Appendix 3.7: Total counts from Patton Ridge

Taxa	PRCT 4	PRCT 5	PRCT 6	PRST 1	PRST 2	PRST 3	PRST 4
Xenophyophore sp.	0	0	0	0	0	0	0
Demospongiae sp.	0	0	0	0	2	0	0
Puffball sponge	128	85	16	0	17	10	14
Rhizaxinella gadus	0	1	0	0	0	0	0
Asbestopluma sp.	0	0	0	1	32	6	0
Mycale sp.	0	0	208	0	0	1	0
Thenea sp.	0	0	0	0	0	0	0
Other Hexactinellidae sp.	3	11	0	0	55	0	0
Hexactinellidae sp. 1	0	1	0	2	0	1	1
Hexactinellidae sp. 4	0	0	0	0	0	0	0
Hexactinelidae sp. 5	0	0	0	0	0	20	1
Rosselidae sp.	0	0	0	0	0	0	0
Farrea sp.	0	33	5	54	18	24	74
Farrea truncata complex	0	0	0	0	0	0	0
Euretidae sp.	0	0	0	0	0	0	4
Aphrocallistes vastus	0	0	0	1	3	7	0
Heterochone calyx	0	2	3	3	4	2	19
Sclerothamnopsis compressa	0	0	0	8	0	0	3
Staurocalyptus sp.	3	8	2	3	5	1	19
Rhabdocalyptus sp.	0	0	0	0	0	1	0
Chonelasma sp.	0	0	0	0	1	1	3
Hyalonema sp.	0	0	0	0	0	0	0
Euplectellidae sp.	0	0	0	0	1	0	0
Saccocalyx pedunculata	0	0	0	0	0	1	0
Encrusting sponge	0	4	0	0	0	0	0
Poecillastra sp.	2	0	0	3	2	2	6
Ctenophore sp.	0	0	0	0	0	0	0
Jellyfish sp. 2	2	0	0	0	0	0	0
LRJ	0	0	0	0	0	0	0
Solmissus incisa	0	0	0	0	0	0	0
Siphonophora sp.	1	0	0	0	0	0	1
Dromalia sp.	0	0	0	5	2	0	0
Red *Swiftia* sp.	0	0	0	13	0	0	0

Victorgorgia sp.	0	0	0	0	0	0	0
Paragorgia sp.	0	11	6	0	0	4	6
Acanthogorgia sp.	0	0	0	0	0	6	14
Parastanella sp.	0	5	0	0	0	0	0
Heteropolypus sp.	10	18	7	7	8	5	29
Plexaurid sp.	0	0	0	0	0	0	0
Zoanthidae sp.	0	0	0	0	0	0	0
Sea Pen	0	2	0	1	0	0	0
Anthoptilum sp.	0	0	0	0	2	0	39
Umbellula sp.	49	3	0	27	2	0	0
Halipteris sp.	3	1	0	48	0	0	4
Narella sp.	0	0	0	0	0	0	0
Cup coral	0	0	0	0	0	0	0
Corallimorphus sp.	0	0	0	0	0	0	3
Lillipathes sp.	0	0	0	0	0	0	0
Actinaria sp.	0	20	0	4	5	8	3
Actinerus sp.	0	0	0	0	0	0	0
Purple actinaria	0	0	0	0	0	0	0
Metridoidea sp.	0	11	0	0	0	0	0
Urticina sp.	0	0	0	0	0	0	5
Hormathiidae sp.	0	0	0	0	0	0	0
Liponema brevicore	0	0	0	0	0	0	1
Cerianthidae sp.	0	0	0	0	0	0	0
Actinaria sp. 1	0	0	0	0	0	0	0
Actinaria sp. 2	0	0	0	0	0	0	0
Actinoscyphia aurelia	0	0	0	0	0	0	0
Acesta sp.	0	0	0	0	0	0	0
Grimpoteuthis sp.	0	0	0	0	0	0	0
Tritonia sp.	0	0	0	0	0	0	0
Heliocranchia sp.	0	0	0	0	0	0	0
Laetmonice sp.	0	0	0	0	0	0	0
Myxicola sp.	485	223	391	253	98	22	43
Swima sp. nov.	0	0	0	0	0	0	0
Daddy long leg isopod	0	0	0	0	0	0	0
Pelagic shrimp	43	5	0	0	0	0	0
Benthic decapod	0	0	0	8	3	1	0
Sternostylus sp.	0	0	0	0	0	0	0
Pantopoda sp.	0	0	0	0	0	0	0
Chorilia lonipes	20	13	29	10	9	12	16

Arthropod sp. 1	0	0	0	0	0	0	0
Arthropod sp. 4	0	0	0	0	0	0	0
Glyptolithodes cristatipes	0	0	0	0	0	0	0
Chionecetes tanneri	0	0	1	0	0	0	0
Paralomis sp.	0	3	1	0	1	0	0
Squat lobster	0	0	0	2	0	1	0
Paguroidea sp.	0	0	0	0	0	0	0
Hermit crab	0	0	0	0	0	0	0
Asteroid sp. 1	30	24	14	22	0	0	5
Asteroid sp. 4	0	0	0	17	0	0	0
Goniasteridae sp. 1	0	0	0	0	0	0	0
White asteroid	0	0	0	0	0	0	0
Bumpy asteroid	0	0	0	0	0	0	0
Asteridae sp.	0	0	0	0	0	0	0
Benthopectinidae sp.	1	0	1	0	0	0	0
Porianopsis sp.	0	0	0	1	0	0	0
Pteraster sp.	8	2	0	0	31	2	0
Hymenaster sp.	0	0	0	0	0	0	0
Ceramaster sp.	1	1	2	0	4	4	3
Valvatida sp.	0	0	0	0	0	0	0
Myxoderma sp.	0	0	0	0	0	0	0
Goniasteridae sp.	0	0	0	0	0	0	0
Hippasteria sp.	1	1	0	0	0	1	3
Sunstar sp.	0	0	0	0	0	0	0
Ophiuroid sp.	0	0	0	0	0	0	0
Ophiacantha diplasia	0	0	1639	0	0	1635	417
Ophiuroid sp. 1	0	0	0	0	0	0	0
Ophiuroid sp. 2	0	0	0	0	0	0	0
Ophiuroid sp. 3	0	0	0	0	0	0	0
Ophiuroid sp. 4	0	0	0	0	0	0	0
Ophiuroid sp. 5	0	0	0	0	0	0	0
Asteronyx sp.	0	0	0	0	0	0	0
Gorgonocephalus eucnemis	0	0	0	0	0	0	0
Freyellidae sp.	0	0	0	0	0	0	0
Brisingidae sp.	9	131	24	60	30	8	105
Zenometridae sp.	0	0	0	0	0	0	0
Antedonidae sp.	0	0	0	0	0	0	0
Psathyrometra fragilis	0	0	0	0	0	0	0
Hyocrinus sp.	0	0	0	0	0	0	0

Araesoma sp.	0	0	1	6	0	0	0
Holasteroida sp.	0	0	0	0	0	0	0
Aspidodiadematidae sp.	0	0	0	0	0	0	0
Strongylocentrotus fragilis	574	1	0	6	0	0	0
Scotoplanes sp.	0	0	0	0	0	0	0
Peniagone sp.	0	0	0	0	0	0	0
Elipidiidae sp.	0	0	0	0	0	0	0
Pannychia sp.	320	16	40	112	63	18	4
Deiamatidae sp. 1	0	0	0	0	0	0	0
Deiamatidae sp. 2	0	0	0	0	0	0	0
Synallactida sp.	0	0	0	0	0	0	0
Psolus sp.	4	2	2	13	0	0	44
Benthodytes sp.	0	0	0	0	0	0	0
Enteropneust sp.	0	0	0	0	0	0	0
Tunicate sp.	0	0	0	0	0	0	0
Pyrosome sp.	0	0	0	0	0	0	0
Facciolella sp.	0	0	0	0	0	0	1
Lycodes sp.	0	0	0	0	0	0	0
Parmaturus xaniurus	0	0	0	0	0	0	0
Skate sp.	0	0	0	0	0	0	0
Other fish sp.	0	0	0	1	0	0	0
Sebastes zacentrus	16	1	7	3	3	4	0
Sebastes spp.	0	0	0	0	0	0	0
Sebastes melanostomus	0	0	0	0	0	0	0
Sebastes aurora	0	0	0	0	0	2	0
Sebastolobus alascanus	5	21	0	5	10	0	2
Sebastolobus altivelis	5	0	1	3	0	1	0
Liparidae sp.	0	0	0	1	4	2	0
Zoarcidae sp.	3	3	1	15	0	0	0
Bathysaurus sp.	0	0	0	0	0	0	0
Flatfish sp.	0	0	1	0	0	1	0
Eptatretus stoutii	4	3	2	6	2	3	9
Grenadier sp.	1	0	0	0	0	0	0
Cyclops fish	1	0	0	0	0	0	0
Myctophid sp.	0	0	0	0	0	0	0

Appendix 3.8: Total counts from San Juan Seamount

Taxa	SJS CT1	SJS CT2	SJS CT3	SJS CT4	SJS CT5	SJS NT1	SJS NT2	SJS NT3	SJS NT4	SJS NT5
Xenophyophore sp.	0	0	0	0	0	0	5	0	0	0
Demospongiae sp.	0	0	0	0	0	0	0	0	0	1
Puffball sponge	0	0	0	0	1	11	0	0	12	5
Rhizaxinella gadus	0	0	0	0	0	0	0	0	0	0
Asbestopluma sp.	0	0	0	0	7	3	46	148	111	129
Mycale sp.	0	0	0	0	0	0	0	0	0	0
Thenea sp.	0	0	0	0	0	0	0	0	0	0
Other Hexactinellidae sp.	0	0	3	0	3	0	0	2	3	15
Hexactinellidae sp. 1	0	0	9	0	3	0	0	0	0	0
Hexactinellidae sp. 4	0	0	0	0	0	0	0	0	0	0
Hexactinelidae sp. 5	0	0	0	0	0	0	0	0	0	0
Rosselidae sp.	0	0	0	0	0	0	0	0	0	1
Farrea sp.	5	67	128	94	149	32	119	72	56	65
Farrea truncata complex	0	2	0	0	0	0	0	0	0	0
Euretidae sp.	0	0	0	2	0	0	0	0	0	0
Aphrocallistes vastus	0	0	0	0	5	0	0	0	2	0
Heterochone calyx	0	0	4	4	66	0	0	3	3	5
Sclerothamnopsis compressa	0	0	0	0	1	0	2	0	0	0
Staurocalyptus sp.	0	12	9	5	10	0	1	19	42	27
Rhabdocalyptus sp.	0	0	28	2	11	0	0	0	0	0
Chonelasma sp.	0	0	0	2	1	0	2	11	7	7
Hyalonema sp.	0	0	0	0	0	0	0	0	0	0
Euplectellidae sp.	0	0	0	0	0	5	4	19	9	4
Saccocalyx pedunculata	0	0	6	0	0	0	0	0	0	0
Encrusting sponge	0	0	0	0	0	0	0	0	3	1
Poecillastra sp.	0	0	3	64	55	0	0	7	3	4
Ctenophore sp.	0	0	0	0	0	0	0	0	0	0
Jellyfish sp. 2	0	2	0	0	1	0	0	0	0	0

LRJ	1	0	0	0	1	0	0	0	0	0
Solmissus incisa	0	0	1	0	0	0	0	0	0	0
Siphonophora sp.	0	0	0	0	0	0	0	0	0	0
Dromalia sp.	0	0	0	0	0	5	4	0	0	0
Red *Swiftia* sp.	0	0	292	841	346	0	0	0	0	0
Victorgorgia sp.	0	0	0	0	0	0	3	73	39	77
Paragorgia sp.	0	0	83	87	367	0	0	27	13	21
Acanthogorgia sp.	0	0	0	8	301	0	18	1437	728	581
Parastanella sp.	0	0	564	0	0	3	3	4	10	4
Heteropolypus sp.	0	0	57	41	140	1	5	2	3	8
Plexaurid sp.	0	0	0	0	0	0	1	0	1	0
Zoanthidae sp.	0	0	0	0	0	0	0	0	4	1
Sea Pen	0	0	0	0	0	0	0	0	0	0
Anthoptilum sp.	0	0	0	0	0	0	0	0	0	0
Umbellula sp.	0	0	0	0	0	0	0	0	0	0
Halipteris sp.	0	0	31	0	0	0	0	0	0	0
Narella sp.	0	0	19	6	0	0	0	0	0	3
Cup coral	0	0	0	0	0	0	12	27	17	1
Corallimorphus sp.	0	1	0	0	0	0	0	0	0	0
Lillipathes sp.	0	0	0	0	0	0	5	6	0	0
Actinaria sp.	0	2	35	32	0	1	5	3	3	8
Actinerus sp.	0	0	0	0	0	0	0	0	0	1
Purple actinaria	0	0	0	0	0	0	0	0	0	3
Metridoidea sp.	4	0	5	0	0	0	3	10	14	1
Urticina sp.	0	0	0	0	0	0	0	0	0	0
Hormathiidae sp.	0	0	3	0	0	0	1	1	0	0
Liponema brevicore	0	1	0	0	0	0	0	0	1	4
Cerianthidae sp.	0	0	0	0	0	16	27	2	6	0
Actinaria sp. 1	0	0	0	0	0	0	0	0	0	0
Actinaria sp. 2	0	0	0	0	0	1	8	14	23	12
Actinoscyphia aurelia	0	0	0	14	0	0	0	0	0	0
Acesta sp.	0	0	1	0	0	38	45	17	9	1
Grimpoteuthis sp.	0	0	0	0	0	0	0	0	0	1
Tritonia sp.	0	0	0	0	0	0	0	0	0	0
Heliocranchia sp.	0	0	0	0	1	0	0	0	0	0
Laetmonice sp.	0	0	0	0	0	0	0	0	0	0

Myxicola sp.	0	1	0	0	0	0	0	0	0	0
Swima sp. nov.	0	0	0	0	0	0	0	0	0	0
Daddy long leg isopod	0	0	0	0	0	0	0	0	0	0
Pelagic shrimp	10	0	0	0	0	0	0	0	0	0
Benthic decapod	7	8	11	0	2	2	3	2	0	0
Sternostylus sp.	0	0	0	0	0	0	0	1	2	0
Pantopoda sp.	0	0	0	0	0	0	0	0	0	0
Chorilia lonipes	0	0	0	0	18	7	0	0	0	0
Arthropod sp. 1	0	0	0	0	0	0	0	5	6	0
Arthropod sp. 4	0	0	0	0	0	0	3	0	0	0
Glyptolithodes cristatipes	0	0	0	0	0	0	0	0	0	0
Chionecetes tanneri	0	0	0	0	0	0	0	0	0	0
Paralomis sp.	0	4	0	0	2	1	0	6	0	4
Squat lobster	4	22	555	24	62	8	12	27	24	39
Paguroidea sp.	0	0	0	0	0	0	0	0	0	0
Hermit crab	0	0	0	0	0	0	0	0	0	0
Asteroid sp. 1	0	3	10	1	6	0	0	0	0	0
Asteroid sp. 4	0	0	0	0	3	0	0	0	0	0
Goniasteridae sp. 1	0	0	0	0	0	0	0	0	0	0
White asteroid	0	0	0	0	0	0	0	0	0	4
Bumpy asteroid	0	0	0	0	0	0	0	0	0	0
Asteridae sp.	0	0	0	0	0	0	1	2	0	0
Benthopectinidae sp.	0	0	0	0	0	0	0	0	0	0
Porianopsis sp.	0	1	0	0	1	0	0	0	0	0
Pteraster sp.	1	0	4	0	1	0	2	2	3	1
Hymenaster sp.	0	0	0	0	0	0	0	0	0	0
Ceramaster sp.	0	2	0	2	6	1	1	2	3	0
Valvatida sp.	0	0	0	0	0	0	0	0	0	0
Myxoderma sp.	0	0	0	0	0	0	0	0	5	0
Goniasteridae sp.	0	0	0	0	0	0	0	0	0	0
Hippasteria sp.	0	0	2	4	8	0	0	0	0	1
Sunstar sp.	0	0	0	0	0	0	0	0	0	0
Ophiuroid sp.	0	0	0	0	0	0	0	0	0	14
Ophiacantha diplasia	0	0	0	0	0	0	0	0	0	0

Ophiuroid sp. 1	0	0	0	0	0	47	19	18	10	0
Ophiuroid sp. 2	0	0	0	0	0	492	985	0	0	4
Ophiuroid sp. 3	0	0	0	0	0	53	283	25	23	0
Ophiuroid sp. 4	0	0	0	0	0	38	414	22	16	0
Ophiuroid sp. 5	0	0	0	0	0	0	0	0	0	0
Asteronyx sp.	0	0	0	0	0	0	0	0	0	0
Gorgonocephalus eucnemis	0	0	0	0	0	0	2	89	44	38
Freyellidae sp.	0	0	0	0	0	0	0	0	0	0
Brisingidae sp.	0	0	0	540	460	1	12	12	6	3
Zenometridae sp.	0	0	0	0	0	0	3	1	2	0
Antedonidae sp.	0	0	0	0	0	7	9	0	3	0
Psathyrometra fragilis	0	0	0	0	0	0	0	0	0	0
Hyocrinus sp.	0	0	0	0	0	0	0	0	0	0
Araesoma sp.	1	28	0	0	0	21	12	12	7	5
Holasteroida sp.	0	0	0	0	0	0	0	0	0	0
Aspidodiadematidae sp.	0	18	0	0	0	0	0	1	0	2
Strongylocentrotus fragilis	0	0	0	0	0	0	0	0	0	0
Scotoplanes sp.	0	0	0	0	0	7	4	0	0	0
Peniagone sp.	0	0	0	0	0	0	0	0	0	0
Elipidiidae sp.	0	0	0	0	0	0	0	0	0	0
Pannychia sp.	0	0	9	3	0	0	3	3	0	0
Deiamatidae sp. 1	0	0	0	0	0	0	0	0	0	0
Deiamatidae sp. 2	0	0	0	0	0	0	0	0	0	0
Synallactida sp.	0	0	0	0	0	8	0	0	0	0
Psolus sp.	0	15	9	5	0	0	2	8	62	115
Benthodytes sp.	0	0	0	0	0	0	0	0	0	0
Enteropneust sp.	0	0	0	0	0	0	0	0	0	0
Tunicate sp.	27	0	0	0	0	0	0	0	0	0
Pyrosome sp.	0	0	0	0	0	1	0	0	0	0
Facciolella sp.	0	0	0	0	0	0	0	0	0	0
Lycodes sp.	0	0	0	0	0	0	0	0	0	0
Parmaturus xaniurus	0	0	0	0	0	0	0	0	0	0
Skate sp.	0	1	0	0	0	0	0	0	0	0
Other fish sp.	0	0	0	2	0	2	0	0	0	0

Sebastes zacentrus	0	5	0	3	2	0	0	0	0	0
Sebastes spp.	0	0	0	0	0	0	0	0	0	0
Sebastes melanostomus	0	0	0	0	0	0	0	0	0	0
Sebastes aurora	0	0	0	0	0	0	0	0	0	0
Sebastolobus alascanus	5	0	0	1	0	0	0	1	2	0
Sebastolobus altivelis	0	0	0	1	1	0	0	0	0	0
Liparidae sp.	4	0	0	0	0	0	0	0	0	0
Zoarcidae sp.	0	0	0	0	1	0	0	0	0	0
Bathysaurus sp.	0	0	0	0	0	0	0	0	0	0
Flatfish sp.	0	0	0	0	1	0	0	0	0	0
Eptatretus stoutii	0	0	1	2	4	0	0	0	0	0
Grenadier sp.	1	0	0	1	3	1	0	5	1	1
Cyclops fish	0	0	0	0	0	0	0	0	0	0
Myctophid sp.	0	0	0	0	0	0	0	0	0	0

Appendix 4: Southern California Borderland megafaunal diversity metrics from each transect

Cruise	Code	Site	Transect	S	H'	J'	Average Oxygen (µM O2/L)	Depth (m)
FK210726	CET1	Coronado Escarpment	1	28	1.19	0.36	24.3	469
FK210726	CET2	Coronado Escarpment	2	25	1.93	0.60	25.31	459
FK210726	CET3	Coronado Escarpment	3	24	1.92	0.61	27.04	449
FK210726	CET4	Coronado Escarpment	4	27	2.04	0.62	28.17	435
FK210726	CET5	Coronado Escarpment	5	30	2.00	0.59	30.6	391
NA124	SCE1	San Clemente Escarpment	1	22	0.72	0.23	44.12	1682
NA124	SCE2	San Clemente Escarpment	2	14	0.50	0.19	39.60	1645
NA124	SCE3	San Clemente Escarpment	3	24	2.01	0.63	38.07	1478
NA124	SCE4	San Clemente Escarpment	4	19	2.56	0.87	36.05	1404
NA124	40MB2	40 Mile Bank	2	26	3.13	0.96	5.89	859
NA124	40MB3	40 Mile Bank	3	33	3.49	1.00	4.56	780
NA124	40MB4	40 Mile Bank	4	30	2.56	0.75	2.65	660
NA124	CB1	Cortes Bank	1	15	2.19	0.81	5.09	571
NA124	CB2	Cortes Bank	2	32	3.17	0.92	5.88	508
NA124	CB3	Cortes Bank	3	28	3.02	0.91	10.13	463
NA124	NEB1	Northeast Bank	1	12	2.50	1.01	23.91	1198
NA124	NEB2	Northeast Bank	2	23	2.56	0.82	7.29	903
NA124	NEB3	Northeast Bank	3	26	2.44	0.75	4.21	791
NA124	NEB4	Northeast Bank	4	26	2.02	0.62	3.35	662
NA124	NEB5	Northeast Bank	5	29	2.95	0.88	6.40	532
FK210726	LJST1	Little Joe Seamount	1	26	2.87	0.88	109.43	2735
FK210726	LJST2	Little Joe Seamount	2	26	2.88	0.88	106.3	2573
FK210726	LJST3	Little Joe Seamount	3	34	3.32	0.94	104.55	2497
FK210726	LJST5	Little Joe Seamount	5	28	2.97	0.89	102.38	2376
NA124	PRC4	Patton Ridge Central	4	28	2.17	0.65	3.56	716
NA124	PRC5	Patton Ridge Central	5	32	2.75	0.79	3.36	655
NA124	PRC6	Patton Ridge Central	6	24	1.34	0.42	6.02	550
NA124	PRS1	Patton Ridge South	1	34	2.88	0.82	3.84	703
NA124	PRS2	Patton Ridge South	2	28	3.03	0.91	3.03	645
NA124	PRS3	Patton Ridge South	3	33	0.74	0.21	3.83	589
NA124	PRS4	Patton Ridge South	4	32	2.55	0.74	4.93	561
NA124	SJSC1	San Juan Seamount Central	1	12	2.38	0.96	22.60	1105
NA124	SJSC2	San Juan Seamount Central	2	19	2.61	0.89	13.03	950
NA124	SJSC3	San Juan Seamount Central	3	27	2.35	0.71	4.02	725
NA124	SJSC4	San Juan Seamount Central	4	27	1.89	0.57	3.44	667
NA124	SJSC5	San Juan Seamount Central	5	36	2.65	0.74	3.59	608
FK210726	SJSNT1	San Juan Seamount North	1	28	2.04	0.61	43.11	1417
FK210726	SJSNT2	San Juan Seamount North	2	39	2.15	0.59	41.16	1348
FK210726	SJSNT3	San Juan Seamount North	3	41	1.90	0.51	34.59	1263
FK210726	SJSNT4	San Juan Seamount North	4	42	2.49	0.67	32.21	1227
FK210726	SJSNT5	San Juan Seamount North	5	41	2.50	0.67	27.05	1157

*H' calculated in log(10)