BULLETIN OF MARINE SCIENCE, 86(1): 35–52, 2010 CORAL REEF PAPER

# A SURVEY OF THE REEF FISHES, PURPLE HYDROCORAL (*STYLASTER CALIFORNICUS*), AND MARINE DEBRIS OF FARNSWORTH BANK, SANTA CATALINA ISLAND

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## ABSTRACT

Farnsworth Bank is a relatively small, semi-isolated feature composed of sharp pinnacles and located on the seaward side of Santa Catalina Island, southern California. Despite its heavy colonization by the rare purple hydrocoral *Stylaster californicus* (Verrill, 1866), and its popularity as a fishing and diving site, no complete fish survey of this site had been conducted. Using the occupied submersible Delta, we made four dives (comprising 15 transects and 342 habitat patches) in waters between 30 and 90 m deep, totaling 12,605 $m^2$ (6325 linear m) of sea floor. During the survey, fishes, purple hydrocoral colonies, and marine debris were assessed. We observed a total of 10,404 fishes, representing at least 43 species and 13 families. Rockfishes (genus *Sebastes*), comprising 25 species and 7070 individuals, dominated the assemblage. The most abundant fish species were squarespot rockfish, blacksmith, and dwarf-red rockfish, all schooling and aggregating epibenthic or midwater taxa. Commonly observed solitary species included blackeye goby and rosy rockfish. Most economically important fish species were uncommon and were represented by small individuals. Purple hydrocoral colonies were observed at depths between 31 and 66 m, primarily between about 30 and 40 m, and only on rocky substrate. Although we observed hydrocoral colonies with diameters as large as 120 cm, most were 40 cm or less and the largest colonies tended to be in the shallowest waters. Relatively large amounts of debris, mostly recreational and commercial fishery related lines and nets, were observed.

Farnsworth Bank is one of the more striking geological structures within the southern California Bight. Located about 2.4 km southwest of Ben Weston Point, Santa Catalina Island (Fig. 1), the bank (covering about 6 ha) is a series of hard bedrock pinnacles, rising to as shallow as 15 m (but mostly in 24 m and deeper) from a soft sediment sea floor (Engle and Coyer, 1981). Farnsworth Bank and Santa Catalina Island are separated by a minimum sea floor depth of 73 m. Characterized by clear waters throughout much of the year, and within relatively easy reach of the southern California mainland, Farnsworth Bank has long been popular with recreational divers and anglers and with commercial fishermen (Engle and Coyer, 1981).

One of the bank's unusual features is the high abundance of the poorly-known purple hydrocoral *Stylaster californicus* (Verrill, 1866) that covers much of the hard surfaces of the upper parts of the feature (Engle and Coyer, 1981). Preferring low turbidity and high current waters, purple hydrocoral is found only at a relatively few locations within its geographic (Cordell Bank, northern California to Islas San Benito, central Baja California) and depth (5–98 m) ranges (Engle and Coyer, 1981; Lissner and Dorsey, 1986; L. Etherington, Cordell Bank National Marine Sanctuary, pers. comm.; J. Engel, Marine Science Institute, University of California, Santa Barbara, pers. comm.).

For a number of years, purple hydrocoral in southern California was commercially harvested for use in jewelry and as curios. Responding to this perceived threat to the coral, the State of California designated Farnsworth Bank as an Ecological Reserve

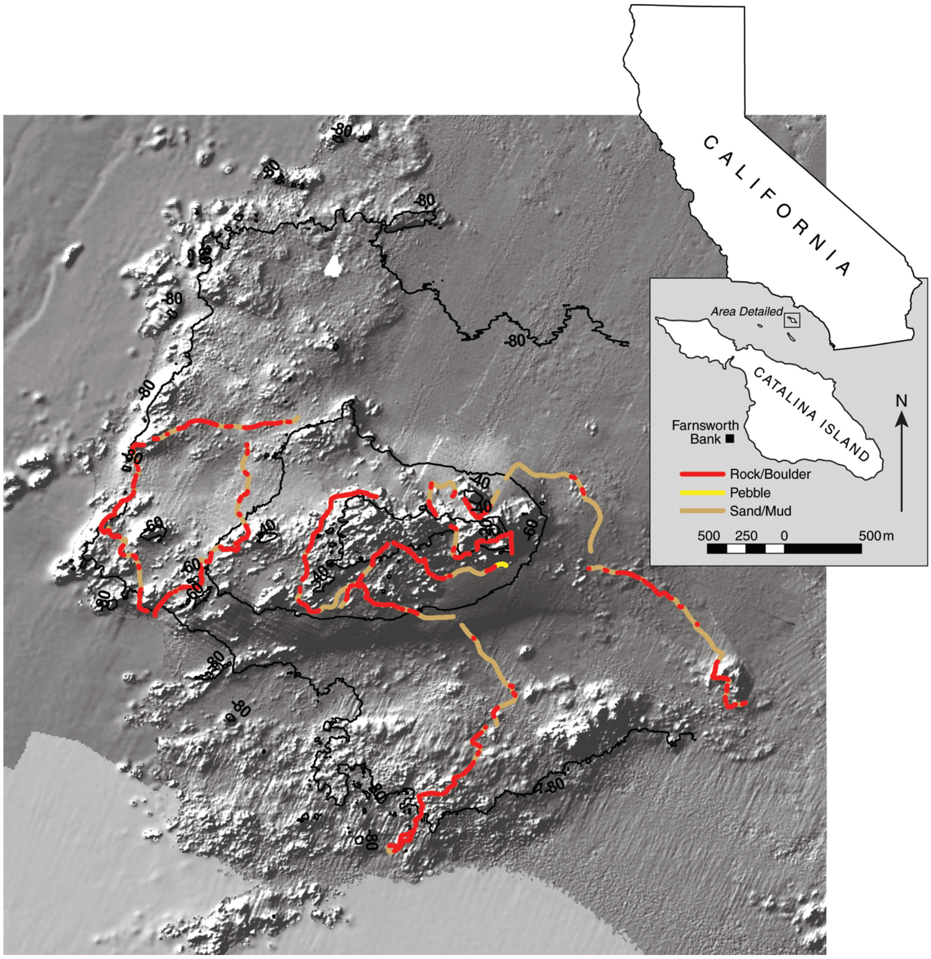


Figure 1. Multibeam and sidescan image of Farnsworth Bank, Santa Catalina Island. Included are the submersible survey paths, conducted on 6 October 2008, with habitat characterizations. Data were acquired, processed, archived, and distributed by the Seafloor Mapping Lab of California State University Monterey Bay.

and banned all purple hydrocoral harvest. All other activities, including recreational diving, and recreational and commercial fishing, are permitted (California Department of Fish and Game, 2007). However, despite its reserve status, only cursory and qualitative SCUBA-based surveys of the fish species assemblage of Farnsworth Bank have been conducted (summarized in Engle and Coyer, 1981). Recently, Farnsworth Bank has been included in a list of possible sites to be given complete protection. Given the singular nature of this bank, we undertook a survey of its fish assemblages and hydrocoral colonies, and assessed the occurrence of marine debris.

## Methods

Field Sampling.—The survey was conducted on 6 October 2008 aboard the research submersible Delta, which is 4.8 m in length, accommodates one scientific observer and one pilot, and has a maximum operating depth of 365 m. During a dive, a constant distance within 1 m of the seafloor and a constant speed between 0.5 and 1.0 knot was attempted. Dives were made during daytime hours, and were documented with an externally mounted hi-8 video camera positioned above the middle viewing-porthole on the starboard side of the submersible. The scientific observer conducted a belt-transect survey through this same starboard viewing port, verbally recording onto the videotape all fishes. The observer estimated the total length (TL) of these fishes using reference light points from two parallel lasers installed 20 cm apart on either side of the external video camera. These lasers also helped delineate the width (2 m) of the transects.

To determine the densities of purple hydrocoral, we used footage from both the external video camera and from a second color video camera that was positioned inside the submersible in front of the lower port on the starboard side. In the laboratory, the external and internal videos were watched simultaneously. Hydrocoral patches with an average diameter of at least 5 cm were counted, and the diameter of each colony was estimated to the nearest 5 cm. Similar to the fish survey methodology, we recorded all hydrocorals within 2 m of the observer. Depth and habitat data were recorded for each colony.

Marine debris was verbally noted by the observer and was later described in more detail in the laboratory. For this analysis, we placed debris in one of the following categories: (1) light fishing line (primarily monofilament line used in recreational fishing); (2) heavy line/cable (including line associated with nets or traps, remnants of net lead or float line, or metal cable); (3) nets; (4) traps; (5) anchor gear (anchor, chain, and anchor line); (6) miscellaneous debris (including a hose and a beverage can). We recorded all debris seen, no matter the distance from the observer.

Transect length was estimated by navigation fixes (latitude and longitude coordinates) received from a Thales GeoPacific Winfrog ORE Trackpoint 2 USBL system at two-second intervals, and a Winfrog DAT file was generated for each dive. Distance and duration between fixes were calculated to obtain a point-to-point submersible speed; errant navigation fixes were removed when speed exceeded 2 m $s^{-1}$. The navigation fixes were then smoothed using a nine-point moving average, and transect length was estimated from the total distance between the smoothed points. Transect length was divided by transect duration to obtain an average transect speed. The length of individual habitat patches was estimated from average speed of the submersible during each transect. This method, direct observations of fish assemblages from the DELTA submersible, has been used extensively to characterize both fish diversity and their ontogenetic movements (Yoklavich and O'Connell, 2008).

This survey methodology underestimates the densities of some small and cryptic taxa, such as the bluebanded and zebra gobies. In addition, schools of benthopelagic taxa, such as blacksmith, will occasionally aggregate in the water column above the DELTA and are not counted. Many years of experience along the Pacific Coast have shown that if the DELTA or other occupied submersibles are moving at a constant and slow rate of speed, as in these surveys, there is little obvious effect on the behavior of demersal fishes (Yoklavich et al., 2007; Love and Yoklavich, 2008).

ANALYSES.—In our analyses, substratum types (micro-scale habitats) were characterized within the 2-m swath along each dive track, based on images from the external video camera. Using the geological definitions of Greene et al. (1999), four substratum types were initially characterized from the videotapes. These included sand (S), pebble (P), boulder (B), and rock ridge (R). A two-character code was assigned each time a distinct change in substratum type was noted along the dive tract, thus delineating habitat patches of uniform type. The first character in this code represented the substratum that accounted for at least 50% of the patch, and the second character represented the substratum type that accounted for at least 20% of the patch (e.g., a patch designated as "SP" comprised at least 50% sand and at least 20% pebbles). The area of each habitat patch was determined by multiplying length of the patch by the width of the swath (2 m). We then combined these substratum types into six habitat categories based on high (H) and low (L) rock relief and on low relief soft (S) sediments, where HH = BB, BR, RR, RB; HS = RS, BS; LS = PS; SH = SR, SB; SL = SP; SS = SS.

A cluster analysis of the densities of those species characteristic of the study area (defined as having been observed in five or more transects and 15 or more individuals) was performed and the densities for each of these species calculated by dividing the number observed by the transect area, where area equals two times the distance surveyed in meters. Densities for each species were standardized to a mean of zero and standard deviation of one. The procedure hclust of the statistical package R (R, 2005) was used for the analysis, along with the average linkage option of the Unweighted Pair-Groups Method for performing the hierarchical agglomerative clustering. The Euclidean method was used for calculating distances.

## Results

A total of four dives (comprising 15 transects and 342 habitat patches) were made in waters between 30 and 90 m deep and this totaled 12,605 $m^2$ (6325 linear m) of sea floor (Fig. 1, Table 1). Most of the surveys were conducted at bottom depths of about 40–80 m. Among the six habitat categories, more SS (soft-soft) and HS (hard-soft) habitats (3628 $m^2$ and 3627 $m^2$, respectively), were surveyed than the other habitat types (Table 1). A complex of very sheer and vertical pinnacles that are heavily broken with crevices characterizes Farnsworth Bank. The bank is surrounded by sand and with the exception of a small patch of pebbles in about 60 m of water (Fig. 1, Table 2), we observed no low, hard-relief sea floor. Overall, we surveyed slightly more hard sea floor (H and L combined, 6687 $m^2$) than soft substrata (S, 5918 $m^2$) (Table 2).

A total of 10,404 fishes were observed representing at least 43 species and 13 families (Tables 3, 4). Rockfishes (genus *Sebastes*), comprising 25 species and 7070 individuals, dominated the bank (Table 4). The most abundant fish species were squarespot rockfish, blacksmith, and dwarf-red rockfish, all schooling and aggregating epibenthic or midwater taxa. Commonly observed solitary species included benthic blackeye goby and rosy rockfish. Halfbanded and pygmy rockfishes, as well as señorita and California sheephead, were also commonly seen. Those fish species characteristic of Farnsworth Bank tended to either live over high relief habitats (on reef crests and sides), or were ecotonal species, found along the reef-sediment interface (Fig. 2). Despite the large amount of sand habitat surveyed, there were no species that were characteristic of strictly soft sea floor (Fig. 2, Table 4). In general, economically important fish species were not abundant (Table 4). Among species that are targeted by recreational fishers, spear fishers, and commercial fishermen, only sheephead were commonly observed.

Table 1. Area of Farnsworth Bank ($m^2$) surveyed by habitat category and 10 m depth bins, October 2008. (H = high relief dominated, L = low-relief dominated, S = soft-substrata dominated).

| | Bottom type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Depth category (m) | HH | HS | LS | SH | SL | SS | Total | Portion of total |
| 30 | 97 | | | | | | 97 | 0.01 |
| 40 | 1,061 | 444 | | 160 | 105 | 7 | 1,777 | 0.14 |
| 50 | 558 | 577 | | 468 | 65 | 543 | 2,211 | 0.18 |
| 60 | 139 | 616 | 65 | 208 | 32 | 1,006 | 2,077 | 0.16 |
| 70 | 696 | 1,013 | | 1,039 | | 1,538 | 4,285 | 0.34 |
| 80 | 434 | 968 | | 213 | | 466 | 2,080 | 0.17 |
| 90 | | 10 | | | | 67 | 77 | 0.01 |
| Total | 2,995 | 3,627 | 65 | 2,089 | 201 | 3,628 | 12,605 | 1 |
| Portion of total | 0.24 | 0.29 | 0.01 | 0.17 | 0.02 | 0.29 | 1 | |

Table 2. Area of Farnsworth Bank ($m^2$) surveyed by aggregate habitat category and 10 m depth bins, October 2008. (H = high relief dominated, L = low-relief dominated, S = soft-substrata dominated).

| Depth category (m) | H | L | S | Total | Portion of total |
|---|---|---|---|---|---|
| 30 | 97 | 0 | 0 | 97 | 0.01 |
| 40 | 1,505 | 0 | 272 | 1,777 | 0.14 |
| 50 | 1,135 | 0 | 1,076 | 2,211 | 0.18 |
| 60 | 765 | 65 | 1,246 | 2,077 | 0.16 |
| 70 | 1,709 | 0 | 2,577 | 4,285 | 0.34 |
| 80 | 1,402 | 0 | 679 | 2,080 | 0.17 |
| 90 | 10 | 0 | 67 | 77 | 0.01 |
| Total | 6,622 | 65 | 5,918 | 12,605 | 1 |
| Portion of total | 0.53 | 0.01 | 0.47 | 1 | |

Most of the fishes that we observed on Farnsworth Bank were small and few were > 25 cm TL (Fig. 3A). Several species that are capable of reaching relatively large sizes were present only as small individuals. This was particularly noteworthy with lingcod and sheephead, two economically important species. For these two taxa, almost no individuals larger than the minimum legal retention size were observed (Figs. 3B, C).

While purple hydrocorals were observed at depths between 31 and 66 m, they were most common in the shallower parts of the study site, primarily at depths between about 30 and 40 m (Table 5). Hydrocorals were only found on rocky substrate and occurred at high densities on both horizontal and vertical faces. Although we observed hydrocoral colonies with diameters as large as 120 cm, most were 40 cm or less (Table 5) and the largest colonies tended to be in the shallowest waters. We did not observe any damaged hydrocoral colonies.

We documented 49 pieces of marine debris on Farnsworth Bank and nearby sea floor, which averaged to 0.77 pieces per 100 m of transect (Fig. 4, Table 6). Light monofilament line from recreational fishing activities was by far the material most often observed. However, we also saw heavier lines or cables, nets, traps, and miscellaneous debris. Although debris was scattered throughout the feature, the heaviest concentrations were in the shallower and more rugged portions (Fig. 4). In particular, five of the eight anchors were lodged in the shallower, central portion, as were two of the three nets. We did not observe any fishes or invertebrates trapped in lost gear, although we were unable to adequately see inside all of the traps.

## Discussion

Farnsworth Bank is composed of very large and sheer pinnacles that plunge abruptly to a surrounding sandy sea floor. We observed almost none of the hard, but low-relief structures (e.g., cobbles and pebbles) that are present around most of the reefs in southern California waters. In their shallow SCUBA surveys, Engle and Coyer (1981) also noted that only small amounts of coarse sediment, composed of biogenic material, such as shells, sea urchin tests and spines, and coralline algae, fell from the bank. Guy Cochrane (United States Geological Survey, pers. comm.) speculates that Farnsworth Bank is composed of hard, igneous material that resists

Table 3. Common and scientific names of fishes observed at Farnsworth Bank in this study, as well as by Engle and Coyer (1981), Bergen (1973) (as quoted by Engle and Coyer, 1981), and Given (1967) (as quoted by Engle and Coyer, 1981).

| Species |
| --- |
| Family Scyliorhinidae |
| Swell shark, *Cephaloscyllium ventriosum* (Garman, 1880) |
| Family Carcharhinidae |
| Blue shark, *Prionace glauca* (Linnaeus, 1758) |
| Family Squatinidae |
| Pacific angel shark, *Squatina californica* Ayres, 1859 |
| Family Torpedinidae |
| Pacific electric ray, *Torpedo californica* Ayres, 1855 |
| Family Muraenidae |
| California moray, *Gymnothorax mordax* (Ayres, 1859) |
| Family Ophidiidae |
| Spotted cusk-eel, *Chilara taylori* (Girard, 1858) |
| Family Bythitidae |
| Red brotula, *Brosmyphycis marginata* (Ayres, 1854) |
| Family Syngnathidae |
| Unidentified pipefish, *Syngnathus* sp. |
| Family Scorpaenidae |
| Bank rockfish, *Sebastes rufus* (Eigenmann and Eigenmann, 1890) |
| Black-and-yellow rockfish, *Sebastes chrysomelas* (Jordan and Gilbert, 1881) |
| Blue rockfish, *Sebastes mystinus* (Jordan and Gilbert, 1881) |
| Bocaccio, *Sebastes paucispinis* Ayres, 1854 |
| Calico rockfish, *Sebastes dallii* (Eigenmann and Beeson, 1894) |
| California scorpionfish, *Scorpaena guttata* Girard, 1854 |
| Copper rockfish, *Sebastes caurinus* Richardson, 1844 |
| Dwarf-red rockfish, *Sebastes rufianus* Lea and Fitch, 1972 |
| Flag rockfish, *Sebastes rubrivinctus* (Jordan and Gilbert, 1880) |
| Freckled rockfish, *Sebastes lentiginosus* Chen, 1971 |
| Gopher rockfish, *Sebastes carnatus* (Jordan and Gilbert, 1880) |
| Greenspotted rockfish, *Sebastes chlorostictus* (Jordan and Gilbert, 1889) |
| Greenstriped rockfish, *Sebastes elongatus* Ayres, 1859 |
| Halfbanded rockfish, *Sebastes semicinctus* (Gilbert, 1897) |
| Honeycomb rockfish, *Sebastes umbrosus* (Jordan and Gilbert, 1880) |
| Kelp rockfish, *Sebastes atrovirens* (Jordan and Gilbert, 1880) |
| Olive rockfish, *Sebastes serranoides* (Eigenmann and Eigenmann, 1890) |
| Pygmy rockfish, *Sebastes wilsoni* (Gilbert, 1915) |
| Rosy rockfish, *Sebastes rosaceus* Girard, 1854 |
| Shortbelly rockfish, *Sebastes jordani* (Gilbert, 1896) |
| Speckled rockfish, *Sebastes ovalis* (Ayres, 1862) |
| Squarespot rockfish, *Sebastes hopkinsi* (Cramer, 1895) |
| Starry rockfish, *Sebastes constellatus* (Jordan and Gilbert, 1880) |
| Swordspine rockfish, *Sebastes ensifer* Chen, 1971 |
| Treefish, *Sebastes serriceps* (Jordan and Gilbert, 1880) |
| Vermilion rockfish, *Sebastes miniatus* (Jordan and Gilbert 1880) |
| Widow rockfish, *Sebastes entomelas* (Jordan and Gilbert, 1880) |
| Family Hexagrammidae |
| Lingcod, *Ophiodon elongatus* Girard, 1854 |
| Painted greenling, *Oxylebius pictus* Gill, 1862 |

Table 3. Continued.

| Species |
|---|
| Family Cottidae |
| Cabezon, *Scorpaenichthys marmoratus* (Ayres, 1854) |
| Coralline sculpin, *Artedius corallinus* (Hubbs, 1926) |
| Roughcheek sculpin, *Ruscarius creaseri* (Hubbs, 1926) |
| Unidentified sculpins |
| Family Serranidae |
| Kelp bass, *Paralabrax clathratus* (Girard, 1854) |
| Family Malacanthidae |
| Ocean whitefish, *Caulolatilus princeps* (Jenyns, 1840) |
| Family Carangidae |
| Jack mackerel, *Trachurus symmetricus* (Ayres, 1855) |
| Yellowtail, *Seriola lalandi* Valenciennes, 1833 |
| Family Kyphosidae |
| Halfmoon, *Medialuna californiensis* (Steindachner, 1876) |
| Opaleye, *Girella nigricans* (Ayres, 1860) |
| Family Embiotocidae |
| Black perch, *Embiotoca jacksoni* Agassiz, 1853 |
| Kelp perch, *Brachyistius frenatus* Gill, 1862 |
| Pile perch, *Rhacochilus vacca* (Girard, 1855) |
| Pink seaperch, *Zalembius rosaceus* (Jordan and Gilbert, 1880) |
| Rubberlip seaperch, *Rhacochilus toxotes* Agassiz, 1854 |
| Sharpnose seaperch, *Phanerodon atripes* (Jordan and Gilbert, 1880) |
| Striped seaperch, *Embiotoca lateralis* Agassiz, 1854 |
| Family Pomacentridae |
| Blacksmith, *Chromis punctipinnis* (Cooper, 1863) |
| Garibaldi, *Hypsypops rubicunda* (Girard, 1854) |
| Family Labridae |
| California sheephead, *Semicossyphus pulcher* (Ayres, 1854) |
| Señorita, *Oxyjulis californica* (Günther, 1861) |
| Family Bathymasteridae |
| Bluebanded ronquil, *Rathbunella hypoplecta* (Gilbert, 1890) |
| Family Stichaeidae |
| Unidentified prickleback |
| Family Labrisomidae |
| Deepwater blenny, *Cryptotrema corallinum* Gilbert, 1890 |
| Island kelpfish, *Alloclinus holderi* (Lauderbach, 1907) |
| Family Clinidae |
| Giant kelpfish, *Heterostichus rostratus* Girard, 1854 |
| Unidentified kelpfish, *Gibbonsia* sp. |
| Family Gobiidae |
| Blackeye goby, *Rhinogobiops nicholsii* (Bean, 1882) |
| Bluebanded goby, *Lythrypnus dalli* (Gilbert, 1890) |
| Zebra goby, *Lythrypnus zebra* (Gilbert, 1890) |
| Family Scombridae |
| Pacific bonito, *Sarda chiliensis* (Cuvier, 1832) |
| Family Paralichthyidae |
| Pacific sanddab, *Citharichthys sordidus* (Girard, 1854) |
| Family Pleuronectidae |
| C-O sole, *Pleuronichthys coenosus* Girard, 1854 |
| Rex sole, *Glyptocephalus zachirus* Lockington, 1879 |
| Family Molidae |
| Ocean sunfish, *Mola mola* (Linnaeus, 1758) |

Table 4. All fish species observed in this study. For each species, fewer than 25% of the individuals occurred in less than the "common shallow" depth and fewer than 25% of the individuals occurred deeper than the "common deep" depth. Habitats were sorted in descending order of importance. Those habitats that are bolded equal 50% or more of the total individuals observed. Habitat categories (H = high relief rock, L = low relief rock, and S = soft) are defined in Methods. The names of "characteristic" species, defined as having been observed in five or more of all transects and at least 15 fish counted, are bolded. Species with asterisks are economically important taxa targeted by recreational and commercial fishers.

| | Number | | Length (cm) | | | Common occurrence | | | Habitat in descending order of occurances (most common in bold) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common name | Fish | Patches | Min | Max | Min | Shallow | Deep | Max | | | | | | |
| **Squarespot rockfish** | 4,161 | 135 | 5 | 25 | 30 | 30 | 80 | 90 | **HH** | **LS** | HS | SH | SL | SS |
| **Blacksmith** | 2,427 | 48 | 10 | 30 | 30 | 30 | 40 | 60 | **HH** | SL | HS | SH | | |
| **Dwarf-red rockfish** | 1,213 | 36 | 5 | 20 | 40 | 60 | 80 | 80 | **HH** | HS | SH | | | |
| Unident. rockfish[1] | 830 | 66 | 5 | 20 | 40 | 40 | 80 | 80 | **LS** | HH | HS | SH | SS | |
| **Blackeye goby** | 472 | 163 | 5 | 15 | 30 | 30 | 70 | 80 | **LS** | **HS** | HH | SH | SS | SL |
| **Rosy rockfish** | 258 | 113 | 5 | 30 | 30 | 30 | 60 | 80 | **LS** | **HH** | HS | SL | SH | SS |
| **Halfbanded rockfish** | 178 | 35 | 5 | 20 | 70 | 80 | 90 | 90 | **SH** | **HS** | SS | HH | | |
| **Señorita** | 173 | 38 | 10 | 20 | 30 | 30 | 40 | 80 | **LS** | HH | HS | SH | SS | |
| **California sheephead*** | 132 | 80 | 10 | 50 | 30 | 30 | 60 | 80 | **LS** | **HH** | SL | HS | SH | SS |
| **Pygmy rockfish** | 115 | 22 | 5 | 15 | 50 | 70 | 90 | 90 | **HH** | HS | | | | |
| Unident. rockfishes[1] | 74 | 56 | 5 | 25 | 30 | 30 | 70 | 80 | HH | HS | SL | SH | SS | |
| Unident. *Sebastomus* | 41 | 31 | 5 | 25 | 40 | 40 | 70 | 80 | **HS** | **HH** | SH | SS | | |
| **Swordspine rockfish** | 36 | 23 | 5 | 25 | 50 | 50 | 80 | 80 | **HS** | **SH** | HH | | | |
| Speckled rockfish | 28 | 8 | 15 | 25 | 70 | 70 | 80 | 80 | **HH** | **HS** | SH | | | |
| **Sharpnose seaperch** | 26 | 16 | 10 | 20 | 30 | 30 | 40 | 80 | **HH** | HS | SS | SH | | |
| **Deepwater kelpfish** | 22 | 21 | 5 | 20 | 45 | 50 | 60 | 80 | **SL** | SS | SH | HS | | |
| **Starry rockfish*** | 22 | 18 | 5 | 30 | 40 | 50 | 80 | 80 | **HH** | HS | SH | | | |
| **Lingcod*** | 17 | 12 | 30 | 70 | 40 | 40 | 40 | 80 | **HH** | SL | HS | SH | | |
| **Bocaccio*** | 16 | 14 | 10 | 55 | 50 | 50 | 80 | 80 | **HH** | HS | SH | | | |
| **Freckled rockfish** | 16 | 11 | 10 | 20 | 60 | 60 | 70 | 80 | **HS** | SH | | | | |
| Greenspotted rockfish* | 15 | 10 | 5 | 25 | 50 | 90 | 90 | 90 | **HS** | **SH** | HH | SS | | |
| Honeycomb rockfish | 14 | 13 | 10 | 25 | 40 | 50 | 60 | 70 | **HS** | **HH** | SH | SS | | |
| Vermilion rockfish* | 14 | 12 | 15 | 45 | 50 | 50 | 60 | 80 | **SL** | HS | HH | SH | | |

Table 4. Continued.

| Common name | Number | | Length (cm) | | | Common occurrence | | | Habitat in descending order of occurances (most common in bold) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fish | Patches | Min | Max | Min | Shallow | Deep | Max | | | | |
| Painted greenling | 11 | 9 | 15 | 15 | 30 | 30 | 30 | 50 | **HH** | | | |
| Treefish* | 9 | 9 | 20 | 30 | 40 | 40 | 60 | 80 | **HH** | HS | | |
| Unident. sanddabs | 8 | 3 | 15 | 25 | 60 | 60 | 60 | 70 | **SS** | | | |
| Pink seaperch | 7 | 7 | 5 | 15 | 50 | 50 | 80 | 80 | **HH** | HS | SH | SS |
| Blue rockfish* | 6 | 5 | 10 | 20 | 40 | 40 | 50 | 60 | **SL** | HH | | |
| Unident. flatfish | 6 | 5 | 10 | 20 | 60 | 60 | 80 | 80 | **SS** | | | |
| Pile perch | 6 | 4 | 10 | 20 | 40 | 40 | 50 | 70 | **HH** | SH | HS | |
| Ocean whitefish* | 5 | 4 | 20 | 25 | 40 | 40 | 70 | 70 | **SS** | **HH** | SH | |
| Gopher rockfish* | 5 | 5 | 15 | 20 | 40 | 40 | 60 | 70 | **SH** | **HH** | HS | |
| Olive rockfish* | 5 | 4 | 25 | 30 | 70 | 70 | 80 | 80 | **HH** | SH | HS | |
| Pacific sanddab | 4 | 2 | 20 | 25 | 60 | 60 | 70 | 70 | **SS** | | | |
| Flag rockfish | 4 | 4 | 10 | 30 | 60 | 60 | 70 | 70 | **LS** | HH | HS | |
| Unident. surfperches | 4 | 2 | 5 | 20 | 50 | 50 | 50 | 50 | **SS** | HS | | |
| Black perch | 3 | 3 | 20 | 20 | 30 | 30 | 30 | 40 | **HH** | | | |
| Unident. sculpins | 3 | 2 | 10 | 10 | 60 | 60 | 60 | 60 | **LS** | | | |
| Pacific electric ray | 3 | 3 | 60 | 60 | 40 | 40 | 50 | 50 | **HH** | **SH** | HS | |
| Copper rockfish* | 2 | 2 | 20 | 20 | 60 | 60 | 70 | 70 | **HS** | | | |
| Greenstriped rockfish | 2 | 2 | 15 | 20 | 70 | 70 | 70 | 70 | **SH** | HS | | |
| California scorpionfish* | 2 | 2 | 20 | 30 | 40 | 40 | 50 | 50 | **HH** | SH | | |
| Bank rockfish* | 2 | 2 | 25 | 30 | 70 | 70 | 80 | 80 | **HH** | HS | | |
| Calico rockfish | 1 | 1 | 10 | 10 | 80 | 80 | 80 | 80 | **HH** | | | |
| Rex sole | 1 | 1 | 10 | 10 | 40 | 40 | 40 | 40 | **HS** | | | |
| Kelp rockfish* | 1 | 1 | 20 | 20 | 60 | 60 | 60 | 60 | **SS** | | | |
| Bluebanded ronquil | 1 | 1 | 20 | 20 | 40 | 40 | 40 | 40 | **HH** | | | |
| Unident. ronquil | 1 | 1 | 20 | 20 | 80 | 80 | 80 | 80 | **SH** | | | |
| Shortbelly rockfish | 1 | 1 | 20 | 20 | 70 | 70 | 70 | 70 | **HS** | | | |
| Widow rockfish* | 1 | 1 | 15 | 15 | 80 | 80 | 80 | 80 | **HS** | | | |

[1] Primarily young-of-the-year

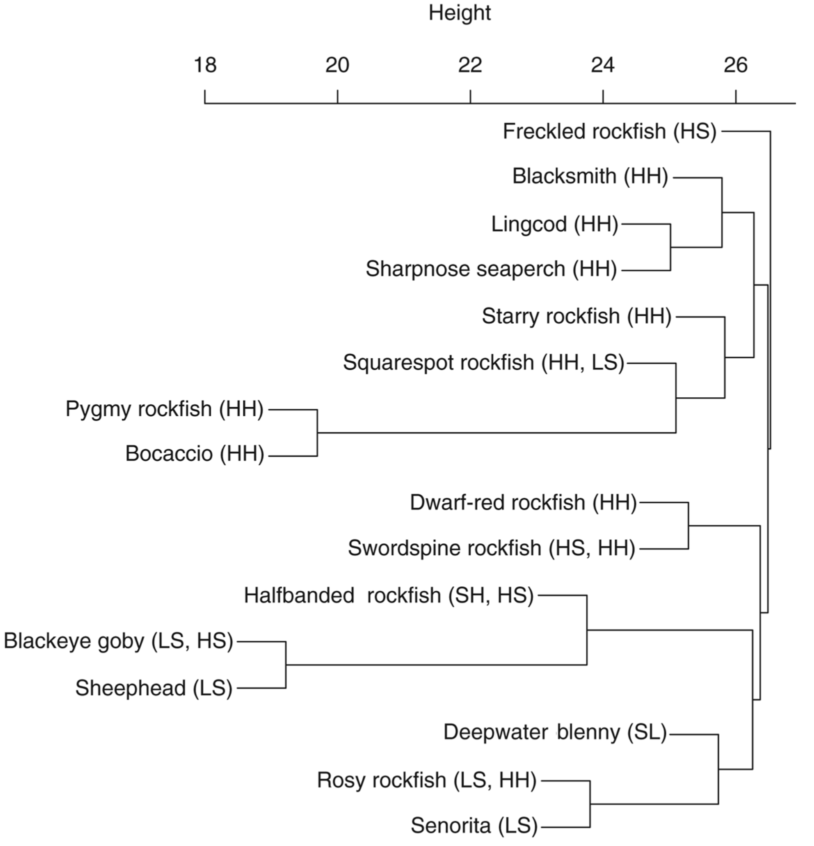


Figure 2. A cluster analysis of 16 characteristic species (15 or more individuals observed in five or more transects). Most common habitats for each species are in parenthesis, H = high-relief rock, L = low-relief rock, S = sand. These three habitats were composed of four possible habitat components, sand (S), pebble (P), boulder (B), and rock ridge (R). A two-character code was assigned each time a distinct change in substratum type was noted along the dive tract, thus delineating habitat patches of uniform type. The first character in this code represented the substratum that accounted for at least 50% of the patch, and the second character represented the substratum type that accounted for at least 20% of the patch (e.g., a patch designated as "BR" comprised at least 50% boulders and at least 20% rock ridges). The area of each habitat patch was determined by multiplying length of the patch by the width of the swath (2 m). We then combined these substratum types into six habitat categories based on high (H) and low (L) rock relief and on low relief soft (S) sediments, where HH = BB, BR, RR, RB; HS = RS, BS; LS = PS; SH = SR, SB; SL = SP; SS = SS.

erosion. He further notes that the limited fall of eroded material may be covered over by sand.

Based on four separate surveys (three using SCUBA and the current one utilizing an occupied submersible), 71 fish species have been reported from Farnsworth Bank (Table 7). These surveys demonstrate that some of the species that are typical of nearshore southern California reefs, such as black perch, garibaldi, giant kelpfish, kelp bass, and kelp perch, are not important components of the bank's fish community. However, these species are most abundant in waters < 20 m deep and their relative scarcity on this bank is likely due, in part, to the paucity of shallow water habitat. In addition, the absence of the large and canopy-forming giant kelp, *Macrocystis pyrifera* (Linnaeus), may also contribute to the scarcity of some of those taxa.

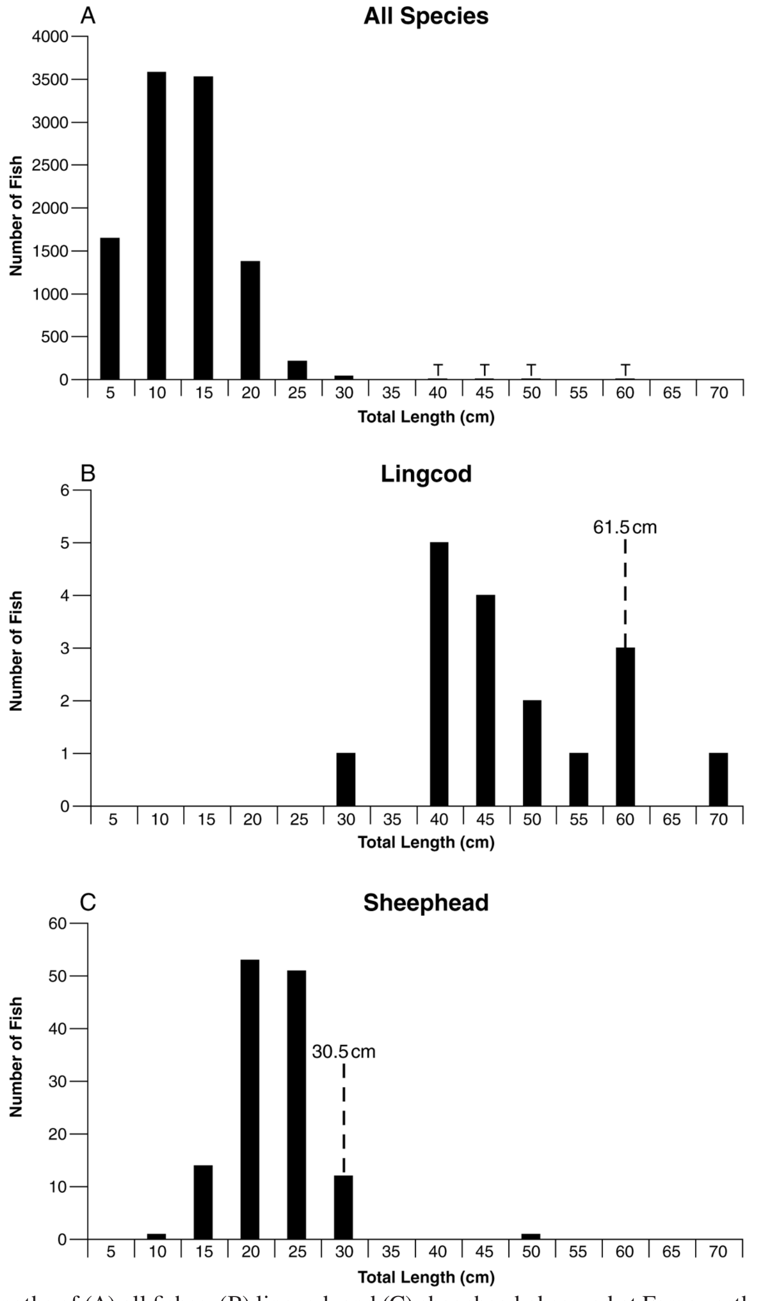


Figure 3. Lengths of (A) all fishes, (B) lingcod, and (C) sheephead observed at Farnsworth Bank, Santa Catalina Island, 6 October 2008. Vertical dotted lines in the lingcod and sheephead figures represent the minimum legal retention size. T = < 15 individuals.

Parenthetically, both kelp bass and garibaldi were also not observed on Tanner and Cortes banks, two other offshore features in the southern California Bight (Lissner and Dorsey, 1986). These two banks are much larger than Farnsworth Bank and, like Farnsworth, they have little habitat in shallow water and did not harbor giant kelp.

Table 5. Density (per 10 m$^2$) of purple hydrocoral (*Stylaster californica*) colonies, in 10 m bins, on the rocky substrata of Farnsworth Bank, September 2008.

| | Colony diameter (cm) | | | | | |
|---|---|---|---|---|---|---|
| Depth (m) | 1–20 | 21–40 | 41–60 | 61–80 | 81–100 | 101–120 |
| 30 | 0.30 | 0.02 | < 0.01 | 0 | < 0.01 | < 0.01 |
| 40 | 0.02 | 0.01 | < 0.01 | < 0.01 | 0 | 0 |
| 50 | < 0.01 | 0 | 0 | 0 | 0 | 0 |
| 60 | < 0.01 | 0 | 0 | 0 | 0 | 0 |
| 70 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 | 0 | 0 | 0 | 0 | 0 | 0 |

Water temperature is likely a major contributing factor in structuring the species assemblage. The relatively warm waters of the Southern California Bight heavily influence Farnsworth Bank. Sea surface temperatures at the bank are usually several degrees warmer than those in the northern part of the Southern California Bight (e.g., around the Northern Channel Islands and in the Santa Barbara Channel) (CoastWatch). This leads to an abundance of such warmer-water species as dwarf-red, freckled, and honeycomb rockfishes, species that become less common to the north. Similarly, we found that more northerly taxa, such as blue and olive rockfishes, were not abundant in our survey. Interestingly, blue rockfish were abundant on the bank in the early 1970s (Bergen, 1973, quoted by Engle and Coyer, 1981; Odemar, 1973). Water temperatures during that time were relatively cool (part of the temperature shifts characteristic of the Pacific Decadal Oscillation, Horn and Stephens, 2006), when this colder-water species was abundant throughout much of the southern California nearshore (Ebeling et al., 1980; Stephens et al., 1994).

Despite some differences based on water temperatures, the fish species assemblages at Farnsworth Bank are representative of a "typical" rocky habitat at similar depths throughout much of southern California (Love et al., 2009). In particular, we noted that the clustering of pygmy, squarespot, and starry rockfishes, and bocaccio at Farnsworth Bank (Fig. 2) is found on many other southern California reefs. All of these species are characteristic of high and complex substrata in mid-shelf depths. In addition, our analyses demonstrated that, with the exception of California sheephead, economically important fish species are not abundant on Farnsworth Bank. Farnsworth Bank has been fished since its discovery in the 19$^{th}$ Century and, by decreasing both the numbers and sizes of target species, both fishing and spear fishing play a role in structuring this fish assemblage. The skewed size frequency distribution of both California sheephead and lingcod, with nearly all the fishes at or below the minimum legal retention lengths, clearly shows the influence of fishing on size

Table 6. Debris observed on Farnsworth Bank, September 2008.

| Debris type | Number observed |
|---|---|
| Light line | 25 |
| Anchor gear | 8 |
| Heavy line/cable | 8 |
| Nets | 3 |
| Traps | 3 |
| Miscellaneous debris | 2 |
| Total | 49 |

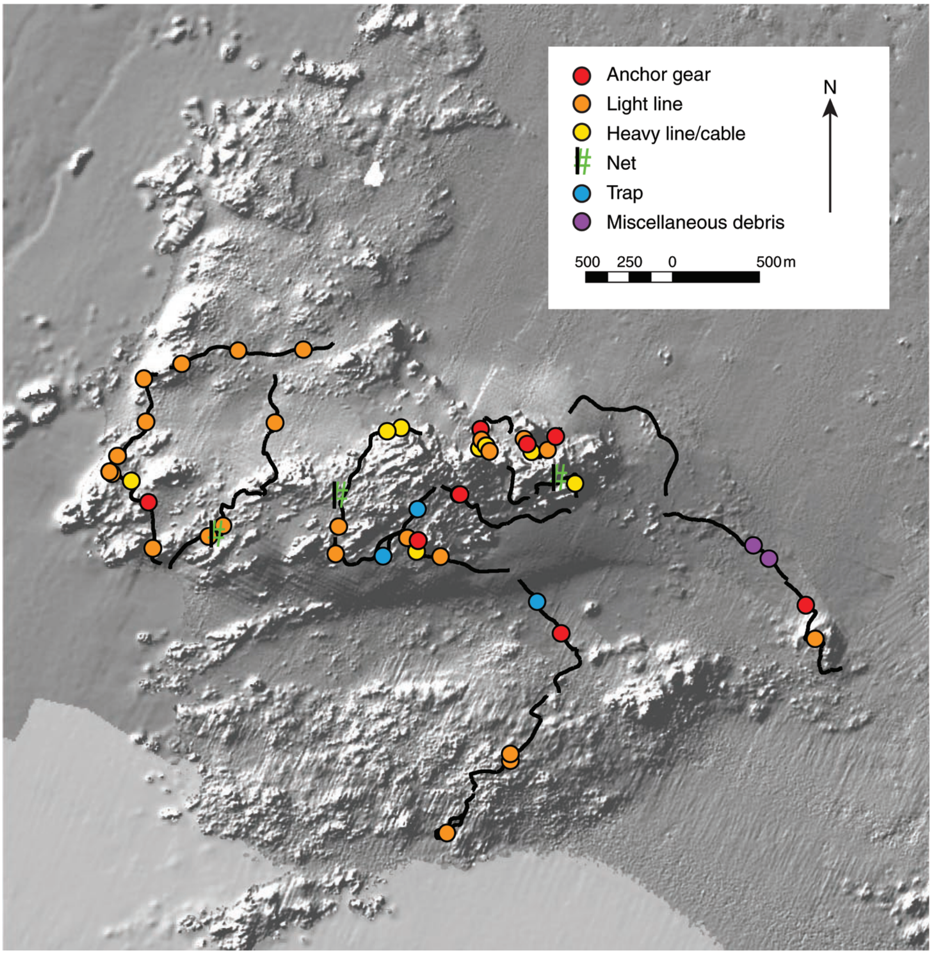


Figure 4. Location and types of marine debris observed at Farnsworth Bank, Santa Catalina Island, 6 October 2008.

distributions. The reduction in both size and number of large, predatory fishes can also lead to an increase in abundance of those smaller species that are now released from predation (Love and Yoklavich, 2006). Indeed, three unfished species, the dwarf taxa squarespot and dwarf-red rockfishes, as well as blacksmith, were found in very large numbers. We have observed an identical pattern of depleted economically important species and very large numbers of prey species on reefs throughout southern California (Love et al., 2009).

Purple hydrocoral was a major feature of Farnsworth Bank and at least a few colonies were found at depths down to 66 m. At depths of between about 30–40 m, where the species was most abundant, colonies often cover all of the rocky substrate, to the exclusion of both algae and other structure-forming invertebrates. Lissner and Dorsey (1986) observed colonies at Cortes and Tanner banks down to depths of 98 m. On these features, colonies were most abundant in three 6-m depth bins between 36 and 61 m. Similarly, a study at Cordell Bank, northern California, found colonies as deep as 92 m, with maximum abundances in depths of 45–75 m (L. Etherington,

Table 7. A list of fishes observed at Farnsworth Bank based on (1) this study, (2) Engle and Coyer (1981), (3) Bergen (1973), quoted in Engle and Coyer (1981), and (4) Given (1967), quoted in Engle and Coyer (1981). The latter three studies were qualitative SCUBA surveys of the shallower parts of the bank. Symbols: 1 = rare or occasional, 2 = common or abundant, X = present but abundance not determined.

| Species | Present study | Eagle and Coyer (1981) | Bergen (1973) | Given (1967) |
|---|---|---|---|---|
| Family Scyliorhinidae | | | | |
| Swell shark | | 1 | X | |
| Family Carcharhinidae | | | | |
| Blue shark | | 1 | 2 | |
| Family Squatinidae | | | | |
| Pacific angel shark | | | 1 | |
| Family Torpedinidae | | | | |
| Pacific electric ray | 1 | 1 | | |
| Family Muraenidae | | | | |
| California moray | | 1 | 1 | X |
| Family Ophidiidae | | | | |
| Spotted cusk-eel | | | X | |
| Family Bythitidae | | | | |
| Red brotula | | | X | |
| Family Syngnathidae | | | | |
| Unidentified pipefish | | | X | |
| Family Scorpaenidae | | | | |
| California scorpionfish | 1 | 1 | 2 | |
| Bank rockfish | 1 | | | |
| Black-and-yellow rockfish | | 1 | | |
| Blue rockfish | 1 | 1 | 2 | |
| Bocaccio | 2 | | | |
| Calico rockfish | 1 | | | |
| Copper rockfish | 1 | 1 | | |
| Dwarf-red rockfish | 2 | | | |
| Flag rockfish | 1 | | | |
| Freckled rockfish | 2 | | | |
| Gopher rockfish | 1 | 1 | X | |
| Greenspotted rockfish | 2 | | | |
| Greenstriped rockfish | 1 | | | |
| Halfbanded rockfish | 2 | | | |
| Honeycomb rockfish | 2 | | | |
| Kelp rockfish | 1 | 1 | 1 | |
| Olive rockfish | 1 | | 1 | |
| Pygmy rockfish | 2 | | | |
| Rosy rockfish | 2 | 1 | X | |
| Shortbelly rockfish | 1 | | | |
| Speckled rockfish | 2 | | | |
| Squarespot rockfish | 2 | | X | |
| Starry rockfish | 2 | 1 | 2 | |
| Swordspine rockfish | 2 | | | |
| Treefish | 1 | 1 | 2 | X |
| Vermilion rockfish | 2 | | 1 | |
| Widow rockfish | 1 | | | |

Table 7. Continued.

| Species | Present study | Eagle and Coyer (1981) | Bergen (1973) | Given (1967) |
|---|---|---|---|---|
| Family Hexagrammidae | | | | |
| Lingcod | 2 | | | |
| Painted greenling | 2 | 1 | 2 | X |
| Family Cottidae | | | | |
| Cabezon | | | X | |
| Coralline sculpin | | 1 | X | |
| Roughcheek sculpin | | 1 | X | |
| Unidentified sculpins | 1 | | | |
| Family Serranidae | | | | |
| Kelp bass | | 1 | 1 | 1 |
| Family Malacanthidae | | | | |
| Ocean whitefish | 1 | | 1 | |
| Family Carangidae | | | | |
| Jack mackerel | | | X | |
| Yellowtail | | | | X |
| Family Kyphosidae | | | | |
| Halfmoon | | 2 | 2 | X |
| Opaleye | | 1 | 2 | X |
| Family Embiotocidae | | | | |
| Black perch | 1 | 1 | X | X |
| Kelp perch | | 1 | | |
| Pile perch | 1 | 1 | X | |
| Pink seaperch | 1 | | | |
| Rubberlip seaperch | | | X | |
| Sharpnose seaperch | 2 | 1 | X | |
| Striped seaperch | | | 1 | |
| Family Pomacentridae | | | | |
| Blacksmith | 2 | 2 | X | X |
| Garibaldi | | 1 | X | |
| Family Labridae | | | | |
| California sheephead | 2 | 1 | 2 | X |
| Señorita | 2 | 1 | 2 | X |
| Family Bathymasteridae | | | | |
| Bluebanded ronquil | 1 | | 1 | |
| Family Stichaeidae | | | | |
| Unidentified prickleback | | | X | |
| Family Labrisomidae | | | | |
| Deepwater blenny | 2 | | X | |
| Island kelpfish | | 2 | X | |
| Family Clinidae | | | | |
| Giant kelpfish | | | X | |
| Unidentified kelpfish | | 1 | 1 | |
| Family Gobiidae | | | | |
| Blackeye goby | 2 | 2 | 2 | X |
| Bluebanded goby | | 2 | 2 | X |
| Zebra goby | | 1 | X | |
| Family Scombridae | | | | |
| Pacific bonito | | | X | |
| Family Paralichthyidae | | | | |
| Pacific sanddab | 1 | | | |
| Family Pleuronectidae | | | | |
| C-O sole | | 1 | X | |
| Rex sole | 1 | | | |
| Family Molidae | | | | |
| Ocean sunfish | | | | X |

Cordell Bank National Marine Sanctuary, pers. comm.). Although a few, unobserved, small colonies may reside in the deeper parts of Farnsworth Bank, it appears that this species has a narrower depth range at Farnsworth Bank than on some other features. Worldwide, stylasterids are found primarily in areas of high current, low turbidity, and stable salinity. They are unable to gain footholds on soft, more friable, terrigenous sediments. In practice, this translates to colonies residing on the steep sides of offshore banks and ridges, or around small islands with plunging, hard, sea floors (Cairns, 1992). Unlike Cordell, Tanner, and Cortes Banks, which are surrounded by sea floors hundreds of meters deep, the sea floor around Farnsworth Bank is relatively shallow (a minimum of 73 m). It is possible that the relatively shallow distribution of purple hydrocoral on Farnsworth Bank reflects the suboptimal conditions (i.e., increased turbidity or sand scouring) associated with the sands around the base of the bank.

Purple hydrocoral skeletons are very brittle and easily broken. Engle and Coyer (1981) and Odemar (1973), reported significant damage to hydrocorals. In particular, the webbing of lost nets often harbored chunks of coral and colonies were often scoured by anchors and anchor chains. Even nonconsumptive SCUBA divers, brushing against colonies, can cause breakage. Thus, we were surprised to observe no damage to colonies in our survey. However, it should be noted that our surveys were mainly conducted below SCUBA diving depth and that those nets we observed appeared to be old and very worn.

We observed a substantial amount of debris, much of it related to recreational or commercial fisheries. Light line, most of it probably monofilament used by recreational anglers, occurred throughout the bank. On the other hand, heavier line, cable, and traps, the remnants of various forms of commercial fishing, were mostly limited to the higher and rockier portions of the feature. Based on our experience from throughout southern California waters, both anchors and nets occurred at relatively high numbers compared to other reef sites. In submersible surveys of the outer islands and banks of southern California (not including Farnsworth Bank), an average of 0.15 pieces of debris per 100 m was observed (D. Watters, National Marine Fisheries Service, pers. comm.) compared to 0.77 on Farnsworth Bank.

Large quantities of lost netting, primarily snagged purse seines, have long been observed on Farnsworth Bank (Odemar, 1973). As far as we are aware, there is no directed net fishing at Farnsworth Bank. However, a number of pelagic fish species are taken with purse seines around southern California islands and these nets are doubtless lost when deployed too close to these pinnacles. All of the nets that we observed were badly torn and we did not observe any ghost fishing.

It might be expected that the rugged topography of Farnsworth Bank would make fishing difficult and might act to help protect larger fishes. And, indeed, we observed substantial amounts of lost fishing-related material, testament both to intensive fishing activities and the difficulty of retrieving gear. However, the paucity, and small size, of economically important fishes implies that there has been extensive depletion despite any harvesting inefficiencies. Assuming that Farnsworth Bank is eventually designated a no-take marine protected area, it will be interesting to observe the patterns of fish recovery on this feature. For instance, as noted previously, it might be expected that an increase in the abundance of predatory species, such as lingcod, will be followed by a trophic cascade, in this case a decrease of such prey species as small rockfishes, arguably what has occurred during the recent lingcod recovery in Puget

Sound (Walters et al., 1999; Beaudreau and Essington, 2007). However, Farnsworth Bank is probably only semi-isolated from Santa Catalina Island, and that, along with its relatively small size, makes species assemblage outcomes uncertain.

## Acknowledgments

We thank D. M. Schroeder, M. Nishimoto, A. Scarborough Bull, M. McCrea, and S. Clark for helping to conduct these surveys and G. Cochrane, J. Engle, and W. Palsson for their insights. Research was conducted aboard the submersible Delta, piloted by C. Ijames and J. Lilly, with assistance of the crew of the R/V Velero. The United States Minerals Management Service, contract number 1435-MO-08-AR-12693, funded this research.

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Date Submitted: 13 April, 2009.
Date Accepted: 2 September, 2009.
Available Online: 5 October. 2009.

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