2011 Comparative Rockfish Survey at Footprint and Piggy Banks

Results from a visual survey conducted in 2011 using the *Lucille* autonomous underwater vehicle (AUV) at Footprint and Piggy Banks off Southern California

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**Introduction**

Traditional fish monitoring techniques, such as trawl surveys, are of limited applicability in rocky areas due to the rugged nature of the terrain. High relief rocky substrate provides challenges to traditional groundfish survey methods that do not allow for accurate population estimates from these areas. In addition, protected areas, even if accessible to trawling, should be monitored with low impact methods to maintain their protected status.

The survey area included two deep, rocky banks and the deeper surrounding seafloor out to 500 m. The banks are located near Santa Cruz and Anacapa Islands.

The goal of this study was to design and implement a survey of groundfish and their habitat within the areas of Footprint and Piggy Banks to determine the utility of a bottom tracking SeaBED class AUV as a tool for conducting low impact monitoring in untrawlable or protected areas. The specific objectives of our project using visual survey techniques from a SeaBED class AUV were to (1) collect data on counts and sizes for several rockfish (*Sebastes*) species (both common and rare, large- and small-bodied, and semi-aggregating and highly demersal/solitary) and other taxa of interest (lingcod [*Ophiodon elongatus*], thornyheads [*Sebastolobus*], and Pacific hake [*Merluccius productus*]); (2) estimate densities (and associated precision) for these taxa; (3) estimate size composition for these species; (4) estimate abundance and biomass (and precision) for these taxa; and (5) estimate biodiversity of fish species within the study site.

The results of our AUV survey are to be compared with those from the two other studies that assessed these fish assemblages using a manned submersible and a remotely operated vehicle (ROV).

**Methods**

Dives were developed to completely survey a randomly selected grid cell on one of the study banks. Underwater visual grid surveys of habitats and associated fishes were conducted using the SeaBED class AUV *Lucille* deployed from the NOAA Research Vessel *Shearwater*. Stereo images of the seafloor were collected using two 5 megapixel, 12-bit dynamic range Prosilica GigE cameras. Two cameras (a stereo pair) were mounted to look directly downward and the third camera was angled forward at 30°. Lighting was provided by a strobe synced with the cameras. The AUV was tracked using a Linkquest USBL navigation system and an acoustic modem.

The entire study site was divided into grid cells of 250 m x 250 m. The grid cells were divided into three focal areas for sampling representing the top of Piggy Bank, the top of Footprint Bank and the deeper flank area around Footprint Bank (Figure One). Cells to be sampled were selected randomly in each area. Within each cell the AUV was programmed to survey a transect pattern covering the majority of the cell at a fixed height from the bottom. The grid pattern contained five, 200 meter grid lines connected by four 25 meters lines for a total track distance in each cell of 1.1 km. Adjacent or nearby cells enabled multiple cells to be sampled with one dive. The AUV collected digital still imagery from two downward looking cameras and one angled camera. Photographs were taken every 10 seconds and were synced with an onboard strobe. Twenty-seven sites were sampled over 10 days during daytime hours (0800-1730) (Figure 1). One to four cells were sampled per day. Dive duration varied between 45 minutes to 1 hour 22 minutes (mean dive duration was 1 hour 14 minutes). Physical oceanography measurements were taken from a CTD mounted on the AUV. Overall, twenty-five cells were sampled, distributed among the three strata as shown in Figure 1 and in Table 2.



Figure 1. Sampling locations (o) of the 25 samples in the area.

The AUV was equipped with two navigational sensors: the RDI 1200 kHz Doppler Velocity Log as the primary navigational sensor and the iXSea OCTANS gyrocompass and inertial motion sensor. The AUV was tracked using a Link Quest TrackLink 1500 ultra-short baseline (USBL) navigation system. Location of the AUV during each dive was estimated using USBL range and bearing measurements relative to the ship, the X,Y coordinates of the vehicle position relative to its dive origin, and the GPS coordinates of the dive launch point. Subsurface communication was provided by the WHOI 256008 acoustic micromodem and surface communication used a FreeWave FGR-115 RCRF radio modem. Depth was determined using a Paroscientific depth sensor. Salinity, temperature and pressure were collected using a Sea-Bird model 49 FastCat CTD mounted on the AUV.

Images were down-loaded at the end of each mission and each image was color-corrected. All non-overlapping color-corrected digital stills from the port downward looking camera were reviewed following the cruise and fishes were identified and counted. Photos from the angled camera were used to assist in species identification only. The area of each image was estimated using the measured altitude off the bottom and the specified camera field of view. As the altitude maintained by the AUV changed, so did the image area. Marine debris and any evidence of anthropogenic effects were noted.

Seafloor habitats in each photograph were categorized using a two-character code (Table 1) The first character signified the primary habitat type that covered greater than 50% of the field of view, while the second character defined the secondary habitat type covering between 20% and 50%. If the primary habitat coverage exceeded 80%, that letter was denoted twice (e.g., CC).

**Results**

We sampled grids in 27 cells (3 grids were truncated for various reasons) on Footprint (n=13), the flank of Footprint (n=6) and on Piggy Bank (n=8), surveying a total of 70,006 m2 (Table x, Figure x). Seventeen of the 27 cells contained only one 100-meter depth stratum, while ten cells varied in depth across two 100-meter strata. The range of depth change over the course of a cell varied from a low of 10.4 m to a high of 83.3 m. Habitats encountered ranged from high relief rock ridge to mud and sand bottom. The AUV covered bottom depths of 99 m to 487 m.

A variety of habitat types were encountered over the course of all cells (Figure x). Cells on top (200-300 m) of Piggy Bank contained high amounts of rock ridge substrate (30%), mud (33%) and similar amounts of boulder and cobble (17 and 19%). With increasing depth, the percentage of mud and cobble substrates increased. The top two depth strata on the Footprint were primarily cobble and boulder, with sand and rock ridge increasing with depth. Mud was the primary substrate in all depth strata on the flank of the Footprint (86, 99 and 97%).

We identified 51 taxa for the 21,228 fishes from all cells in all three areas (Table X). We were able to identify 18 species of rockfish. The species groupings of unidentified rockfish, Sebastomus and Sebastolobus along with those identified down to species accounted for 75% of the total number of fishes observed. Notable were the 11 observations of cowcod (*S. levis*), 29 of bocaccio (*S. paucispinis*) and 1 bronzespotted rockfish (*S. gilli*). We had 53 observations of lingcod (*Ophiodon elongatus*), 19 Pacific hake (*Merluccius productus*) and 10 sablefish (*Anoplopoma fimbria*).

Fish assemblages varied between depth strata and between the two banks. Twenty-nine species/ taxa only occurred in the Footprint or along the Footprint flanks. Two species were seen on Piggy Bank only and not in the Footprint.

Diversity or richness, measured as cumulative number of species (excluding groups) in cells by depth stratum, was the highest on the Footprint bank in the 100-200 m (23 species) and the flank of the Footprint in the 300-400 m (18 species) depth strata (Table x). Species richness was the lowest on Piggy Bank in all three depth strata (6 species at 200-300 m, 8 species at 300-400 m, and 7 species at 400-500m).

**Discussion**

The photo survey conducted with the Lucille AUV produced data on the abundance of 51 taxa of groundfish, the substrate and habitat within the surveyed cells, and on the biodiversity of two rocky banks off of southern California.

We compared the AUV results with those of the ROV and the submersible (SUB) (Stierhoff et al., 2012 and Yoklavich et al., 2013). All three survey methodologies showed similar characterization of the fish assemblages on Piggy Bank and the Footprint. The AUV was able to sample the deeper 400-500 m stratum on the flank of Footprint, and to provide fish and habitat information that was not available from the ROV or SUB. Species diversity was similar amongst all three methodologies showing greater species richness at the Footprint bank and lower richness at Piggy Bank. The ROV and the SUB included records of rockfish species not identified by the AUV. This could be due to the fact that the cameras on the AUV are positioned downward, rather than forward facing, allowing fish directly in front of the unit to escape detection. Another possible reason could be the difficulty in identifying some rockfish species from the dorsal view. The AUV detected comparable numbers of fishes, but the fish were identified to groupings (i.e. Unidentified rockfish, or Sebastomus) as opposed to species.

**Citations**

Stierhoff, K.L., J.L. Butler, S.A. Mau, and D.W. Murfin. 2012. 2011 Comparative rockfish survey at the Footprint and Piggy Bank: results from the SWFSC’s optical survey conducted using a remotely operated vehicle (ROV). Unpublished report of NMFS SWFSC, La Jolla, CA. 41 p.

Yoklavich, M., T. Laidig, D. Watters, and M. Love. 2013. Understanding the capabilities of new technologies and methods to survey west coast groundfishes; Results from a visual survey conducted in 2011 using the Dual Deepworker manned submersible at Footprint and Piggy Banks off southern California. Unpublished report of NMFS SWFSC, Santa Cruz, CA. 28 p.

Table 1. Sampling effort (area sampled and number of cells), by study site.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Site** | **Depth Stratum (m)** | **Area (sq. m)** | | **Area (sq. km)** |
| Flank of Footprint | 200-300 | 1252.06 | 1.25 | |
|  | 300-400 | 14972.01 | 14.97 | |
|  | 400-500 | 2377.94 | 2.38 | |
| The Footprint | 0-100 | 191.27 | 0.19 | |
|  | 100-200 | 21861.13 | 21.86 | |
|  | 200-300 | 5928.11 | 5.93 | |
| Piggy Bank | 200-300 | 5013.17 | 5.01 | |
|  | 300-400 | 7677.66 | 7.68 | |
|  | 400-500 | 10733.05 | 10.73 | |

All fishes were identified to the lowest possible taxonomic group. We identified 51 taxon, of which, 22 were rockfish species or groupings.

Table X. Summary of observations (total observations and percent of total) for all species observed during the analysis of *Lucille* AUV still images.

|  |  |  |  |
| --- | --- | --- | --- |
| **Scientific Name** | **Common Name** | **Total observations** | **% Total** |
| *Sebastomus* spp. | unidentified Sebastomus | 7030 | 33.13 |
| *Sebastes* spp. | unidentified rockfishes | 4225 | 19.91 |
| Agonidae | unidentified poachers | 2584 | 12.18 |
| *Sebastes semicinctus* | halfbanded rockfish | 1646 | 7.76 |
| *Sebastes jordani* | shortbelly rockfish | 1249 | 5.89 |
| *Zaniolepis frenata* | shortspine combfish | 845 | 3.98 |
| *Sebastes hopkinsi* | squarespot rockfish | 475 | 2.24 |
| *Sebastolobus spp.* | thornyheads | 434 | 2.05 |
| Zoarcidae | unidentified eelpout | 388 | 1.83 |
| *Sebastes rufus* | bank rockfish | 367 | 1.73 |
| Osteichthyes | unidentified fishes | 350 | 1.65 |
| Pleuronectiformes | unidentified flatfishes | 329 | 1.55 |
| *Microstomus pacificus* | Dover sole | 273 | 1.29 |
| *Lyopsetta exilis* | slender sole | 113 | 0.53 |
| *Glytocephalus zachirus* | rex sole | 98 | 0.46 |
| *Sebastes goodei/jordani* | chilipepper/shortbelly rockfish | 75 | 0.35 |
| *Sebastes wilsoni* | pygmy rockfish | 61 | 0.29 |
| Stichaeidae | unidentified pricklebacks | 61 | 0.29 |
| Cottidae | unidentified sculpin | 54 | 0.25 |
| *Ophiodon elongatus* | lingcod | 53 | 0.25 |
| *Zaniolepis* spp. | unidentified combfishes | 53 | 0.25 |
| *Citharichthys spp.* | unidentified sanddab | 49 | 0.23 |
| *Sebastes saxicola* | stripetail rockfish | 42 | 0.20 |
| *Hydrolagus colliei* | spotted ratfish | 38 | 0.18 |
| *Sebastes elongatus* | greenstriped rockfish | 36 | 0.17 |
| Myxinidae | unidentified hagfish | 36 | 0.17 |
| *Sebastolobus alascanus* | shortspine thornyhead | 34 | 0.16 |
| *Sebastes paucispinis* | bocaccio | 29 | 0.14 |
| *Sebastes melanostomus* | blackgill rockfish | 25 | 0.12 |
| *Sebastes rubrivinctus* | flag rockfish | 23 | 0.11 |
| *Merluccius productus* | Pacific hake | 19 | 0.09 |
| *Sebastes constellatus* | starry rockfish | 17 | 0.08 |
| *Sebastes chlorostictus* | greenspotted rockfish | 15 | 0.07 |
| *Lycodes cortezianus* | bigfin eelpout | 14 | 0.07 |
| *Sebastes diploproa* | splitnose rockfish | 14 | 0.07 |
| *Sebastes levis* | cowcod | 11 | 0.05 |
| *Raja rhina* | longnose skate | 10 | 0.05 |
| *Anoplopoma fimbria* | sablefish | 10 | 0.05 |
| *Sebastes miniatus* | vermilion rockfish | 7 | 0.03 |
| *Eopsetta jordani* | petrale sole | 6 | 0.03 |
| *Raja stellulata* | starry skate | 6 | 0.03 |
| *Bathyraja interrupta* | sandpaper skate | 5 | 0.02 |
| *Plectobranchus evides* | bluebarred prickleback | 4 | 0.02 |
| *Parophrys vetulus* | English sole | 4 | 0.02 |
| *Careproctus melanurus* | blacktail snailfish | 3 | 0.01 |
| *Rhinogobiops nicholsii* | blackeye goby | 2 | 0.01 |
| *Sebastes rosenblatti* | greenblotched rockfish | 2 | 0.01 |
| *Sebastes gilli* | bronzespotted rockfish | 1 | <0.01 |
| Scyliorhinidae | unidentified catshark | 1 | <0.01 |
| *Raja* spp. | unidentified skate | 1 | <0.01 |
| *Pleuronichthys spp.* | unidentified turbot | 1 | <0.01 |

Table X. Number of selected species of interest from the *Lucille* AUV dives at depths of 99-486 m on Footprint Bank, flank of Footprint and Piggy Bank, October, 2011. Taxa in bold text were found only on the Footprint and flank of the Footprint.

|  |  |  |
| --- | --- | --- |
| **Scientific Name** | **Common Name** | **Total observations** |
| Sebastomus | unidentified sebastomus | 7030 |
| Sebastes spp. | unidentified rockfishes | 4225 |
| ***Sebastes semicinctus*** | **halfbanded rockfish** | **1646** |
| ***Sebastes jordani*** | **shortbelly rockfish** | **1249** |
| ***Sebastes hopkinsi*** | **squarespot rockfish** | **475** |
| *Sebastolobus spp.* | thornyheads | 434 |
| *Sebastes rufus* | bank rockfish | 367 |
| *Sebastes goodei/jordani* | chilipepper/shortbelly rockfish | 75 |
| ***Sebastes wilsoni*** | **pygmy rockfish** | **61** |
| ***Ophiodon elongatus*** | **lingcod** | **53** |
| ***Sebastes saxicola*** | **stripetail rockfish** | **42** |
| ***Sebastes elongatus*** | **greenstriped rockfish** | **36** |
| *Sebastolobus alascanus* | shortspine thornyhead | 34 |
| *Sebastes paucispinis* | bocaccio | 29 |
| *Sebastes melanostomus* | blackgill rockfish | 25 |
| ***Sebastes rubrivinctus*** | **flag rockfish** | **23** |
| ***Merluccius productus*** | **Pacific hake** | **19** |
| ***Sebastes constellatus*** | **starry rockfish** | **17** |
| ***Sebastes chlorostictus*** | **greenspotted rockfish** | **15** |
| *Sebastes diploproa* | splitnose rockfish | 14 |
| ***Sebastes levis*** | **cowcod** | **11** |
| *Anoplopoma fimbria* | sablefish | 10 |
| ***Sebastes miniatus*** | **vermilion rockfish** | **7** |
| ***Sebastes rosenblatti*** | **greenblotched rockfish** | **2** |
| ***Sebastes gilli*** | **bronzespotted rockfish** | **1** |

Table X. Species richness (number of species), by site and depth stratum, estimated from visual identification from the *Lucille* AUV still photos, October, 2011. All individuals identified down to species (not groups of species) were included in this analysis.

|  |  |  |
| --- | --- | --- |
| **Site** | **Depth Stratum (m)** | **Species richness** |
| The Footprint | 0-100\* | 2 |
|  | 100-200 | 23 |
|  | 200-300 | 17 |
| Flank of Footprint | 200-300\* | 2 |
|  | 300-400 | 18 |
|  | 400-500 | 10 |
| Piggy Bank | 200-300 | 6 |
|  | 300-400 | 8 |
|  | 400-500 | 7 |

\*The area surveyed in these strata was < 2000 sq. m.

Figure x. Percentage of the total primary habitat types (>50% of the habitat observed in frame) quantified from still photos taken by the *Lucille* AUV by 100 m depth strata from Piggy Bank, The Footprint and the flank of Footprint.