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A video lander study of a nearshore rocky reef

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Introduction:

The Oregon Nearshore Strategy (ODFW 2006a, 2016), the marine component of the Oregon Conservation Strategy (ODFW 2006b, 2016), is the overarching state strategy for conserving fish and wildlife in Oregon's marine and estuarine environments. It lists recommendations designed to improve understanding and stewardship of Oregon's nearshore resources and to benefit the Strategy Species inhabiting Oregon's marine and estuarine waters. Strategy Species were deemed to be in greatest need of management attention *and* to have the greatest potential to benefit from management actions based on a combination of criteria that included their population status, ecological importance, vulnerability to human or natural factors and their economic/social/cultural importance.

Management of nearshore resources is most effective when based on sound scientific understanding. A number of the Nearshore Strategy's recommendations focus on research and monitoring needs. These recommendations include conducting fishery-independent surveys that can provide both a more thorough understanding of species-habitat associations that can help inform species distributions and abundance information that can help inform stock assessments for fishery target species. The majority of both the fish and invertebrate Nearshore Strategy Species are known to inhabit rocky subtidal habitats. Many of these species are important to sport and commercial fisheries, so determining their abundance is important for sustainable fisheries management. Sustainability is a fundamental principle guiding management of Oregon's marine fisheries (ODFW 2015a). Sustainability is defined in Oregon law as, "using, developing and protecting resources in a manner that enables people to meet current needs and provides that future generations can also meet future needs, from the joint perspective of environmental, economic and community objectives" (ORS 184.421(4)).

The Oregon Department of Fish and Wildlife (ODFW) manages many, but not all, of Oregon's marine fisheries jointly with the federal government through the Pacific Fisheries Management Council (PFMC) and the National Marine Fisheries Service (NMFS) under the auspices of the Magnusson-Stevens Fishery Conservation and Management Act. Many of the fish species targeted or encountered on the rocky reefs in Oregon's marine waters which stretch to three nautical miles from shore are included in the federal Pacific Coast Groundfish Fishery Management Plan (PFMC 2016). Assessing stocks is the cornerstone of providing scientific advice for sustainable fisheries management. Stock assessments model how the interactions among birth, growth, natural mortality, and fisheries affect a stock's status over time. Ideally the data utilized in assessment models includes three types of information. The first is extensive information on the basic biology of the species. The second is fishery-dependent data; accurate information on the size and age of fish caught as well as the amount of effort it took to catch the fish. The third is fishery-independent data; information on the abundance, distribution and age structure of the fish stock that come from sources other than the fishery such as research surveys or tagging studies. Stock assessments that are both accurate and precise allow setting catch targets for species that can provide provisioning and cultural services to human communities which support thriving commercial and recreational fisheries that avoid overfishing and depletion of fish stocks. If the assessments are uncertain or biased, catch targets may be set either too conservatively or too liberally which can impact near term socio-economic returns and/or impact fish stock abundance and the sustainability of the fishery. Stock assessments for some groundfish species, especially many of the nearshore species of rockfish, have been limited to data-poor (e.g., Quillback and Tiger Rockfish, Dick et al. 2010) or data-moderate (e.g. Brown and Copper Rockfish, Cope et al. 2015) methods because the available data are not adequate to conduct full age-structured stock assessment models. Even those species with full assessments often lack any type of fishery-independent data to help scale the assessment results which rely entirely on modeling fishery-dependent data.

The need for fishery-independent abundance data for rocky reef associated fish species is well established. In addition to the recommendations for fishery-independent surveys in the Nearshore Strategy (ODFW 2016), there are similar calls for fishery-independent data in federal fishery management sources. The federal assessments done to date for these species rely largely on fishery-dependent data. The primary source of fishery-independent data for many Pacific Coast groundfish stocks is the West Coast bottom trawl survey conducted by NMFS. This survey is unable to sample rocky habitats and is not conducted in waters shallower than 55 m (Bradburn et al. 2011). The PFMC published priorities for its research and data needs in July 2013 (PFMC 2013), and updated these priorities in September 2018 (PFMC 2018). Both documents specifically highlighted the need to develop cost effective methods to conduct fishery-independent surveys for groundfish in untrawlable habitats like nearshore rocky reefs. These documents emphasized the need for fishery-independent surveys with low impacts on rockfish species in particular because their life history characteristics translate into relatively low yields for fisheries and long rebuilding times for these stocks if they are overfished. Specifically, it was proposed that use of drop cameras should be investigated. Several recent full stock assessments also called for fishery-independent surveys of nearshore and/or rocky areas:

> "A fisheries-independent nearshore survey should be supported to improve estimates of abundance trends (not having to rely on fisheries data for such trends) and, if possible, absolute abundance. Population scale has proven difficult to estimate for many nearshore species without informative data." (text from the Blue/Deacon Rockfish assessment by Dick et al. 2017)

> "A survey in untrawlable habitat and/or a near shore survey would improve this stock assessment." (text from the Lingcod assessment by Haltuch et al. 2017)

> "Develop and implement a comprehensive visual survey, as currently available bottom trawl surveys do not encounter Yelloweye Rockfish often and the hook-and-line IPHC survey targets halibut and incidentally encounters rockfish." (text from Yelloweye Rockfish assessment by Gertseva and Cope 2017)

> "An independent nearshore survey should be supported in all states to avoid the reliance on fishery-based CPUE indices." (text from the Black Rockfish assessment by Cope et al. 2016)

> "Direct observation of canary rockfish suggests that individuals are often associated with rocky habitat, and therefore may not be available to the bottom trawl gear used to obtain coast-wide fishery-independent data in the California Current." (text from Canary Rockfish assessment by Thorson and Wetzel 2016)

> "Consider the development of a fishery-independent survey for nearshore stocks. As the current base model structure has no direct fishery-independent measure of stock trends, any work to commence collection of such a measure for nearshore rockfish, or use of existing data to derive such an index would greatly assist with this assessment." (text from the China Rockfish assessment by Dick et al. 2016)

> "Fishery-independent surveys of abundance for nearshore species, including Kelp Greenling, would provide information about population trends that don't rely on data collected directly from the fishery and the inherent complexities that those data entail. Surveys that result in time a time series of information covering a representative spatial extent of the population would be most advantageous." (text from Kelp Greenling assessment by Berger et al. 2015)
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> "A fishery-independent nearshore survey should be supported to improve estimates of abundance trends (not having to rely on fisheries data for such trends) and, if possible, absolute abundance. Population scale has proven difficult to estimate for many nearshore species without informative data. Continued support and development of current fishery-independent nearshore surveys is needed to extend the time series and increase spatial coverage." (text from Cabezon assessment by Cope et al. 2019)

Given the established need to gather information on species and habitats in rocky reef areas, staff at ODFW's Marine Resources Program (MRP) designed a video lander to sample rocky reef habitat (Hannah and Blume 2012). The study reported here investigated the use of a video lander to conduct fishery-independent surveys on nearshore rocky reefs. This study focused on Nearshore Strategy Species fishes that inhabit these reefs, but also gathered information on invertebrates observed with the lander and wildlife species sighted from the boat while the lander was sampling underwater to get a more complete picture of the nearshore ecosystem. The specific objectives of the study were to:

- Examine the practicalities of sampling in terms of number of samples that could be collected daily, the logistical considerations and limitations of using a video lander in the field.
- Generate quantitative abundance metrics for observed fishes.
- Investigate the effects of different sampling times on data collected including abundance metrics.
- Examine factors that may influence the fish community.
- Quantify observations of certain macro invertebrates and their distribution and abundance.
- Explore the practicalities of gathering wildlife observations at the surface during a study focused on species and habitats underwater.

This work was undertaken as a pilot study in a relatively small area. The goals of this pilot study are to help implement recommendations of the Nearshore Strategy, PFMC and stock assessors in the hope that findings from this project can be used to inform future work that could be undertaken on broader spatial and temporal scales.

Methods:

Lander Design

A video lander based on the designs of Hannah and Blume (2012, 2014) was utilized to sample the finfish community found in the nearshore waters off Newport, Oregon. The lander was equipped with two DeepSea Power and Light SeaLite®Sphere-3000 lights (3,000 lm, 6,000 Kelvin) and a single Canon® Vixia G 20 high-definition color video camera fit with a wide-angle converter lens (Impact™ DVP-WA50-58 Digital 0.5 X). The camera was set to "progressive scan" and 24 frames/s with video recorded onto SD cards. The lights were powered by 3 rechargeable NiMH 13.2 V batteries wired in parallel. Both the camera and batteries to power the lights were housed in aluminum pressure housings and the camera housing was equipped with a dome port. Both the camera and lights were turned on by a magnetic reed switch wired to a LANC controller board activated by screwing a magnet into the battery housing. The lander frame was made of 32 mm outer diameter aluminum tubing enclosing the lights as well as the camera and battery housings for protection and attached to a sacrificial weighted base by weak links that allow the lander frame with equipment to break free for recovery if the base becomes stuck in the rocks (Figure 1).

Study Area and Sampling Design

The geographic range of sampling was bounded by Cape Foulweather (44.772° N) to the north and the mouth of Alsea Bay (44.419° N) to the south and Oregon's three mile territorial sea limit to the west. Target video lander drop locations were established by selecting a random starting point on a GIS layer of rocky habitat and spacing drop locations at 400 m intervals on a hexagonal grid. Rocky areas were identified using the layer generated by the Active Tectonics Group Seafloor Mapping Lab at Oregon State University as part of a state waters mapping project (Goldfinger et al. 2014). This layer was supplemented by adding a number of small rocky reef areas near the mouth of Alsea Bay. This area, commonly referred to as the "postage stamp", is fished by local fishers and was included as part of the Black Rockfish PIT tag work conducted by ODFW (Krutzikowsky et al. 2019), and is now one of the Oregon marine reserves comparison areas (ODFW 2015b). The study area encompassed 30.19 km^2 of rocky reef (Figure 2). By design the study area for this project encompassed the entire tagging area of the Black Rockfish PIT tag study. A total of 220 drop locations were identified, but a review of nautical charts before sampling started indicated that some target locations were unlikely to be sampled successfully for safety reasons (Figure 2).

Field Work and Sampling Protocols

Sampling was conducted from the 13.1 m CPFV *Miss Raven* on mutually agreeable dates that were dependent on suitable weather conditions, reasonable expectation of adequate water visibility for sampling, and both boat and staff availability. In order to maximize sampling time and minimize transit time to and from port the nominal sampling day was specified as 10 hours departing port shortly after sunrise. On most days as many samples were collected as time allowed. All sampling was done during daylight hours, defined as more than one hour after sunrise and before sunset for the purposes of this study. In general, if rocky substrate was not detected on the vessel's sounder at the target site, the lander was dropped at the nearest location within an approximately 200 m radius that rocky habitat was detected or the target location was not sampled, although some drops early in the study were conducted in soft bottom habitat when rocky habitat was not detected near target locations. Only target sites that could be accessed safely by the vessel in the captain's judgement were sampled. It was anticipated that all samples be could be collected in one year from March through May, but a number of unforeseen circumstances necessitated sampling in three different years to complete the survey. In all, 177 lander drops were made during nine days of sampling: 116 during five days in May 2014; 43 during two days in March 2015; 15 on one day in April 2015; and 3 on one day in March 2016.

The lander was deployed manually over the side of the vessel, and allowed to sink freely to the bottom. The lander was allowed to sample for approximately 15 minutes. Location coordinates were recorded at each station with a GPS unit. At each station a profile of the water column properties (to within ~1 m of the bottom) was collected with a Seabird ® model V-19 plus conductivity temperature depth (CTD) meter equipped with a SB-43 dissolved oxygen sensor while the lander was sampling. A line with a buoy attached was used to retrieve the lander from the bottom with a hydraulic winch. A cable from an electric winch was then attached to lift the lander from the water's surface over the side of the boat on to the deck.

Each time the lander was deployed and sampling the number and species (or species groups) of birds and marine mammals sighted within an estimated 300 m radius of the boat was recorded for a 5 minute interval. Birds and mammals were spotted visually by naked eye or using 8 x 42 Vanguard® Endeavor binoculars. Wildlife in or on the water, on rocks protruding above the water and birds in flight were all recorded. The same individual conducted all wildlife observations.

Video Review

Video review was initially conducted jointly with ODFW's Marine Reserves Ecological Monitoring Project, which was doing similar video lander work. This coordination allowed for sharing ideas, standardizing review protocols, two independent reviews of video samples, and sharing initial results and analysis. Due to design differences between the Marine Reserves and the Nearshore Project video landers, which included physical structure, lighting, and cameras, samples were not pooled for analysis in this document. Help with video review by Marine Reserves staff was limited to the first 115 drops. Subsequent review of video was conducted only by Nearshore Project staff, which did not allow for two independent reviews. Video review data were recorded on paper, then entered into a database. In all cases reviewers were able to comment about the video data and its processing. Those comments are included in the database.

For review purposes the video included only the time from touchdown on the bottom to liftoff. Video reviewers identified each fish and specific macro invertebrates (those identified and counted by the Marine Reserves Program during SCUBA sampling, see ODFW 2014 for complete list) to the lowest taxa possible. Blue and Deacon Rockfish were lumped together as a single species complex in this study for several reasons. These two species are extremely similar in appearance and were considered to be a single species for many years until Deacon Rockfish were recognized as distinct species in 2015 (Frable et al. 2015) after more than half of the video had been analyzed. It has also yet to be demonstrated that the two species can be readily distinguished visually in video samples, especially the smaller individuals. Although some species are distinctive, many small juvenile and young of the year rockfish can be difficult to identify. Following Hannah and Blume (2012) these juveniles were grouped together as unidentified juvenile rockfish. Juveniles, both roundfish that were not identified as rockrockfish and flatfish, were not identified to species for the same reasons. These fish were grouped as unidentified roundfish and flatfish juveniles, respectively. The MaxN for each species was the abundance metric scored when reviewing video from drops. The MaxN metric, the maximum number of that species visible at one time, is commonly used for quantifying abundance for fish species in video lander sampling and is considered to be a conservative approach (Ellis and DeMartini 1995; Watson et al. 2005; Harvey et al. 2007; Hannah and Blume 2014; Easton et al. 2015; Watson and Huntington 2016). The first time that each fish species appears in each video sample (time of first arrival) was recorded (mm:ss) as well as (MaxN) and the first time (mm:ss) that MaxN occurred. The maximum number of each invertebrate species or species group was also recorded.

Bottom substrates were classified into the following categories that are described in relation to the Coastal and Marine Ecological Data Standard (FGDC 2012) in Table 1: Bedrock, bedrock outcrop, large boulder, small boulder, cobble, gravel/pebble, sand, mud, shell hash, and worm substrate. Both a primary substrate and a secondary substrate was designated with the primary substrate comprising ≥ 50% and secondary substrate comprising ≥ 20% of the bottom visible in the frame. Relief was classified as low ≤ 10 cm, medium = 10-50 cm, and high ≥ 50 cm based on the estimated maximum relief over 1 m horizontal distance that the reviewer observed. Biogenic cover gradients were scored by type and structure categories on a Braun-Blanquet (1932) relative cover-abundance scale. Five categories of biogenic habitat were scored from 0 to 5 based on their percent cover of the substrate where 0 = none, 1 < 5%, 2 = 5-25%, 3 = 26-50%, 4 = 51-75% and 5 = 76-100% cover. The five categories of biogenic habitat were defined as: 1) Canopy - stipes and holdfasts are visible but no blades; 2) Midstory - stipe and blades or other biogenic structure 25+ cm in height are visible for part of all of the video but it does not reach to the surface; 3) Understory – biogenic material 5-25 cm including macroalgae, coralline algae, sponges, gorgonians, metridium, etc.; 4) Turf/Crust - biotic crust, turf or mats (approx. <5cm in height) including encrusting sponges, tunicates, turf algae, etc.; 5) Seagrass - amount of substrate covered by seagrass.

Visibility, the ability to see the bottom and identify species due to water clarity and turbidity, was scored from 0-3 for each sample: 0 = surrounding substrate completely obscured, ID not possible; 1= ID ability comprised by visibility; 2 = limited by variable turbidity and/or marine snow but species ID still possible; 3 = surrounding substrate is clear, can ID species readily. View was scored from 0 -2: 0 = Obstructed or camera tilted upward (cannot see benthos), obstruction is <1m away and greater than 50% of frame; 1 = Partially obstructed with obstruction estimated to be >1m away and greater than 50% of frame or lander tilted but benthic substrate still visible; 2 = Not Obstructed; oriented upright. Video from drops with visibility or view scored as 0 were not further reviewed or included in analyzes.

Data Analysis

Fish observations, MaxN, fish density and abundance estimates:

The frequency that fish species or species groups were observed and the MaxN statistics were compiled for the usable video drops. The density of fish species observed in samples was estimated based on the methods similar to those used by others (Burge et al. 2012, Mallet et al. 2014, Berger et al. 2015 Appendix H, Starr et al. 2016):

$$\text{Density} = \text{MaxN for species / viewing area in m}^2$$

All drops were analyzed using these calculations, including those in which a species was not observed. The viewing area was calculated using the formula for a sector of a circle. The horizontal measurement angle was 96.7° calculated from measurements taken on a ruler placed 45.7 cm from the camera lens (Figure 3). The viewable distance (radius of the sector) was based on work by Hannah and Blume (2016) who reported fish detection distances that ranged from 1.57 m to 3.42 m (mean = 2.42 m) at the nearshore Oregon reef off Seal Rocks in a study investigating the effective range of a stereo video lander. Thus, the estimated viewing area for drops reported here ranged from 2.08 m^2 to 9.87 m^2 (mean = 4.94 m^2). Average density values for each species in the study area was calculated that represent a maximum, minimum and mean by using these 3 viewing area estimates as the denominator. This method assumes that the viewing area was constant on all drops which was not the case, but that the values calculated provide a range of average densities for species with bounds based on the viewing area estimates. Density values were standardized to number of fish per 100 m^2 for ease of comparison with other studies. The average density estimates were scaled to calculate a range of population estimates for the entire 30.19 km^2 study area.

Sampling times, species richness and MaxN:

Bottom times, the time from when the lander touched down to time it was lifted from the bottom, represent the sampling time. Bottom sampling times were targeted to be 15 minutes in this study, but shorter times of 4 and 8 minutes for sampling the fish community off Oregon have been recommended by others (Hannah and Blume 2012, and Watson and Huntington 2016, respectively). The data collected in this study was examined to provide information on if or how results would change in terms of species richness, a measure of diversity, and MaxN to help evaluate potential tradeoffs of using these shorter sampling times. The distribution of time of first arrival vs. the number of species observed was plotted for all drops on which fish species were identified for each sampling time period. The time that MaxN first occurred for each species on each drop was utilized to determine how frequently MaxN would have declined if sampling time was truncated at 4 and 8 minutes in the samples collected. These comparisons are intended to inform sampling design of future work by providing insights into the tradeoffs and potential consequences of utilizing various sampling times.

Community Analysis and Environmental Gradients:

Using data from 74 drops (Figure 4) at depths from 12 to 41 m completed during 5 days of sampling in May 2014 we examined the relationship between the fish community and environmental gradients (G. Krutzikowsky and B. Rodomsky, poster presented at Western Groundfish Conference 2016).

Only fishes identified to the species were used in the analysis. In addition to the environmental variables collected for each drop described above, several other environmental variables were considered in the analysis. Rugosity (R, 2m grid resolution), mean slope, max slope, and (fractal) complexity for multiple spatial extents around each drop were derived in ArcGIS from raster bathymetry data, where available. Rugosity was defined as the surface area divided by the planar area (Jenness 2004) for the defined square spatial extent surrounding a drop (Figure 5). Complexity (*d*; the fractional dimension) is estimated as:

$$d = \log_{10}(\text{R})/\log_{10}(1/\text{pixel side length}) \quad \text{(Rodomsky 2011)}$$

Complexity was derived from rugosity values measured at 2, 4, 6, and 10m pixel resolutions from fixed extents surrounding the drop (Figure 5). When plotting log-transformed rugosity vs. 1/pixel resolution the slope of the fitted regression line is an estimate of complexity for the spatial extent surrounding each drop (Russ 1994). Complexity represents a quantified characterization of the geomorphic structure of the bathymetric surface surrounding drop locations; in this case valid for pixel resolutions spanning 2-10m. Complexity metrics also eliminate the relative scale-dependence associated with rugosity estimates. CTD data were processed with the software supplied by Seabird Electronics to provide temperature, salinity and dissolved oxygen measurement at 1 m intervals and the values for each of these variables at the deepest measurement interval at each drop location was utilized in the analysis.

A canonical correspondence analysis (CCA) was conducted (TerBraak 1986) in R 3.2.3 statistical software (R Core Team 2013) with the vegan package (Okasnen 2007). Twenty-three drops lacked the necessary explanatory or response variables, so the data for the analysis consisted of two matrices for 51 drops: species counts by site and environmental metrics by site. MaxN values for all identified fish species were transformed to minimize distributional skew for better model fit. Model inputs consisted of

log_{10}(MaxN+1), log_{10} (continuous gradient variables+0.001) and dummy categorical gradient variables. Stepwise model selection, both forward and backward, was used to select the best-fit model based on *P*-values of $\alpha = 0.05$ as the criteria for inclusion. If an environmental gradient explained a significant trend in the community composition while improving the *P*-value of the overall model, the gradient variable was retained in the final model.

Invertebrates:

Macro invertebrates observed during lander drops were summarized based on the number of species and species groups observed, frequency of observation, total number observed and the maximum number observed during a drop.

Wildlife:

Wildlife species sightings at all 177 stations were summarized. The frequency that each species or species group was observed and the total number observed are reported.

Results:

Data Summary

Video from 145 of the 177 lander drops (82%) was usable, totaling 36 hours 9 minutes and 53 seconds. Samples were collected on 5 days in May 2014 (n = 95), 2 days in March 2015 (n = 36) and 1 day in April 2015 (n = 14). Sampling times varied from 13.37 to 17.87 minutes, with a mean of 14.97 ± 0.54 s.d. minutes. Sampling depths ranged from 5.4 m to 41.0 m.

Thirty-two drops were not analyzed (Table 3). The percentage of videos analyzed in each 10 meter depth range closely matched the percentage of drops made in that depth range. Most were less than 1% different with the biggest difference being just under 2% in the shallowest depth range. Video issues were the most frequent problem, preventing analysis of 15 (46.9%) of those 32 drops, followed by camera view (13 drops, 40.6%), and visibility (4 drops, 12.5%). Video problems included focusing issues (10 drops), no media card in the camera (3 drops), or the video file being lost (2 drops). Six of the ten drops with focus issues were sequential drops where the camera focused on water droplets on the inside of the dome lens. Problems with camera view included: 1) the lander being tilted so that the camera either looked up toward the surface or down toward the bottom; 2) substrate very close to the camera blocked the view.

The most frequently observed primary habitat substrate was bedrock (n = 82), with sand being the second most frequently sampled (n = 26). The primary and secondary habitat substrates were the same in 55% of the samples, but the variety of primary and secondary habitat substrates sampled included 29 different combinations that ranged in sampling frequency from 1 to 56 (Table 4).

Several other habitat variables were scored during video analysis. Relief was classified as high on 72 drops (49.7%), moderate on 26 (17.9%) and low on 47 (33.8%). Turf/crust was the predominant biogenic habitat encountered, occurring on 117 drops (80.7%) and covering 76 – 100% of the bottom in 59 drops (Table 5). Understory biogenic habitat was encountered on 91 drops (62.8%), but covered more than 50% of the substrate on only 17 drops (11.7%). Mid-story biogenic habitat occurred on 11 drops (7.6%). Neither kelp canopy nor seagrass was encountered on any of the drops.

Fish:

Fish were observed on 123 (84.8%) of the 145 drops and at least some of the fish observed were identified to species on 108 (74.5%) of the drops. Sixteen different species of fish were identified in the video samples.

Of the 16 fish species identified, the seven most frequently observed were Kelp Greenling (53% of drops), Black Rockfish (48%), Lingcod (40%), Blue/Deacon Rockfish (33%), Pile Perch (21%), Canary Rockfish (17%) and Striped Perch (10%) (Table 6). The total number observed for each species or species group on all 145 drops (sum of MaxN) ranged from 651 for Black Rockfish to 1 for species such as the Wolf Eel and Yelloweye Rockfish (Table 6). Count data were zero inflated and best represented by either a negative binomial or Poisson distribution. As such, the median MaxN count for all species seen in the 145 video samples was 0, except for Kelp Greenling which was observed on more than half of the drops and had a median MaxN value of 1.

There were a total of 1583 adult fish counted for all lander drops, with 1370 of those (86.5%) identified to species. Seven species made up 97.5% of the total number of adult fish identified to species including Black Rockfish (48.98%), Blue/Deacon Rockfish (17.96%), Kelp Greenling (8.98%), Canary Rockfish (6.20%), Pile Perch (6.13%), Lingcod (5.69%) and Stripped Surf Perch (3.58%) with the other nine species combined making up 2.5% (Figure 6). Of the 213 fish not identified to species most were rockfish (54.93%) and many of these were observed in schools on drops where Black Rockfish and/or Blue/Deacon Rockfish were also observed.

The mean MaxN/drop for species identified varied by three orders of magnitude (Table 7) with more Black Rockfish being observed per drop than any other species. The semi-pelagic schooling species, Black Rockfish and the Blue/Deacon Rockfish complex, were the species with the highest average MaxN counts, followed by Kelp Greenling, Canary Rockfish, Pile Perch, Lingcod, and Striped Surf Perch. Assuming that the viewing area was the same for all drops, a range of density and abundance estimates for each species was calculated from the mean MaxN statistic for different visibility conditions (Table 8) based on fish detection distances reported by Hannah and Blume (2016). Abundance estimates for Black Rockfish range from approximately 1.4 to 6.7 million fish in the study area. Note that these number are presented as a proof of concept and a range of values is given because this study was not able to directly quantify the viewing area on each drop to capture the variability in terms of standard errors or CVs associated with the differing visibility and view conditions.

Effects of Sampling Time:

Sampling times varied from 13.37 to 17.87 minutes, with a mean of 14.97 (± 0.54 s.d.) and median of 14.87 minutes. Results below include comparisons of shorter sampling times than utilized for this study as it relates to sampling fish.

Fish were identified to species on 108 of the 145 drops (74.5%). A sampling time of 8 minutes would have reduced the number of drops that fish were identified from 108 to 103, a 5% reduction. Sampling times of 4 minutes would have reduced the number to 97, a 10% reduction. The total number of identified fish would have decreased from 355 to 318 (10.4%) and 271 (23.7%) for 8 and 4 minute sampling times, respectively.

Species richness varied from 0 to 8 with the 15 minute sampling times. The median time when the maximum number of species had accumulated to the highest richness value general increased as the number of species identified increased from 1 to 8 (Figure 7). Sampling times of 4 minutes include the median arrival times for the first 4 species identified, but do not include the median arrival times for drops with species richness values of 5 or 6. The median times for all drops except those with a species richness value of 8 (n=2) were less than 8 minutes. Nevertheless if sampling times were limited to either 4 or 8 minutes, some species detected as being present during the 15 minute drops would not have been observed at some drop locations. In general, reduced sampling times increased the number of drops that no fish were observed and decreased the species richness values (Figure 8). The average species richness for all drops conducted in the study, including those where no fish were identified to species, decreased from 2.5 to 2.2 and 1.9 for 8 minute and 4 minute sampling times, respectively.

The effects of shorter sampling times on both presence detection and MaxN counts varied among species (Table 9). For the seven species observed in 14 or more drops, truncating sampling time at 4 minutes reduced detection rate from 6 to 36%. An 8 minute sampling time reduced detection rate by as much as 18% for some species. Kelp Greenling, Lingcod and Striped Surf Perch detections were all reduced by 14% or more. Truncating sampling time at 4 minutes reduced MaxN in from 31% to 56% of the drops these seven species were observed and truncating at 8 minutes reduced MaxN in 9% to 28% of the drops. The changes in both presence detection and MaxN also appeared to be substantial for many of the species observed less frequently; however, these species were all detected in fewer than 10 drops.

Fish Community and Habitat Gradients Results:

The 51 lander drops utilized for the CCA analysis included fifteen observed species. The total number observed for each species varied from 1 to 391 and MaxN values ranged from 0 to 92 for the various species (Table 10). Bedrock was the most frequently encountered substrate in these drops, with large boulders being the second most frequently encountered substrate (Table 11).

The CCA model (Table 12) included five environmental gradient variables, longitude, large boulder primary habitat type, complexity at two separate extents (10 & 50m), and dissolved oxygen at depth. The first three axes of the selected model, depicted in Figure 9, were significant and explained 81.5% of the constrained inertia. Model coefficients indicate the direction and magnitude of relative rates of change of environmental gradients per one unit change along each CCA axis. The absolute value of model coefficients per gradient also indicates the relative importance of a gradient in predicting community composition. The variance inflation factors for the five gradient variables in the selected model indicate the correlations among them are low. Constraining environmental gradient scores indicate the vector direction of increase of the gradient. Species scores indicate both points of environmental optima for species and abundance centers per species in the first three CCA axes. As distance increases from the species optima center, the abundance and/or probability of occurrence of the species decreases (Ter Braak 1986). Results depicting the species optima and selected environmental gradient vectors on the CCA axes are provided (Figure 9 a-c).

Invertebrates:

Macro invertebrates on the list were seen on 86 (59.3%) of the 145 drops. In all, there were 21 species or species complexes identified, as well as additional unidentified sea stars, anemones, crabs and octopus. Echinoderms were the most widespread, being observed on 72 (49.2%) of the drops, followed by cnidarians on 20 (13.8%) of the drops, arthropods on 13 (9.0%) of the drops and molluscs on 8 (5.5%)

of the drops (Table 13). The most numerous species observed was the giant white plumed anemone with 147 observed on 14 drops. Eighty-eight of these anemones (59.9%) were seen on 2 drops, both of which had more than 40 present. The next highest count on any drop for this species was 15. The pink sea star was the next most numerous species identified with 54 observed on 25 drops.

Wildlife observations:

Wildlife sighting data were collected at 176 of the 177 lander drop locations and wildlife was observed at 172 (97.7%) of the locations with a median of three species/species categories present. Thirteen individual bird species, two additional bird species groups, and three marine mammal species were observed (Table 14).

The Common Murre was observed at 120 (68.2%) of the drop locations and was the most abundant with approximately 2,250 observed (Table 14). Gulls were always identified to family rather than to species and were observed at 102 (58.0%) of the drop locations. Pacific Loons were migrating during the time that sampling occurred, with all 307 of the birds observed flying northward at the 60 (34.1%) drop locations at which they were sighted. A variety of other bird species were observed, including Pelagic Cormorant, Brandt's Cormorant, Surf Scoter, Pigeon Guillemot, Cassin's Auklet, Brown Pelican, White-winged Scoter, Double-crested Cormorant, Common Loon, Western Grebe, and Tufted Puffin. Some birds were only identified to species group when species identification was not possible or when species numbers in large mixed flocks could not be determined.

California sea lions were the marine mammal observed most frequently and in the greatest number with 19 individuals sighted at 3 (1.7%) of the drop locations (Table 14). Gray whales were observed at 2 (1.1%) of the drop locations, and harbor porpoise at one (0.6%) of locations (Table 14).

Discussion:

The video lander described in this study was used successfully to sample and characterize bottom substrate on nearshore rocky reefs and surrounding areas, examine the fish community and investigate the environmental factors affecting the fish community structure. This project also examined the potential for data collected with this tool to be used to estimate the density and abundance of species of management interest. Eighty-two percent of the drops made produced usable video samples (Table 3) with the biggest problem being issues with the videos most of which were caused by human errors during the early part of the study. The usable video samples closely matched the depths of all the target stations so the results should not be biased by loss of samples in particular depth ranges.

As anticipated, it was not possible to safely sample all of the 220 stations. Having adequate water depth and clearance from surrounding obstructions to safely maneuver the boat limited sampling to depths of about 5 meters or greater and also limited how close sampling could be done near rocky outcrops, islets and shallow submerged rocky spots. Some of these locations have restricted access that require utilizing small channels through shallow reefs that could only be accessed at higher tide levels on relatively calm days and where maneuverability is restricted once on site. At some of the shallowest locations sampled, movement of the lander by wave motion occurred. In practical terms, the general use of the lander along the Oregon coast is likely to be restricted to sampling waters > 5 meters deep.

Sampling was efficient. Up to 25 drops were conducted in a 10 hour day and more than 20 drops were collected on six days. The time between sequential video lander drops was usually just over 20 minutes. It took longer when traveling to stations spaced at greater distances or if time was needed to search for nearby rocky habitat if the target station did not appear to be rock. Batteries for the lights needed to be changed after no more than seven drops or the lights would start to flicker. Camera batteries and SD cards were typically changed out at the same time for efficiency as the cameras need to be removed from the pressure housing to make these changes which adds a little time between drops. The number of samples collected in a day could feasibly be nearly doubled by leap-frog type sampling if two landers were utilized in a sampling design with similarly spaced target drop sites and sampling times. An investment in a second lander could pay for itself by increasing the number of samples collected in a day thus reducing charter costs, but that would ultimately depend on a combination of factors that include not only the sampling design and charter costs, but also the longer term plans for future lander surveys.

The survey was designed to be completed in one season of field work (March through May) with the anticipation that the spring plankton bloom would reduce visibility effectively ending the sampling season. However, factors outside of our control resulted in samples being taken over three years. Nevertheless, completing the survey in less than nine days of field work suggests that one season would have been adequate had those factors not arisen.

Fish Observations, MaxN, Density and Abundance Estimates

Sixteen fish species/species complexes were identified, with Black Rockfish composing almost 50% of all fish identified and the Blue/Deacon Rockfish complex composing approximately 18%, so together these species made up over two-thirds of all fish identified (Figure 6). Kelp Greenling were the most widespread and frequently observed species identified, followed by Black Rockfish, Lingcod, Blue/Deacon Rockfish, Pile Perch, Canary Rockfish and Striped Perch (Table 6). However, the rank order for mean MaxN for these seven species on drops they were observed was different with Kelp Greenling and Lingcod being lowest (Table 6).

The mean MaxN values for all drops (Table 7) reflect a combination of both the frequency that a species was observed and the number of individuals observed during the drops. The density and abundance estimates from this study (Table 8) suggest that video lander surveys have the potential to provide fishery-independent information that are of management interest. This project is part of a growing body of work demonstrating that video landers can be used to collect fishery-independent data that are valuable for use in fishery stock assessments. Whether such data are incorporated directly into stock assessments or used to tune and scale models depends on the temporal and spatial extent of the video lander survey data. Assessment models typically utilize time series data that are collected over broad geographic areas that ideally are representative of the available suitable habitat within stock boundaries. For example, fishery-independent video survey data from stationary camera systems are used to develop indices of abundance for a wide variety of reef fish in the southeast U.S. (SEDAR 2014) and Gulf of Mexico for use in stock assessments for both data-limited species (SEDAR 2016) and species with full assessments such as Gag Grouper (*Mycteroperca microlepis*), Red Grouper (*Mycteroperca microlepis*), Red Snapper (*Lutjanus campechanus*), and Vermillion Snapper (*Rhomboplites aurorubens*) (see the Southeast Data Assessment and Review website for stock assessment projects, reports and updates http://sedarweb.org/sedar-projects). However, these surveys cover very large areas and have been conducted for many years. Examining the power of such surveys to detect population abundance changes over time Conn (2011) suggested that the length of the time series was a major factor. If ODFW were to expand the use of video lander surveys in both spatial and temporal extent these data could become a powerful tool for detecting population changes and more useful for management purposes.

A variety of abundance metrics have been developed for stationary video camera systems including 'time at first occurrence', MaxCount, MaxN (also called MinCount or MAXNO) and most recently MeanCount (Ellis and DeMartini 1995, Priede and Merrett 1996, Willis and Babcock 2000, Watson et al. 2005, Merrit et al. 2011, Bacheler et al. 2013, Schobernd et al. 2014). The MaxN metric is the most widely used for both baited and unbaited video lander studies and is generally considered to be a conservative estimate of abundance (e.g. Willis and Babcock 2000, Watson et al. 2005, Harvey et al. 2007, Watson et al. 2007, Merritt et al. 2011, Hannah and Blume 2012, Easton et al. 2015, Watson and Huntington 2016), but there is still debate on what is the best abundance metric. Concerns have been raised that MaxN does not provide a linear relationship to true abundance and that MeanCount, which is derived from a sample by averaging counts of fish at selected intervals, might be a more useful metric (Conn 2011, Schobernd et al. 2014). However, Campbell et al. (2015) used MaxN and MeanCount metrics collected from the same data set and found that for all species observed, MeanCount data systematically underestimated species presence and also results in less precise (higher variance) abundance estimates than using MaxN data in the delta lognormal models typically used to create the abundance indices from video data for use in stock assessments. Thus the use of MaxN has several advantages. From a practical standpoint, MaxN is a much easier metric to collect during video analysis that takes substantially less staff time to generate than MeanCount and the reduced variance using the MaxN-derived metric also means that this abundance index will be more informative in stock assessment models which put less weight into indices with high variance. Regardless of the abundance metric chosen, it is important to understand the consequences of its use for statistical modeling.

The density and abundance estimates (Table 8) varied inversely as a function of view area, with higher density and abundance estimates corresponding to smaller estimated view areas as expected. While the view angle measurements were taken for the specific equipment used in the study, the single camera system utilized did not provide a direct means of determining the distance metric needed to calculate the area viewed. Instead, the best estimates available for the distance or range at which species can be identified in Oregon nearshore waters were taken from work by Hannah and Blume (2016) who utilized a stereo video lander. Their work was conducted on the same reef system as this study and the stereo camera system allowed them to generate information not only about distances at which fish could be identified but also to measure the lengths of fish. Densities for this study were calculated for all three range estimates provided by Hannah and Blume (2016) in order to provide reasonable bounds on density and abundance estimates, but it should be remembered that these authors noted that differences in camera resolution and light sensitivity as well as camera settings and lights utilized could cause fish detection distances to vary for a lander configured differently. The maximum and mean distances from Hannah and Blume (2016) used for the radius in the view areas calculation are more likely to represent the visibility conditions in this study than their minimum distance for several reasons. First, Hannah and Blume (2016) sampled in a wide range of visibility conditions to examine the effects of both the amount of ambient light and water clarity on the distance that fish could be identified and measured with the stereo lander whereas the conditions for field work in this study were carefully selected to ensure the greatest chances for adequate visual sampling visibility. Second, quality control measures discussed earlier eliminated 17 samples where the field of view was deemed to be inadequate either because of poor visibility, angle of the camera or a view substantially restricted by obstructions. Thus, the minimum and mean abundance estimates provided (Table 8) are likely the best available with the methods utilized here. The minimum abundance estimate which assumes the best visibility and largest viewing area for all drops is the most conservative. However, all the density and abundance estimates presented here assume that each drop sampled the same area, but both the visibility and the view varied among drops. If a stereo camera system was utilized rather than a single camera, the effective sampling area for each drop could be calculated to refine density estimates and provide additional information on variance. The use of stereo cameras for future work would provide two important improvements over the pilot work done in this study. First, it would allow direct quantification of the view area for each drop and second, it would allow for sampling of fish sizes for use in assessments.

Although there is an extensive history of utilizing video techniques to examine marine biodiversity (Mallet and Pelletier 2014), relatively few published studies appear to calculate fish densities from unbaited video landers (Burge et al. 2012, Mallet et al. 2014, Pita et al. 2014, Starr et al. 2016). Lander configurations, field methods, and viewing distance estimation methods varied among these studies, but fish density metrics were all based on MaxN/area viewed calculations similar to those used in this study. Burge et al. (2012) did not find any differences in MaxN-derived densities between baited and unbaited deployments for the grouper species studied; they attributed this to the type of bait used. On a deep rocky reef off Oregon, Hannah and Blume (2014) found that the effects of utilizing bait generally increased MaxN values for demersal fish species. However, utilizing bait as a fish attractant can introduce complications into density calculations such as modeling bait plume dynamics and behavioral responses of target species (e.g., Priede and Bagley 2000, Farnsworth et al. 2007, Heagney et al. 2007, Taylor et al. 2013, Dunlop et al. 2015), which is in part why bait was not used in this study.

Habitat characteristics, fish community composition, and fish density/abundance on nearshore rocky reefs off the Oregon coast have been investigated by ODFW and others over the past several decades utilizing a variety of visual techniques including SCUBA, remotely operated vehicles (ROVs), and video landers. Study areas have included nearshore as well as deeper offshore waters. Reports on much of this work provide fish density estimates or abundance metrics (e.g., Miller et al. 1997, Fox et al. 2000, Amend et al. 2001, Merems 2003, Fox et al. 2004, Weeks and Merems 2004, Weeks et al. 2006, Donnellan et al. 2009, ODFW 2014). The ROV surveys include Siletz reef, Cape Perpetua, Orford reef and the Otter Rock - Cape Foulweather area. These studies report fish densities (number of fish per 100 m^2), but do so for the various reefs characterized in a variety of different ways including by transects done in rocky habitats of various patch sizes, by habitat characteristics such as depth, relief or substrate type, and by year for the same transect locations. There is a considerable range of values in the density estimates reported for any given species (Appendix A). Possible reasons for the wide variety of densities reported include differences between sampling units, geographic locations, and study years. It is interesting to note that the density-based rank orders reported for the various species differs among these studies. The differences in cameras and averaging methods makes comparisons with this lander study difficult, however densities reported for the ROV surveys tend to be lower. More recent ROV work has utilized HD cameras and the methods for data processing and analysis at ODFW have been revised, but the results are not yet published (Scott Marion, personal communication). SCUBA surveys were conducted at McKenzie Reef and Orford Reef in the 1990s (Miller et al. 1997) and at the marine reserves at Redfish Rocks and Otter Rock and their comparison areas in 2010 and 2011 (Milligan et al. Appendix A in ODFW 2014). Both of these studies report densities of Black Rockfish, Blue Rockfish, China Rockfish, Kelp Greenling, Lingcod and Cabezon all of which were observed and reported in this study. The methods utilized for calculating fish densities and the presentation of results make it difficult to compare the work by Milligan et al. (2014), but the densities of these six species reported by Miller et al. (1997) are all lower than densities reported in this study.

Our study area was chosen to allow comparison with the Black Rockfish PIT tag population estimates (Krutzikowsky et al. 2019). The current study area entirely encompassed and slightly exceeded the spatial extent of the PIT tagging work. Black Rockfish abundance estimates from the PIT tag study area that were used in the last assessment ranged from 1.1 to 2.6 million Black Rockfish, with estimated CVs from 3.3 to 5.9% (Cope et al. 2016). The minimum and mean estimated abundance ranged from 1.4 to 2.8 million Black Rockfish in this study (Table 8), but differences viewing area that would affect density calculations could not be measured with the single camera utilized in this lander study to provide estimates of CVs. These estimates of abundance, which are based on measured distances that fish could be identified on Seal Rock reef with a stereo camera lander by Hannah and Blume (2016) in a differing visibility conditions, provide a reasonable range of values for comparison with the PIT tagging work**.** However, any similarities to the estimates of abundance in this study with those from the PIT tagging work should be viewed with caution given the fact that the detection distances from the work by Hannah and Blume (2016) utilized here came from a stereo lander configured with different cameras and lights.

Any density estimates derived from landers should consider the known natural behavior of species as well as any effects of landers on fish behavior. For example, estimates for schooling species such as Black Rockfish, Yellowtail Rockfish and the Blue/Deacon Rockfish, which may occur in the midwater and thus out of the sampling area, could be biased low. Another source of bias may be fish avoidance or attraction. While studies in Oregon waters have not noted any significant behavioral responses to landers (Hannah and Blume 2012, Easton et al. 2015, Watson and Huntington 2016) there is certainly room for more thorough investigation of this topic (e.g., Stoner et al. 2008). The density and abundance estimates in this study assume that all fish in the sampled area are detected and identified; however, this may not be the case, especially for cryptic species. There are survey techniques and models for estimating density and abundance that deal with imperfect detection, although their use in marine systems is less well developed than for terrestrial systems (see Katsanevakis et al. 2012 for a review of techniques applied in the marine environment). Distance sampling techniques and models are widely used and require knowing the distance to each animal detected from a line or point. There is considerable literature on distance sampling and software to both help design surveys and analyze results (Thomas et al. 2010). Another method for dealing with imperfect detection is the use of occupancy and presence/absence models (e.g., Coggins et al. 2014, MacKenzie et al. 2018,). These models may involve repeatedly sampling the same location multiple times to examine if a species is detected on some occasions but not others or modeling presence absence based on explanatory environmental variables when sampling a larger area. Follana-Berná et al. (2019) propose another method to account for imperfect detection of species by unbaited underwater video cameras when calculating density estimates, but its practical use may be limited to specific species and habitats. A preponderance of zeros in count data from video landers suggests that zero-inflated and/or zero-adjusted models should be explored. Geospatial modeling techniques have proven to be a powerful tool for estimating fish abundance from survey data (Rivoirard et al. 2000) and should also be investigated.

Geostatistics may provide insights into the spatial structure of the population sampled. While some of these topics can be explored with data in hand, other aspects will require more field work with appropriate experimental design.

Sampling Time

Determining optimal sampling times is an important component of a cost-benefit analysis that weighs the tradeoffs between the number of samples that can be efficiently obtained during a day, the effects of longer or shorter sampling times on resulting data, and the study objectives. The authors of early work in a variety of water depths off Oregon chose to use 4 to 5 minute sampling times (Hannah and Blume 2012). Easton et al. (2015) also used 4 to 5 minute bottom times sampling a nearshore rocky reef. Authors with a different video lander (Watson and Huntington 2016) suggested that 8 minute sampling times would better represent species diversity on Oregon nearshore rocky reefs and that longer sampling times did not substantially increase the MaxN recorded for the five most common species observed in their study.

Often there is a balance to be struck between sampling time and number of samples that can be gathered given limiting resources (e.g., funds, boat time, weather windows, etc.). In this study a 15 minute bottom time with 400 m spacing between sites was used. This allowed for sampling up to 25 stations in a 10 hour day, which included travel time in and out of port. Easton et al. (2015) made at least 54 drops on a single day using 5 minute bottom times with 175 m spacing operating in a different area off the Oregon coast from a different port.

The time the lander is on bottom is the total potential sampling time available for analysis. Samples in this study were 15 minutes, and shorter sampling times of 8 and 4 minutes suggested by other authors (Watson and Huntington 2016, Hannah and Blume 2012) resulted in 14 and 30% more drops with no fish identified and changes to the distribution of species richness values that were greater than 0 (Figure 8) such that the overall average species richness for all drops combined was reduced. For the seven species observed most frequently, detection declined by as much as 18 to 36% for 8 and 4 minute sampling, respectively (Table 9). MaxN counts for these seven species would also have been reduced in as many as 9 to 56% of the drops with these shorter sampling times. Thus, if shorter sampling times had been used both the detection of species at sites they were present and MaxN counts would have been lower at some locations sampled. The effects of these types of changes in survey results that utilize shorter sampling times may depend on how the data are utilized. For example, the work of Campbell et al. (2015) suggests that systematically underestimating species presence in survey data is problematic for stock assessments. Future studies will need to consider the objectives and tradeoffs when deciding how long to sample.

Community Analysis

The community analysis was done with a subset of the larger data set. The resultant model had 3 axes that represented linear combinations of 5 environmental variables: longitude, large boulder primary habitat, fractal complexity at 10 m and 50 m, and dissolved oxygen (Table 12). Interestingly, longitude was selected by the model as most important for this small dataset. Both the longitudinal range and the depth range for samples in this study were extremely limited, but depth was not one of the environmental variables selected by the model. Longitude may be a proxy for a combination of important oceanographic and ecological processes that help provide food as well as the overall depth of the general region of the drops, but the exact mechanisms are unclear. The coastline of the study site has a nearly north-south orientation and bottom depth generally increases with longitude, but the depths recorded at lander drops are on the top of the generally rocky habitat. Substrate type within view and complexity of the surrounding area also make ecological sense as important factors for the fish species encountered. Large boulder substrates typically have numerous nooks, cracks and crannies and provide more substantial structure on the scale of typically sized adult fish species examined in this study than does bedrock, which is often flat, or the smaller unconsolidated substrates like small boulder, cobble, gravel/pebble, sand, or mud. Most of the fish species observed in this study range well outside the small area visible in the video samples, so it is not surprising that complexity of the surrounding area also was selected as important in the model. Dissolved oxygen was also selected by the model as an important component shaping the fish community.

It will be interesting to examine datasets with larger spatiotemporal extent with this type of analysis. The geographic range of these species covers a much larger spatial extent than was examined in this study and oceanographic conditions vary considerably on a variety of different time scales, so a dataset that covered a larger spatiotemporal extent may either reinforce that the environmental gradients that were determined to be important in the current analysis are consistently important on a larger scale or that other factors become more important on those scales. Similarly a comparison of the results from this analysis with those from a similar analysis with data from either another location along the Oregon coast on a similar scale or at the same location at a different time of year may also provide insights into the similarities or differences on gradients important in shaping the fish communities in different areas or different seasons. Work on the outer portions of another nearshore rocky reef off Oregon suggests there may be both some seasonal differences in the species composition of the fish community and some similarities in habitat associations for some of the species (Easton et al. 2015), but it is unclear if such differences and similarities are widespread or localized.

Invertebrates

The video lander proved capable of capturing videos of invertebrates that were on the list. Staff reviewing video identified and counted 404 invertebrates including 299 identified to species. This is likely a minimum estimate as many invertebrate species are cryptic and likely to be hidden or missed. But the larger, more readily visible invertebrate species can easily be seen and counted. A wide variety of taxa were identified with echinoderms, which were observed at nearly half of the drop sites (Table 13), being the most widely distributed. Most invertebrates were observed at less than 10 percent of the drop locations, with only two types of sea stars observed more frequently, both of which were seen at less than 20 percent of the drop locations. The giant white plumed anemone had the highest number of individuals counted, but the vast majority of those were observed in two of the 14 drops on which this species was observed suggesting patchy distribution for this species with high densities at some locations.

Wildlife observations

Collecting wildlife observation data while conducting the video lander survey proved to be a relatively easy addition to the survey work that did not interfere with other sampling operations. This work provided an inventory of species observed during the survey. It demonstrates that at least a qualitative examination of wildlife species in the area can be accomplished during video lander survey work with minimal effort.

Wildlife species extensively utilize the nearshore area, with sightings occurring at 97.7% of the locations surveyed and a median of three species or species groups present. The diverse array of species included thirteen individual species of birds identified, two additional bird species groups and three species of marine mammals (Table 14). Common Murre were the most frequently sighted bird species occurring at 68% of the drop locations and had the highest total count; gulls as a group were the second most frequently sighted birds.

There were areas of high concentration of some species. For example, the majority of the California sea lions observed were at a station very close to a rock where the animals were hauled out. Similarly, almost half of the Common Murres observed were at a few stations near Yaquina Head where this species nests during spring and early summer months. There was also one very large mixed flock of scoters on the water's surface at one location. More work with survey design would be needed to use data collected on future surveys in any type of quantitative manner. One of the issues is that although the observation area around the boat was limited to 300 m, the boat itself drifted at very different rates during the 5 minute observation periods depending on winds and currents making the area surveyed during each sample unequal. Additional location information would need to be gathered to make informed estimates of the survey area for each sample.

Conclusions

Video landers show great promise as a non-extractive survey tool for generating fishery-independent data in rocky reef habitats. These tools are being used in a variety of configurations in multiple countries including the United States to inform fishery management. The landers used by ODFW to date are relatively inexpensive to construct, can be used in a variety of weather conditions and deployed in a wide range of depths including those deeper than can be sampled by SCUBA, and have less impact than hook and line or trawl surveys on the species under study. However, there is still debate on the efficacy of these tools and the data collected for use in stock assessments. Determining the relationship between the abundance metrics derived from video survey data and true abundance for species remains an area of active research. This study is the first attempt to quantify fish density and abundance on a specific reef area off Oregon from video lander data and it has spurred a reexamination of video lander data in hand. Staff at MRP are currently making a coordinated effort to examine data from approximately 3,000 lander drops conducted at a wide variety of depths and locations all along the Oregon coast since 2009. Examining fish densities from both design-based and model based perspectives is one of the primary objectives of this work. Investigating ways to improve the efficiency and use of video landers to survey rocky habitat and the analysis of data collected will undoubtedly continue and ODFW/MRP is well positioned to be an important part of that work.

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Tables

Table 1. Bottom Substrate Classifications.

Both a primary and secondary bottom substrate was assigned to each lander drop based on the percentage of the visible bottom that it covered. The substrate descriptions and how they relate to the Coastal and Marine Ecological Classification Standard (CMECS, Federal Geographic Data Committee 2012) are given in this table. Designation as primary substrate indicates the substrate covered more than 50% of the bottom visible. Designation as secondary substrate indicates the substrate covered more than 20% of the bottom visible.

Substrate classes	**CMECS equivalent**	**Desciption**
Bedrock	Bedrock	Substrate with mostly continuous formations of bedrock
Bedrock Outcrop	Megaclast	Individual rocks or outcrops of bedrock with sizes greater than or equal to 4.0 meters in any dimension
Large Boulder	Boulder	Median Gravel size of 1 m to < 4.0 m, including angular and rounded blocks
Small boulder	Boulder	Median Gravel size of 25 cm to < 1 m
Cobble	Cobble	Median Gravel size of 64 mm to < 25cm
Gravel Pebble	Pebble-Granule	Median Gravel size of 2 mm to < 64 mm
Sand	Sand	Particles 0.0625 mm to < 2 mm in diameter
Mud	Mud	Particles less than 0.0625 mm in diameter
Shell hash	Shell substrate	Primarily composed of shells or shell particles; shell particles have a median size from 2 mm to 64 mm (though larger is acceptable); if particles are small than 2mm, score as sand
Worm substrate	Worm substrate	Primarily composed of the cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna

Table 2. Explanatory environmental variables examined in canonical correspondence analysis.

The explanatory environmental variables listed below were examined as potential environmental gradients affecting the observed fish community of 15 species in a canonical correspondence analysis model for 51 lander drops conducted in May 2014.

Explanatory Variables
Date
Time of Day
Depth
Latitude
Longitude
Temperature near the bottom (~ 1 m above)
Salinity near the bottom (~ 1 m above)
Dissolved Oxygen near the bottom
Rugosity (4, 8, 10, 20, 30, 40 & 50 m extents)
Complexity (10, 30 & 50 m extents)
Mean Slope (4 & 30 m extents)
Maximum Slope (4 & 30 m extents)
Visibility
View
Canopy Cover
Midstory Cover
Understoy Cover
Seagrass Cover
Turf Crust Cover
Primary Substrate
Secondary Substrate

Table 3. Sampling depths and video analysis.

Distribution by depth bin of the 177 total video lander drops and of the 145 drops for which video samples were analyzed. The most frequent reason for not analyzing video was an issue with the camera view such as the lander being tilted or the view being mostly blocked by substrate. Video problems were the second most frequent reason for not analyzing video and included focusing issues, no card put in the camera to record video, or the video file being lost.

Depth (m)	Total number of drops (percentage)	Number of drops with video analyzed (percentage)	Reasons for no video analysis
<10	18 (10.2%)	12 (8.3%)	View - 1; Visibility - 1; Video problem - 4
10 to <20	83 (46.9%)	67 (46.2%)	View - 8; Visibility - 3; Video problem - 5
20 to <30	56 (31.6%)	47 (32.4%)	View - 3; Visibility - 0; Video problem - 6
30 to <40	18 (10.1%)	17 (11.7%)	View - 1; Visibility - 0; Video problem - 0
40 to <50	2 (1.1%)	2 (1.4%)	N/A

Table 4. Substrate information

Twenty-nine different combination of primary and secondary habitat substrate types were observed in the 145 video lander drops analyzed. The number of times each combination was observed with totals for each primary habitat substrate is provided. Note that only 1 sample was observed for Cobble, Gravel Pebble, and Hash primary substrates.

Primary Habitat Substrate	Secondary Habitat Substrate	#
Bedrock	Bedrock	56
Bedrock	Hash	2
Bedrock	Large Boulder	7
Bedrock	Mud	1
Bedrock	Sand	11
Bedrock	Small Boulder	5
Bedrock (total)		**82**
Large Boulder	Bedrock	3
Large Boulder	Cobble	1
Large Boulder	Hash	1
Large Boulder	Large Boulder	7
Large Boulder	Sand	3
Large Boulder	Small Boulder	5
Large Boulder (total)		**20**
Small Boulder	Bedrock	1
Small Boulder	Cobble	5
Small Boulder	Hash	2
Small Boulder	Large Boulder	1
Small Boulder	Small Boulder	3
Small Boulder (total)		**12**
Cobble	Cobble	**1**
Gravel Pebble	Hash	**1**
Hash	Large Boulder	**1**
Sand	Bedrock	2
Sand	Bedrock Outcrop	1
Sand	Cobble	1
Sand	Hash	4
Sand	Large Boulder	4
Sand	Sand	13
Sand	Small Boulder	1
Sand (total)		**26**
Mud	Bedrock	1
Mud	Small Boulder	1
Mud (total)		**2**

Table 5. Summary of biogenic habitat observed on lander drops.

All biogenic habitat variables were scored on a 0 to 5 scale based on percent coverage with 0 = none; 1 = 1-5%; 2 = 6-25%; 3 = 26-50%; 4 = 51-75%; 5 = 76-100%. Turf/Crust was the most extensive biogenic habitat observed covering 76-100% of the substrate on 41% of the drops and 51-75% of the substrate on an additional 20% of the drops.

SCORE	CANOPY # DROPS (%)	MIDSTORY # DROPS (%)	UNDERSTORY # DROPS (%)	TURF/CRUST # DROPS (%)	SEAGRASS # DROPS (%)
0	145 (100%)	131 (90%)	52 (48%)	28 (19%)	145 (100%)
1	0	4 (3%)	42 (29%)	3 (2%)	0
2	0	6 (4%)	34 (23%)	11 (8%)	0
3	0	1(1%)	10 (7%)	15 (10%)	0
4	0	0	6 (4%)	29 (20%)	0
5	0	0	1 (1%)	59 (41%)	0

Table 6. Fish species observed during 145 video lander drops.

Table includes information on the frequency that target species were seen in video lander drops and the maximum number (MaxN) seen in a single video frame during the drops on which the species was observed. Species are ordered from most to least frequently observed with juvenile fish broken out separately at the bottom of the table. The minimum, maximum, mean and standard deviation of MaxN values provided only include drops in which the species was observed.

Common Name	# of drops observed	% of drops observed	Sum of MaxN	Min. of MaxN	Max. of MaxN	Mean of MaxN	S.D. of MaxN
Kelp Greenling	77	53.1%	123	1	12	1.6	1.7
Black Rockfish	70	48.3%	671	1	92	9.6	13.7
Lingcod	58	40.0%	78	1	4	1.3	0.6
Blue/Deacon Rockfish	48	33.1%	246	1	73	5.2	10.6
Pile Perch	31	21.4%	84	1	14	2.7	2.8
Canary Rockfish	25	17.2%	85	1	16	3.4	3.6
UNID Rockfish	23	15.9%	117	1	26	5.1	6.9
UNID Roundfish	17	11.7%	71	1	30	4.2	7.5
Striped Surf Perch	14	9.7%	49	1	15	3.5	3.7
UNID Flatfish	10	6.9%	10	1	1	1.0	0.0
Yellowtail Rockfish	8	5.5%	10	1	2	1.3	0.5
UNID Sculpin	7	4.8%	11	1	3	1.6	0.8
Copper Rockfish	7	4.8%	7	1	1	1.0	0.0
Cabezon	6	4.1%	6	1	1	1.0	0.0
Quillback Rockfish	5	3.4%	5	1	1	1.0	0.0
UNID Greenling	4	2.8%	4	1	1	1.0	0.0
China Rockfish	2	1.4%	2	1	1	1.0	0.0
Tiger Rockfish	1	0.7%	1	1	1	1.0	--
Wolf Eel	1	0.7%	1	1	1	1.0	--
Yelloweye Rockfish	1	0.7%	1	1	1	1.0	--
Shiner Perch	1	0.7%	1	1	1	1.0	--
UNID Juvenile Rockfish	36	24.8%	184	1	32	5.1	6.3
UNID Juvenile Roundfish	2	1.4%	2	1	1	1.0	0.0

Table 7. Mean MaxN/drop with Standard Error for fish identified to species.

The mean MaxN (# of fish/drop) with standard error and coefficient of variation (CV) for species observed during a video lander survey targeting rocky reef areas in Oregon nearshore waters from Cape Foulweather to Alsea Bay (n = 145 drops). Species are presented in order of decreasing relative abundance.

Species	**Mean MaxN**	**Standard Error**	**CV (%)**
Black Rockfish	4.63	0.884	43.4
Blue/Deacon Rockfish	2.12	0.564	31.2
Kelp Greenling	0.848	0.124	57.0
Canary Rockfish	0.586	0.162	30.1
Pile Perch	0.579	0.141	34.0
Lingcod	0.538	0.064	57.0
Striped Surf Perch	0.338	0.127	22.2
Yellowtail Rockfish	0.0690	0.025	22.7
Copper Rockfish	0.0483	0.018	22.4
Cabezon	0.0414	0.016	20.7
Quillback Rockfish	0.0345	0.015	18.8
China Rockfish	0.0138	0.010	22.7
Tiger Rockfish	6.90×10^{-3}	0.010	8.3
Wolf Eel	6.90×10^{-3}	0.010	8.3
Yelloweye Rockfish	6.90×10^{-3}	0.010	8.3
Shiner Perch	$6.90 \times 10^{-}$	0.010	8.3

Table 8. Density and abundance estimates for identified fish species.

Density estimates for each species were calculated based on the MaxN/estimated view area for all 145 drops. Abundance estimates are scaled up from density estimates for the sampled area to the entire 31.19 km^2 rocky reef study area. The 16 species are arranged from highest to lowest estimated density and abundance. The range of density and abundance estimates provided are based on three estimates of the viewing area 2.08 m^2, 3.42 m^2 and 9.87m^2, calculated from the portion of a circle within camera view and three estimates of fish detection distances reported by Hannah and Blume (2016) for stereo lander work on an Oregon nearshore rocky reef in various visibility conditions. These viewing areas translate to the maximum, mean, and minimum density and abundance estimates, respectively, reported in this table. The range of values are reported rather than a mean value and the standard error, standard deviation or CV because the variability in visibility and view that would affect density calculations could not be measured with the single camera utilized in this study.

Common Name	maximum density estimate #/100 m^2	mean density estimate #/100 m^2	minimum density estimate #/100 m^2	maximum abundance estimate	mean abundance estimate	minimum abundance estimate
Black Rockfish	222.40	93.61	46.87	6,714,237	2,825,955	1,414,959
Blue/Deacon Rockfish	81.54	34.32	17.18	2,461,533	1,036,043	518,748
Kelp Greenling	40.77	17.16	8.59	1,230,777	518,022	259,374
Canary Rockfish	28.17	11.86	5.94	850,537	357.,982	179,242
Pile Perch	27.84	11.72	5.87	840,530	353,771	177,133
Lingcod	25.85	10.88	5.45	780,492	328,501	164,481
Striped Surf Perch	16.24	6.84	3.42	490,309	206,366	103,328
Yellowtail Rockfish	3.31	1.40	0.70	100,063	42,116	21,087
Copper Rockfish	2.32	0.98	0.49	70,044	29,481	14,761
Cabezon	1.99	0.84	0.42	60,038	25,269	12,652
Quillback Rockfish	1.66	0.70	0.35	50,032	21,058	10,544
China Rockfish	0.66	0.28	0.14	20,013	8,423	4,217
Tiger Rockfish	0.33	0.14	0.07	10,006	4,212	2,109
Wolf Eel	0.33	0.14	0.07	10,006	4,212	2,109
Yelloweye Rockfish	0.33	0.14	0.07	10,006	4,212	2,109
Shiner Perch	0.33	0.14	0.07	10,006	4,212	2,109

Table 9. Sampling times and fish species.

Fish identified to species, number of drops observed during 15 minute drops in this study, mean time of first arrival, mean time of MaxN and the number and percentages of drops where an identified fish species time of first arrival or MaxN time was after 4 and 8 minutes are provided here. Fish observed on only one drop have the time of first arrival and time of MaxN for that observation in columns labeled as means for those numbers. The numbers in the >4 minute and >8 minute columns represent how many times (what percentage) that species would either not have been observed on a drop or the MaxN would have been less than with the 15 minute bottom times utilized in this study.

Common Name	**# of drops observed**	**Mean arrival time min.**	**# arrivals > 4 min.**	**# arrivals > 8 min.**	**Mean time of MaxN min.**	**# MaxN >4 min.**	**# MaxN >8 min.**
Kelp Greenling	77	1.47	25 (32%)	14 (18%)	4.65	36 (47%)	20 (26%)
Black Rockfish	70	0.89	4 (6%)	1 (1%)	3.17	22 (31%)	6 (9%)
Lingcod	58	2.83	15 (26%)	8 (14%)	3.84	19 (33%)	11 (19%)
Blue/Deacon Rockfish	48	2.38	10 (21%)	4 (8%)	4.58	20 (42%)	12 (25%)
Pile Perch	31	2.42	8 (21%)	2 (6%)	3.59	11 (35%)	6 (19%)
Canary Rockfish	25	1.92	3 (12%)	0 (0%)	5.11	14 (56%)	7 (28%)
Striped Surf Perch	14	3.24	5 (36%)	2 (14%)	3.96	6 (43%)	2 (14%)
Yellowtail Rockfish	8	3.14	2 (25%)	1 (13%)	3.27	2 (25%)	1 (13%)
Copper Rockfish	7	3.94	3 (43%)	1 (14%)	3.94	3 (43%)	1 (14%)
Cabezon	6	5.31	3 (50%)	2 (33%)	5.31	3 (50%)	2 (33%)
Quillback Rockfish	5	4.39	3 (60%)	1 (20%)	4.39	3 (60%)	1 (20%)
China Rockfish	2	2.17	0 (0%)	0 (0%)	2.17	0 (0%)	0 (0%)
Tiger Rockfish	1	2.80	0 (0%)	0 (0%)	2.80	0 (0%)	0 (0%)
Wolf Eel	1	11.63	1 (100%)	1 (100%)	11.63	1 (100%)	1 (100%)
Yelloweye Rockfish	1	4.72	1 (100%)	0 (0%)	4.72	1 (100%)	0 (0%)
Shiner Perch	1	7.17	1 (100%)	0 (0%)	7.17	1 (100%)	1 (100%)

Table 10. Fish species observed in the 51 drops utilized in the CCA.

The total number and range of MaxN values for fish species observed in the 51 drops utilized in the canonical correspondence analysis.

Fish Species	**Total Observed in Analysis**	**Range of MaxN values**
Black Rockfish (*Sebastes melanops*)	391	0 - 92
Blue/Deacon Rockfish (*S. mystinus & S. diaconus*)	241	0 - 73
Kelp Greenling (*Hexagrammos decagrammus*)	70	0 - 12
Canary Rockfish (*S. pinniger*)	64	0 - 16
Lingcod (*Ophiodon elongatus*)	41	0 - 3
Pile Surf Perch (*Rhacochilus vacca*)	37	0 - 14
Striped Surf Perch (*Embiotoca lateralis*)	27	0 - 15
Quillback Rockfish (*S. maliger*)	5	0 - 1
Yellowtail Rockfish (*S. flavidus*)	5	0 - 2
Cabezon (*Scorpaenichthys marmoratus*)	5	0 - 1
China Rockfish (*S. nebulosus*)	2	0 - 1
Copper Rockfish (*S. caurinus*)	1	0 - 1
Tiger Rockfish (*S. nigrocintus*)	1	0 - 1
Yelloweye Rockfish (*S. ruberrimus*)	1	0 - 1
Wolf Eel (*Anarrhichthys ocellatus*)	1	0 - 1

Table 11. Primary and secondary substrates encountered on the drops utilized in the CCA.

The number of times each primary and secondary substrate occurred in the 51 drops utilized in the canonical correspondence analysis examining the effects of environmental variables on the observed fish community.

Substrate Classification	**Description**	**Observed as Primary**	**Observed as Secondary**
Bedrock	Substrates with mostly continuous formation of bedrock	29	18
Large Boulder	Median Gravel size 1 m to < 4.0 m, including angular and rounded blocks	13	8
Small Boulder	Median Gravel size 25cm to < 1 m	8	8
Cobble	Median Gravel size 64mm to < 25 cm	0	6
Sand	Particle size 0.0625mm to < 2 mm in diameter	1	5
Mud	Particles size less than 0.0625 mm	0	2
Shell substrate	Shells or shell particles with median size > 2 mm	0	4

Table 12. Summary of the selected canonical correspondence analysis (CCA) model.

The first 3 axes of the CCA model were significant at $\alpha = 0.05$ with 5 explanatory environmental gradient variables selected in the model. The relative importance of the selected gradient variables on each axis is indicated by the absolute value of their model coefficients. The gradient scores indicate the vector direction of increase of the gradient on each of the axes. Species scores indicate both points of environmental optima for species and abundance centers for the species on the 3 CCA axes. As distance increases from the species optima, the abundance and/or probability of occurrence for the species decreases. P-values for each axis and selected environmental gradients are provided.

Summary of Final Selected Model

Final Model* **	$\log_{10}$(Fish Spp. MaxN) = $\log_{10}$(Longitude) + Large Boulder Primary Habitat + $\log_{10}$(Complexity (50m)) + $\log_{10}$(Complexity (10m)) + $\log_{10}$(Dissolved Oxygen)			
	Model Inertia			
Total Inertia	Constrained	Unconstrained	Inertia Explained	
2.6873	0.4612	2.261	17.2%	
Constrained Inertia Explained	CCA 1***	CCA 2***	CCA 3*	Total for 3 axes
	38.9%	22.3%	20.3%	81.5%
	Model Coefficients			**Variance Inflation Factor**
Longitude* **	-0.7329	0.4802	-0.0296	1.1077
Large Boulder 1° Habitat **	0.3298	0.6910	-0.0681	1.1960
Complexity: 50m extent*	-0.0759	0.4405	-0.9101	1.3896
Complexity: 10m extent*	0.5576	0.1075	1.1217	1.4165
Dissolved Oxygen*	0.1382	-0.6621	-0.3115	1.1783
	Constraining Environmental Gradient Scores			
Longitude	-0.8267	0.3207	0.1845	
Primary Habitat Type	0.5148	0.4430	-0.2784	
Complexity: 50m extent	0.2409	0.4865	-0.3741	
Complexity: 10m extent	0.2773	0.3803	0.5722	
Dissolved Oxygen	0.1397	-0.3973	-0.3690	
	Species Scores			
Black Rockfish	0.0651	-0.0846	0.3324	
Blue Rockfish	-0.0128	0.2832	0.0295	
Kelp Greenling	-0.1859	-0.4614	-0.2458	
Canary Rockfish	-0.7181	0.0362	-0.2262	
Lingcod	-0.0695	-0.0197	-0.1025	
Pile Surf Perch	0.4615	0.2423	-0.7014	
Striped Surf Perch	1.6973	-0.4466	-0.1155	
Quillback Rockfish	-0.6457	0.3552	0.0214	
Yellowtail Rockfish	0.8452	0.9678	-0.2320	
Cabezon	0.2653	-0.2068	0.5257	
China Rockfish	0.2452	1.0247	-0.4112	
Copper Rockfish	-0.4565	1.1794	0.8301	
Tiger Rockfish	0.0318	0.7378	1.3193	
Yelloweye Rockfish	0.0318	0.7378	1.3193	
Wolf Eel	-0.5446	-2.2281	0.3994	

***** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$**

Table 13. Invertebrates

Invertebrates detected on 145 video lander drops. The list is sorted in order of frequency of detection, first by phylum, then by identified species, then by taxa not identified by species within the phylum. The phylum grouping lists the number of drops on which any members of the phylum were identified; multiple members of any phyla may have been identified on the same drop. Note that only specific macro invertebrates identified and counted by the Marine Reserves Program during SCUBA sampling were identified and counted during video review for this study (see ODFW 2014 for complete list).

Common Name	**Scientific Name**	**# of drops (%)**	**Total number**
	Echinodermata	72 (49.7%)	157
Pink Sea Star	*Pisaster brevispinus*	25 (17.2%)	54
Blood Star	*Henricia spp.*	21 (14.5%)	31
Ochre Star	*Pisaster ochraceus*	12 (8.3%)	17
Leather Star	*Dermasterias imbricata*	7 (4.8%)	8
Six-armed Star	*Leptasterias aequalis*	5 (3.4%)	7
Red Sea Urchin	*Mesoocentrotus franciscanus*	5 (3.4%)	5
Stimpson's Sun Star	*Solaster stimpsoni*	2 (1.4%)	2
Rainbow Star	*Orthasterias koehleri*	1 (0.7%)	2
False Ochre Star	*Evastereas troschellii*	1 (0.7%)	4
Bat Star	*Patiria miniata*	1 (0.7%)	1
Unidentified Sea Star		17 (11.7%)	26
	Cnidaria	20 (13.8%)	172
Giant White Plumed Anemone	*Metridium giganteum*	14 (9.7%)	147
Giant Green Anemone	*Anthopleura xanthogrammica*	4 (2.8%)	7
White-spotted Rose Anemone	*Urticina lofotensis*	1 (0.7%)	1
Fish-eating Anemone	*Urticina piscivora*	1 (0.7%)	1
Unidentified Anemone		1 (0.7%)	26
	Arthropoda	13 (9.0%)	62
Giant Acorn Barnacle	*Balanus nubilus*	2 (1.4%)	7
Dungeness Crab	*Metacarcinus magister*	2 (1.4%)	6
Unidentified Crab		9 (6.2%)	49
	Mollusca	8 (5.5%)	12
Rock Scallop	*Crassadoma gigantea*	2 (1.4%)	4
Gumboot Chiton	*Cryptochiton stelleri*	2 (1.4%)	2
Rough Keyhole Limpet	*Diodora aspera*	1 (0.7%)	1
Giant Pacific Octopus	*Enteroctopus dofleini*	1 (0.7%)	1
Unidentified Octopus		2 (1.4%)	4
	Porifera	1 (0.7%)	1
Tennis-ball sponge	*Craniella spp.*	1 (0.7%)	1

Table 14. Wildlife observations.

Wildlife species or species group observed within 300 meters of the vessel during 5 minute visual survey undertaken while the video lander was sampling underwater. Birds in flight as well as those on the water were recorded. Similarly, marine mammals hauled out on rocks as well as those sighted in the water were recorded. Wildlife species were sighted at 172 of the 176 (97.7%) stations where observations were collected. Thirteen bird species, seven bird species groups, and three marine mammal species were observed. The bird species groups recorded included gulls, cormorants, alcids, phalaropes, scoters and sandpipers that were not identified to species.

Common Name	**Scientific Name**	**Number of Sites Present (%)**	**Total Number Observed**
Birds Identified to Species			
Common Murre	*Uria aalge*	120 (68.2%)	2,250
Pacific Loon	*Gavia pacifica*	60 (34.1%)	307
Pelagic Cormorant	*Phalacrocorax pelagicus*	46 (30.7%)	67
Brandt's Cormorant	*Phalacrocorax penicillatus*	14 (7.6%)	18
Surf Scoter	*Melanitta perspicillata*	12 (6.8%)	265
Pigeon Guillemot	*Ceppus columba*	7 (3.8%)	11
Cassin's Auklet	*Ptychoramphus aleuticus*	5 (2.8%)	14
Brown Pelican	*Pelecanus occidentalis*	5 (2.8%)	10
White-winged Scoter	*Melanitta fusca*	4 (2.3%)	9
Double-crested Cormorant	*Phalacrocorax auritus*	4 (2.3%)	4
Common Loon	*Gavia immer*	4 (2.3%)	4
Western Grebe	*Aechmophurus occidentalis*	1 (0.6%)	2
Tufted Puffin	*Fratercula cirrhata*	1 (0.6%)	1
Birds Identified to Species Group			
Gulls	*Larinae*	102 (58.0%)	246
Cormorants	*Phalacrocorax*	54 (30.7%)	159
Scoters	*Melanitta*	15 (8.5%)	544
Alcids	*Alcidae*	5 (2.8%)	7
Sandpipers	*Scolopacidae*	4 (2.3%)	18
Phalaropes	*Phalaropus*	1 (0.6%)	3
Loons	*Gavia*	1 (0.6%)	1
Marine Mammals			
California Sea Lion	*Zalophus californianus*	3 (1.7%)	19
Gray Whale	*Eschrichtius robustus*	2 (1.1%)	2
Harbor Porpoise	*Phocoena phocoena*	1 (0.6%)	3

Figures

Figure 1. Video lander. The aluminum lander frame that protects the camera housing, battery housing, and lights is mounted on a weighted sacrificial base. The video lander was dropped over the side of the vessel and allowed to sink freely to the bottom with a line and floating buoy attached for retrieval. The lander was retrieved with a hydraulic winch then lifted over the side of the vessel by attaching a line from an electric winch.

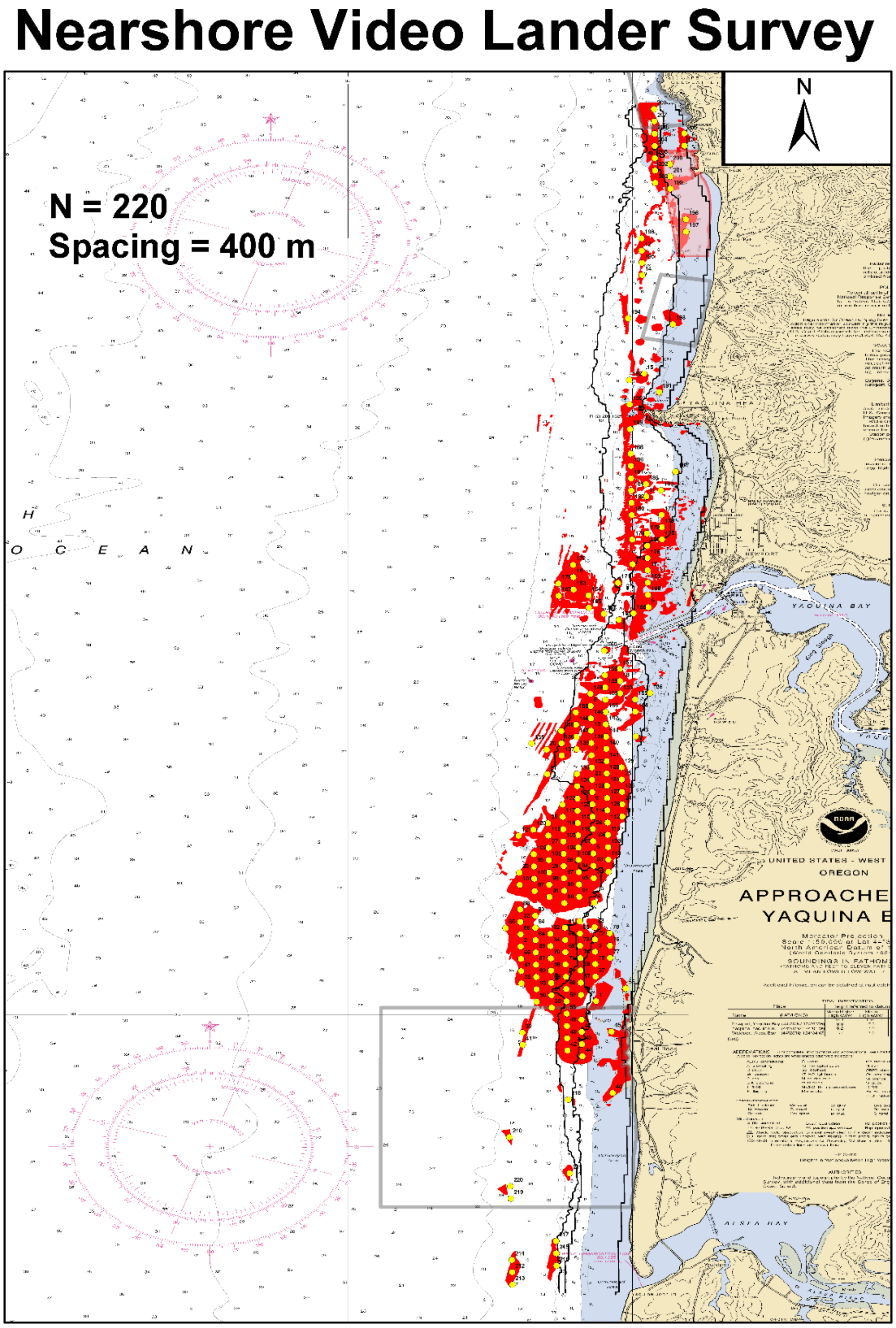

Figure 2. Entire region of the study with the rocky reef study area shown in red and target drop sites represented by yellow dots. The total rocky reef planar area depicted in red is 30.19 km^2.

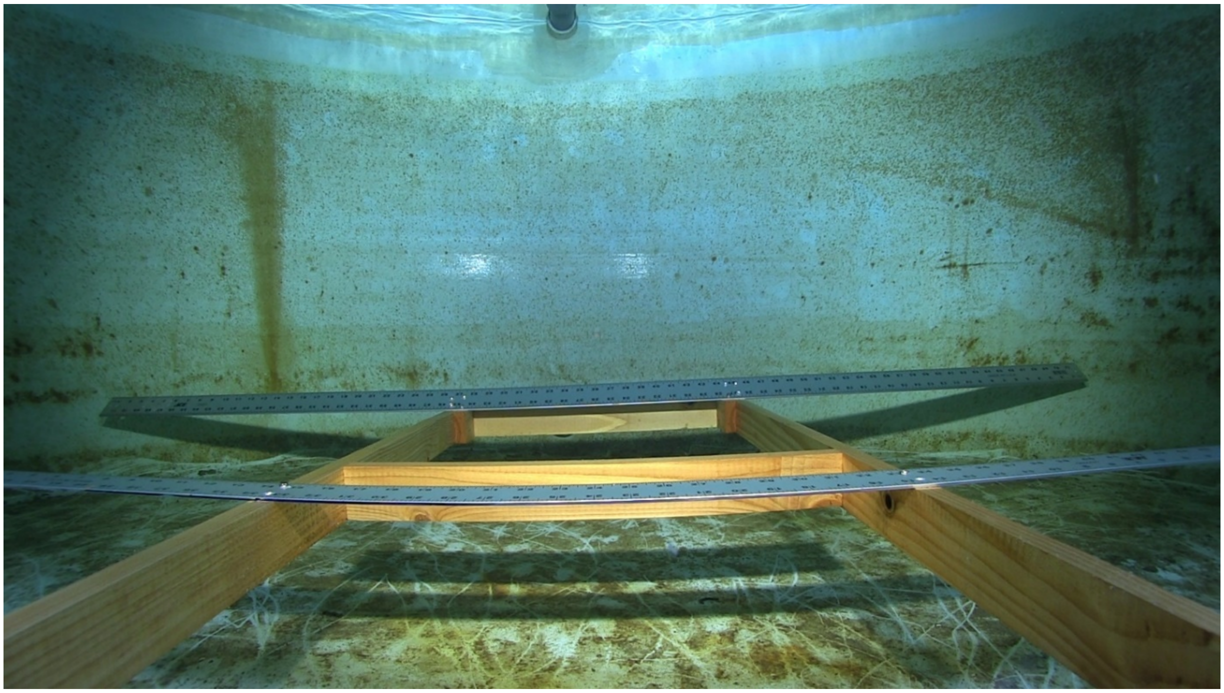

Figure 3. Field of view was determined from measurements taken from the ruler closest to the camera in this still frame captured from the video. The outer edge of the ruler closest to the camera where measurements were taken was placed 45.72 cm from the camera lens. The viewing angle of the wide angle lens worked out to be 96.7^{o}. The more distant ruler outer edge was placed 105.41 cm from the camera lens.

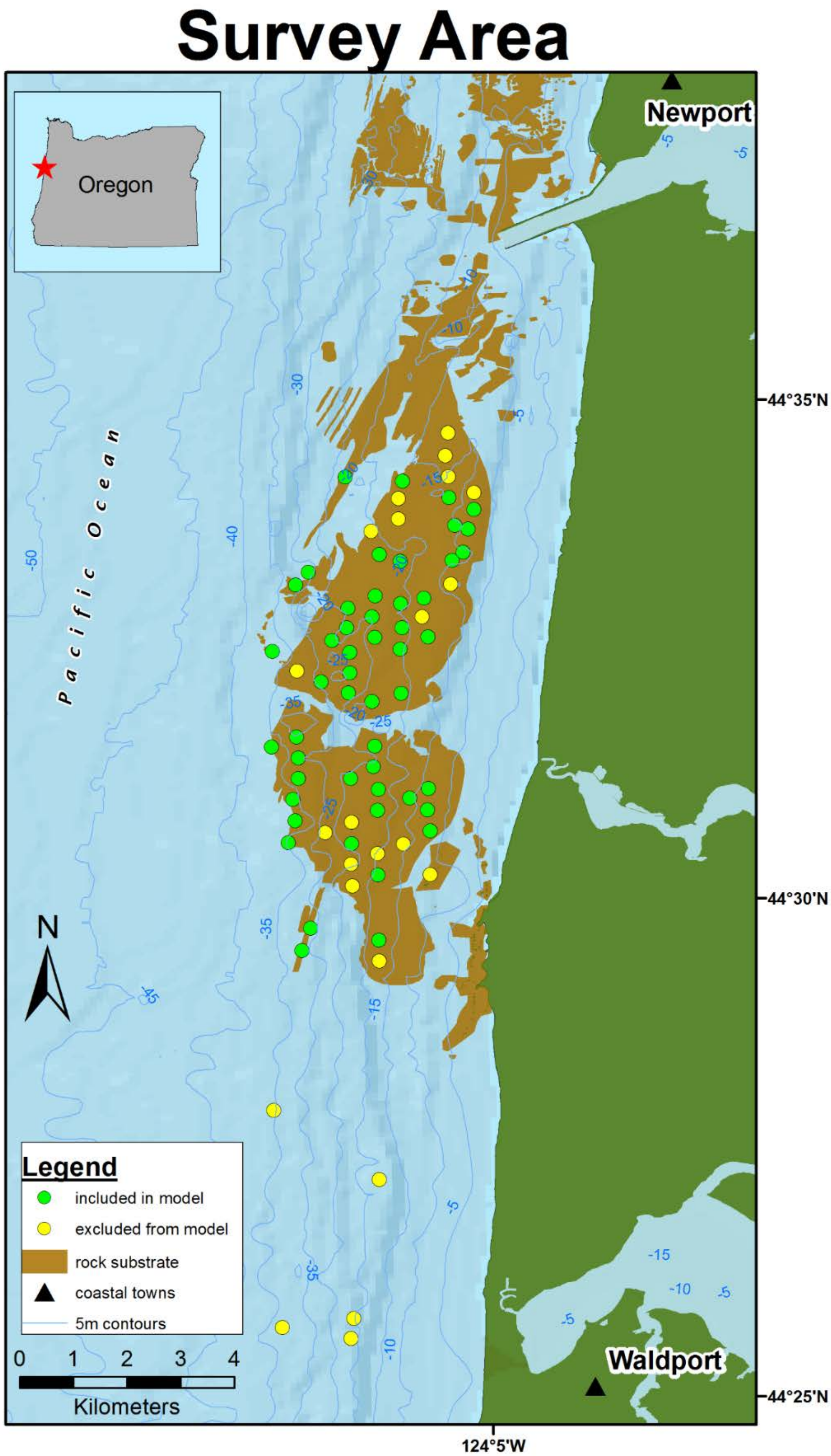

Figure 4. Map depicting the video lander drops examined in the direct environmental gradient analysis portion of the study and those drops included in the canonical correspondence final model.

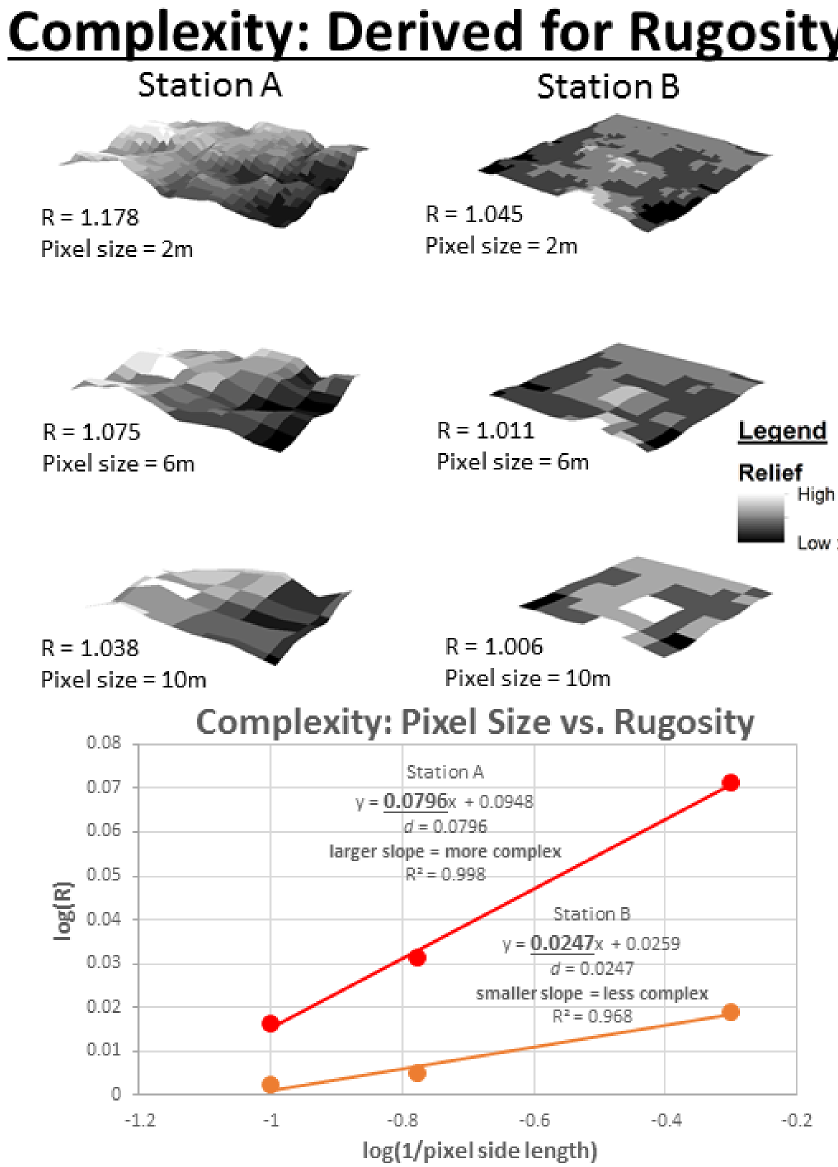

Figure 5. Relationship between rugosity and complexity. Rugosity was defined as the surface area divided by the planar area. Complexity (d; the fractional dimension) was derived from rugosity measured at 2, 4, 6, and 10 meter pixel resolutions from fixed extents surrounding the drop. The slope of the fitted regression line plotted for log-transformed rugosity vs. 1/pixel resolution is an estimate of complexity for the spatial extent around each drop location. Complexity represents a quantified characterization of the geomorphic structure of the bathymetric surface surrounding the drop. Complexity metrics eliminate the scale-dependence associated with rugosity estimates.

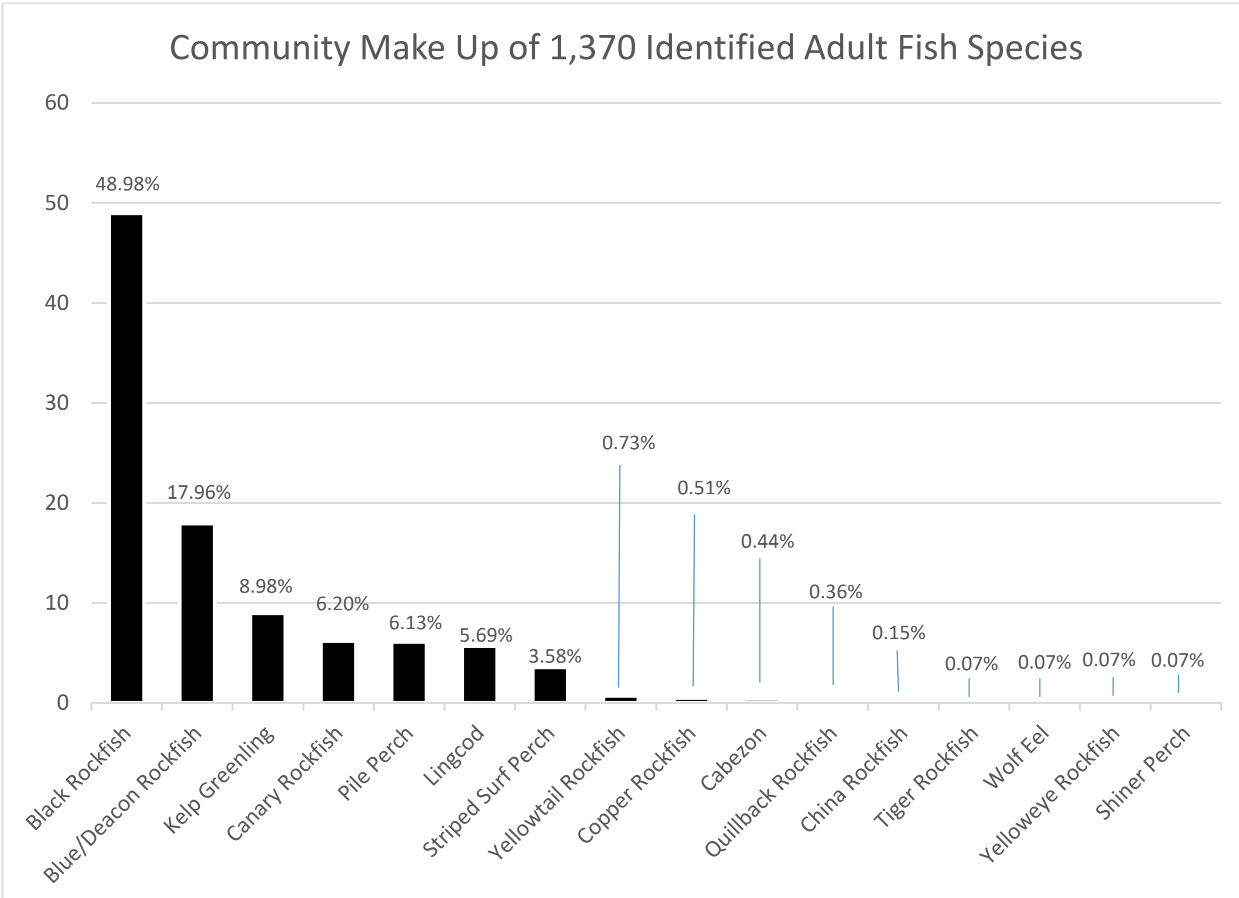

Figure 6. Community make up of 1,370 adult fish identified to species. This includes all adult fish on all 145 lander drops on a nearshore rocky reef complex off the central Oregon coast. Note that species are listed on the X axis in decreasing order of their total count for all lander drops with its percentage of all adult fish identified given above the bar on the graph that represents the count.

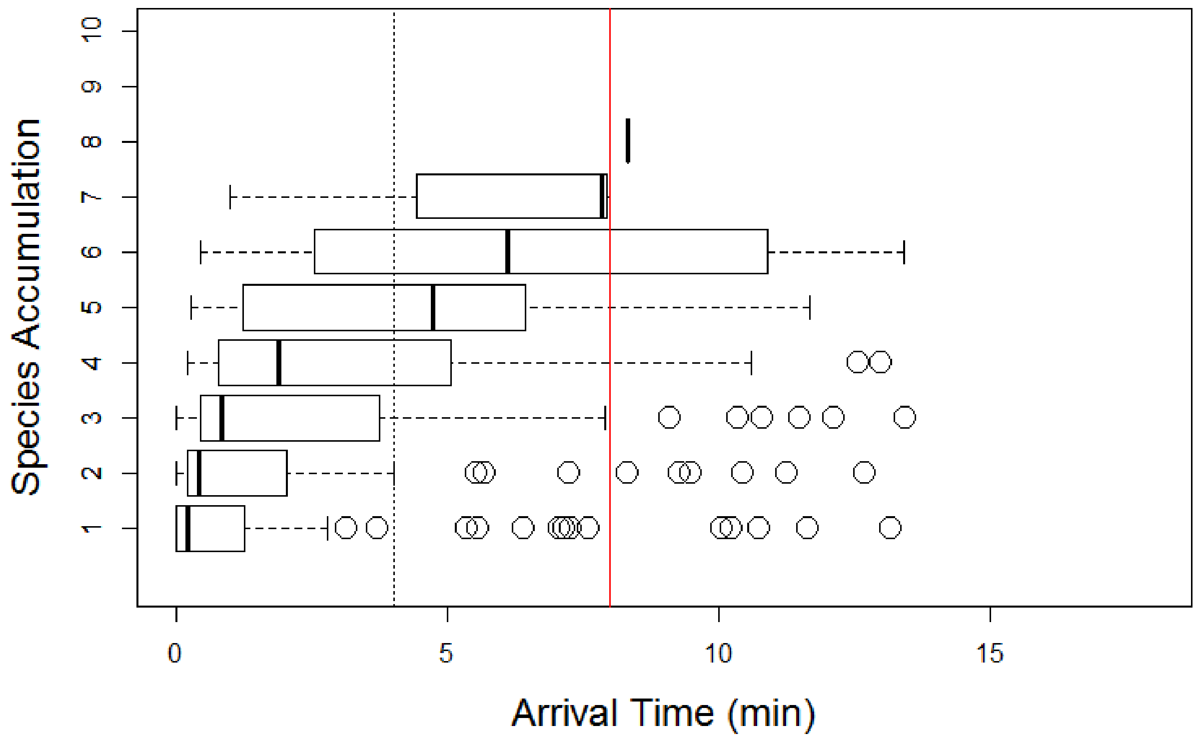

Figure 7. Species accumulation over drop duration. Overall there were 355 observations of fish on 108 drops in this study. Eight different target species was the greatest number seen on any drop. The number of species observed vs. the distribution of arrival time of the last identified species observed in the video is plotted in a box-and-whisker plot format showing median, quartiles, 9th and 91st percentiles and outliers. Bottom times for samples averaged 14.97 ± 0.54 sd (range 13.4 to 17.4) minutes. The vertical dashed line at 4 minutes and red line at 8 minutes represent suggested video lander sampling times off Oregon in other studies.

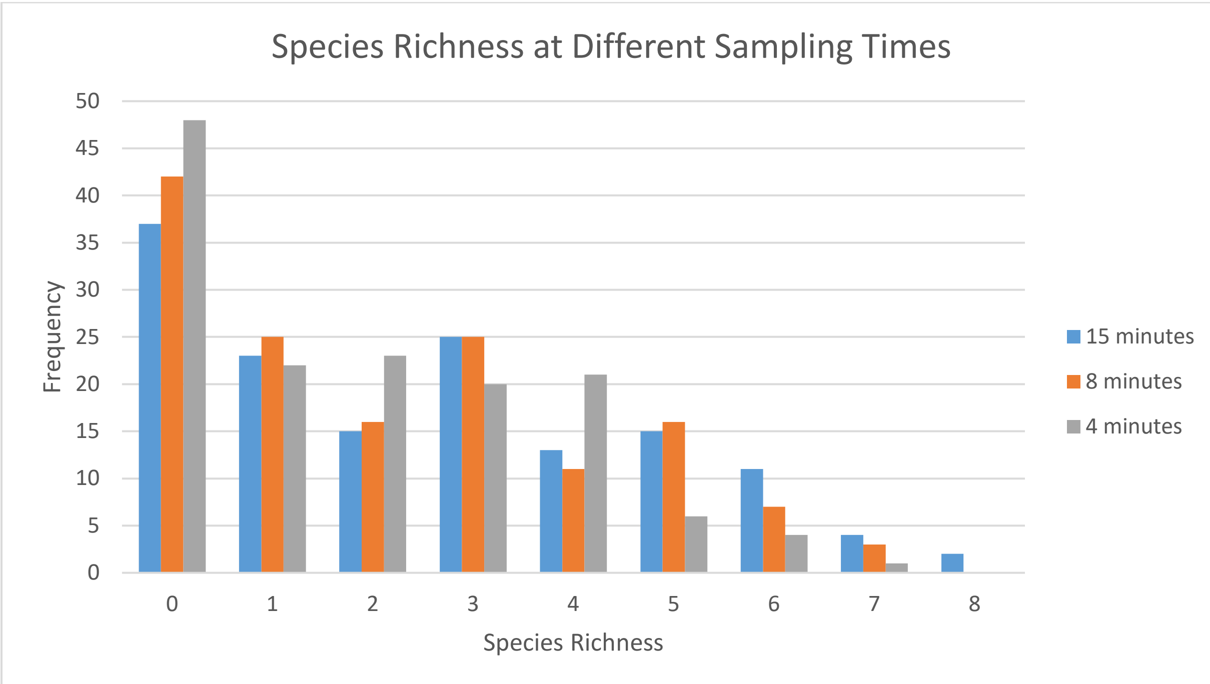

Figure 8. Frequency of species richness values for lander drops that fish species were identified on all 145 video lander drops. Fish were identified to species in 108 (74.4%) of the drops with sampling times for this study, nominally 15 minutes. Comparisons are provided with sampling times truncated at 8 minutes and 4 minutes, times recommended by Watson and Huntington (2016), and utilized by Hannah and Blume (2012), respectively. The overall number of lander drops with an identified fish species observed decreases from 108 to 103 and 97 with the reduced sampling times so the percentage of drops with identified fish decreases from 74.4% to 71.0% and 66.9%, respectively. The total number of observations of all identified species combined decreases from 355 to 318 and 271 with 8 and 4 minute sampling times, reductions of 10.4% and 23.7%, respectively. The shorter sampling times result in increased number of drops with no fish identified and reduced numbers of drops with the highest species richness values.

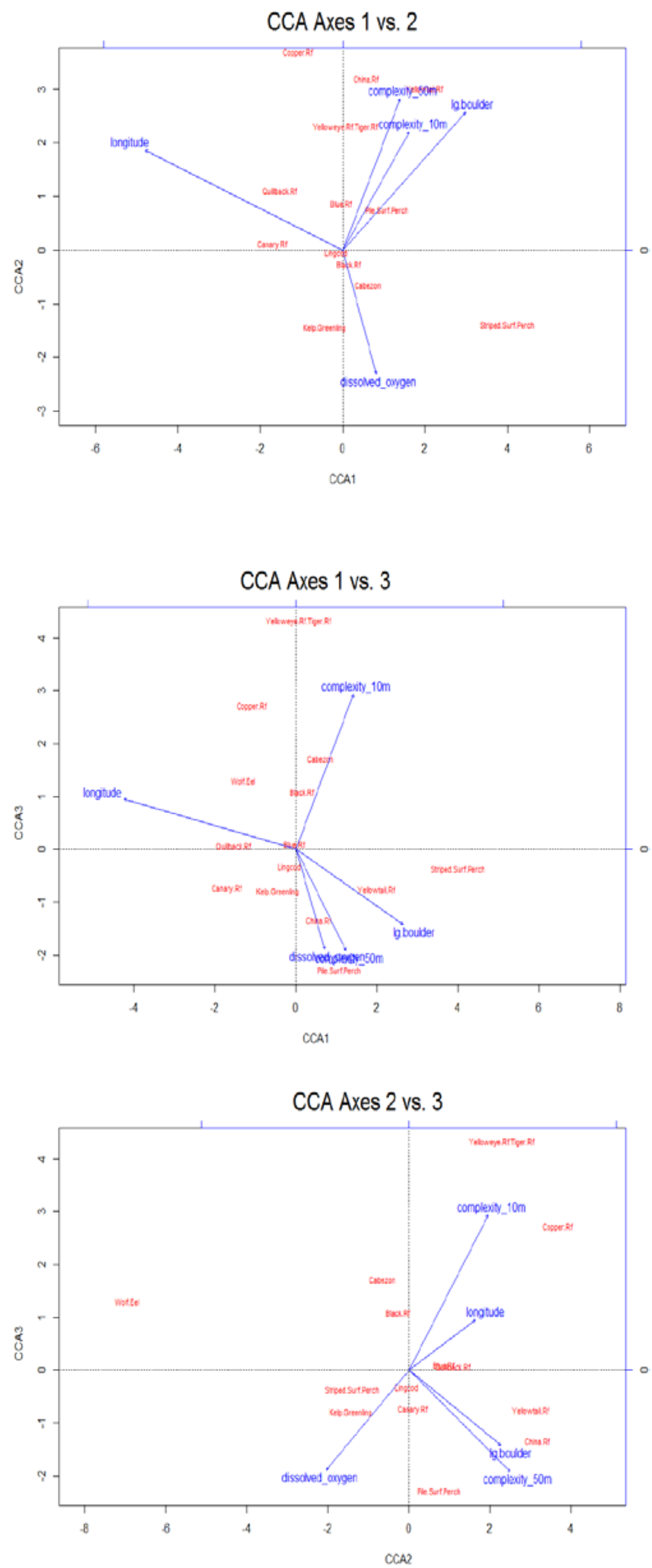

Figure 9. Results of Canonical Correspondence Analysis (CCA) depicting the 15 species optima locations and the vector direction of increase for the five selected environmental explanatory variables on CCA axes 1 and 2 (top), 1 and 3 (middle), and 2 and 3 (bottom).

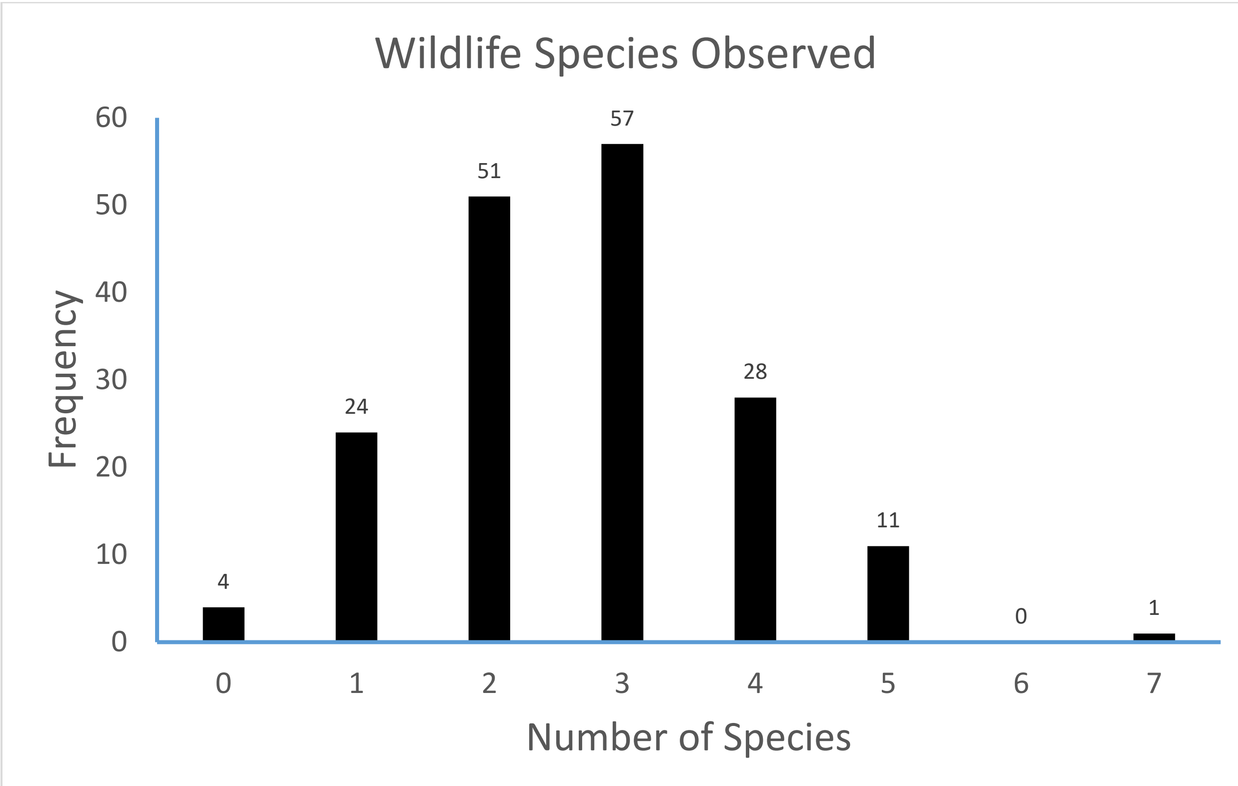

Figure 10. Wildlife observed. Frequency plot of the number of species or species groups observed at 176 video drop locations targeting rocky reef habitat off the central Oregon coast. Wildlife species included birds and marine mammals. The number of species is a minimum because some species were only identified to the family level (e.g., gulls) and other species were sometimes only identified to genus.

Acknowledgements:

This work would not have been possible without the help and encouragement of a number of individuals. Brett Rodomsky was a key person in implementing this study. He assisted in everything from study design, field work, video review, GIS work, the fish community conical correlation analysis that we presented as a poster, and review of this document. The marine reserves ecological monitoring team was also very helpful in the collaborative efforts early in the video review stages of this work., especially Brittany Huntington and Jessica Watson. I would like to thank the skipper and crew of the *F/V Miss Raven* for their help with the field work and getting us in to some of the target drop location that posed challenges that could only be overcome by their intimate knowledge navigating these waters. Gway Kirchner believed in this project from the beginning and helped ensure it could move forward from concept to reality. Bob Hannah and Matt Blume provided valuable input on field work operations during the planning stages and assistance with getting our video lander set up. Maggie Sommer, Troy Buell and Leif Rasmuson all provided valuable reviews of this document that helped improve it. Funding for this work was provided by the people of Oregon.

APPENDIX A. Rocky Reef Fish Abundance Information from Other ODFW Visual Survey Work.

Extensive effort to investigate subtidal rocky habitat and fish abundance in marine waters off Oregon has been underway since the late 1990s. A number of reports on visual survey work have been produced by ODFW staff, some of which are available on the ODFW MRP website or the Marine Reserves website. These studies vary considerably in their specific purpose, study questions, sampling techniques and the ways in which they report information. All together the information is far too extensive and varied to easily summarize the fish density and/or abundance metrics estimates succinctly, but a number of tables that provide fish density or abundance metrics have been extracted from these reports and reproduced here to consolidate the information for convenience. Each table retains its number from the source document and is introduced with a brief statement about the source document. The reader is directed to the original reports for details on the various methods used to calculate the density or abundance metrics reported as there are considerable differences. It should be noted that although densities from ROV surveys are reported in the same units (#/ 100 m^2), the sampling unit used to compute these reported fish abundance statistics varies considerably. The methods utilized in the two SCUBA surveys also differed and the results reported provide different fish density units.

There are a number of reports on ROV surveys conducted by the MRP Habitat Project that provide estimates of fish density on several nearshore rocky reefs (Fox et al. 2000, Amend et al. 2001, Merems 2003, Fox et al. 2004, Weeks and Merems 2004, Weeks et al. 2005, Weeks et al. 2007, Donnellan et al. 2009). These ROV surveys utilized a standard definition camera to collect visual observations of fish and habitat. Several reports (Fox et al. 2000, Amend et al. 2001, Merems 2003) focus on ROV survey work at Cape Perpetua and Siletz Reef with a more comprehensive comparison of these two reefs presented by Fox et al. (2004). Multi-year summaries of work at Cape Perpetua are presented by Weeks and Merems (2004) and Weeks et al. 2005. Donnellan et al. (2007) present fish density information for ROV survey work at Orford Reef. Fish densities from ROV survey work at Otter Rock and Cape Foulweather is reported by Donnellan et al. (2009). In all fish densities based on ROV surveys utilizing a standard definition video camera is reported for four different rocky reef areas: Siletz Reef, Otter Rock/Cape Foulweather, Cape Perpetua and Orford Reef. The Marine Reserves Program provides a report with estimates of fish density and abundance metrics from visual survey work done on rocky reefs at two marine reserves Otter Rock and Redfish Rocks and the associated marine protected areas and comparison areas (ODFW 2014). This report includes MaxN abundance statistics for fish species observed from a video lander very similar in design and configuration to the lander used for this project, but the marine reserves work utilized a standard definition camera and 4 minute bottom times for samples. Fish density estimates from SCUBA belt transect surveys conducted by Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) divers in 2010 and 2011 are also included as an appendix to the report. Density estimates from the SCUBA surveys are not reproduced here for a variety of reasons that make comparisons difficult (e.g., transects include both a bottom and mid-water count of fish by two divers stacked one above the other and results are presented graphically using metrics presented on a logarithmic scale per 60 m^2 transect area, which is the sampling unit). The MRP Habitat Project team also conducted ROV surveys as part of this baseline monitoring work in 2010-2011, but has yet to produce fish density estimates which are to be added as an addendum to the 2014 report when finished.

The following tables taken from Miller et al. (1997) provide estimates of rocky reef fish densities derived from SCUBA surveys conducted in waters < 20 m at Orford and McKenzie reefs.

Table 3.1. Mean density (no./100m^2) and standard deviation (s.d.) of fish species counted along belt transects within high-relief habitat at Orford and McKenzie reefs in 1996 and 1997. Sample size (n) refers to number of transects. Transect length = 80 m in 1996, 90 m in 1997.

Species	Orford Reef, 1996 High Relief, n = 6 No./100m2 (s.d.)	McK. Reef, 1996 High Relief, n = 6 No./100m2 (s.d.)	Orford Reef, 1997 Plot A, n = 8 No./100m2 (s.d.)	Orford Reef, 1997 Plot C, n = 8 No./100m2 (s.d.)
black rockfish	15.5 (15.4)	12.8 (14.0)	9.6 (7.4)	2.2 (4.7)
blue rockfish	2.0 (3.7)	6.6 (14.7)	0.08 (0.21)	0
china rockfish	0.83 (0.69)	0.42 (0.47)	0.76 (0.92)	0.14 (0.24)
juv. rockfish	7.1 (10.1)	4.1 (5.0)	2.2 (4.0)	3.4 (7.1)
kelp greenling	1.9 (1.5)	1.7 (1.3)	2.8 (2.2)	2.6 (1.4)
lingcod	0.10 (0.23)	0.31 (0.31)	0.15 (0.26)	0.31 (0.44)
cabezon	0.10 (0.23)	0.10 (0.23)	0	0
combined bottom species*	2.9 (1.3)	2.5 (1.2)	3.8 (2.4)	3.0 (1.5)

* Combined bottom species include china rockfish, kelp greenling, lingcod, and cabezon.

Table 3.2. Mean density (no./100m^2) and standard deviation (s.d.) of fish species counted along belt transects within low-relief habitat at Orford and McKenzie reefs in 1996 and 1997. Sample size (n) refers to number of transects. Transect length = 80 m in 1996, 90 m in 1997.

Species	Orford Reef, 1996 Low Relief, n = 6 No./100m2 (s.d.)	McKenzie Reef, 1996 Low Relief, n = 6 No./100m2 (s.d.)	Orford Reef, 1997 Plot B, n = 8 No./100m2 (s.d.)
black rockfish	5.9 (11.0)	8.1 (16.8)	0.08 (0.21)
blue rockfish	0	0.52 (1.16)	0
china rockfish	0.31 (0.48)	0.31 (0.48)	0
juv. rockfish	0.52 (0.76)	1.67 (2.16)	0.70 (0.91)
kelp greenling	2.1 (2.4)	1.3 (1.4)	1.8 (1.1)
lingcod	0.10 (0.23)	0.21 (0.29)	0.16 (0.27)
cabezon	0.10 (0.24)	0.10 (0.24)	0
combined bottom species*	2.6 (2.4)	1.9 (1.6)	2.0 (1.1)

* Combined bottom species include china rockfish, kelp greenling, lingcod, and cabezon.

Amend et al. (2001) reported mean fish densities from ROV surveys conducted at Cape Perpetua comparing data from 2000 and 2001 in the table below.

Table 3.2.2. Mean densities (back transformed from log-transformed data) and p values for paired t-tests comparing 2000 and 2001 data by species or groups.

Species or Groups	2000 back-transformed mean density (#/100m^2)	2001 back-transformed mean density (#/100m^2)	p
Total Fish	22.72	17.95	0.569
Total Adult Fish	19.11	13.85	0.373
Total Adult Rockfish	14.59	7.94	0.209
Black Rockfish	1.74	1.35	0.761
Canary Rockfish	4.82	2.12	0.002*
Copper Rockfish	0.73	0.45	0.218
Kelp Greenling	2.62	1.56	0.142
Juvenile Rockfish	2.10	2.25	0.926
Lingcod	0.71	1.62	0.134
Quillback Rockfish	1.36	1.03	0.581
Yelloweye Rockfish	0.25	0.12	0.447
Yellowtail Rockfish	0.89	1.25	0.715

The following table from Fox et al. (2004a) provides fish densities observed on strip transect ROV surveys of different sized rocky reef patches off Cape Perpetua sampled in summer 2000. Video samples from five randomly selected rocky reef patches in each size category were examined. Sampled transect areas for the various rocky reef patch sizes were not provided by the authors, but transects conducted on smaller rocky patches sampled less area than transects on larger patches.

Table 3. Mean and standard deviation (S.D.) values for habitat patch size parameters and fish densities of the top 15 species observed for the four patch size categories (untransformed data). **(Source: Fox et al. 2004a.)**

	Large Patches		Medium Transects		Small Patches		Tiny Patches	
Variable	mean	S.D.	mean	S.D.	mean	S.D.	mean	S.D.
Rocky Habitat Patches								
Area (m^2)	6608	5415	783	219	220	61	48	26
Perimeter (m)	971	617	193	66	73	17	29	9
Perimeter/area ratio	0.17	0.08	0.24	0.04	0.34	0.04	0.71	0.28
Fish (#/100m^2)								
Total fish	18.3	11.9	29.3	25.2	47.6	43.8	29.8	30.1
Total adult fish	12.4	4.8	22.7	16.6	40.0	30.3	23.9	21.7
Total rockfish	10.0	4.3	18.1	12.4	33.3	29.0	9.5	21.1
Black rockfish	3.8	3.4	3.2	7.1	14.9	29.0	0.0	0.0
Blue rockfish	0.0	0.1	1.3	2.8	0.0	0.0	0.0	0.0
Brown rockfish	0.1	0.1	0.5	0.6	0.4	0.8	0.0	0.0
Cabezon	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.8
Canary rockfish	3.3	3.3	6.5	1.5	11.6	13.5	9.5	21.1
China rockfish	0.0	0.1	0.2	0.5	0.2	0.5	0.0	0.0
Copper rockfish	0.6	0.4	0.4	0.2	2.7	4.6	0.0	0.0
Kelp greenling	1.3	0.5	1.9	1.5	6.0	2.7	11.5	16.0
Juvenile rockfish	5.9	9.4	6.6	9.1	7.5	15.0	6.0	11.8
Lingcod	0.7	0.5	1.7	1.8	0.7	0.8	2.5	3.3
Quillback rockfish	1.6	0.9	2.0	1.7	1.2	1.7	0.0	0.0
Ratfish	0.2	0.2	1.0	2.1	0.0	0.0	0.0	0.0
Wolf eel	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Yelloweye rockfish	0.3	0.3	1.0	1.4	0.3	0.7	0.0	0.0
Yellowtail rockfish	0.2	0.1	2.9	5.7	1.9	3.2	0.0	0.0

The following table from Fox et al. (2004a) provides estimates of fish densities by transect, sampled area and rocky reef patch size for standard definition video samples collected on ROV surveys of Cape Perpetua during three summers of sampling.

Table 5. Fish densities (# / 100 sq. m.) from 2000, **2001 and** *2002* surveys on Cape Perpetua. Fish categories are those used during video review. Rock patch size increases from left to right. **(Source: Fox et al. 2004a.)**

Rock Patch ID	1.4g	3b	1.4t	1.4v	1.1d	1.3a	1.1c	1.1k	3a	1.4a	2a	1.3b	
Patch Area (m^2)	164.1	178.1	243.3	296.2	695	769.4	843.1	1102.9	2392.4	4798.3	4911.3	16106.8	Year
Transect Area (m^2)	66.4	93.5	119.8	170.6	225.4	351.1	246	468.6	311	548.8	1014.9	1026.9	2000
	109	**59.9**	**84**	**151.2**	**176**	**325.4**	**244.7**	**376.9**	**685.4**	**961.8**	**841.3**	**1260.8**	**2001**
					260.79	*288.31*	*182.9*	*289*		*502.13*	*625*	*1246.5*	*2002*
Black rockfish	1.5			12.3	0.4	0.9		0.4	1.6	2.2	2.2	7.3	2000
Sebastes melanops		**70.3**	**1.4**					**0.3**	**7.8**	**52.0**	**8.1**	**0.6**	**2001**
								0.3			*0.6*	*0.3*	*2002*
Blue rockfish							2.8			2.0		0.9	2000
S. mystinus										**0.1**			**2001**
												0.5	*2002*
Brown rockfish							1.2					0.1	2000
S. auriculatus		**2.0**			**0.7**			**0.6**	**0.2**		**0.1**		**2001**
								0.3				*0.1*	*2002*
Canary rockfish			8.3	11.1	9.8	1.1	7.3	2.8	0.3	1.5	0.7	0.9	2000
S. pinniger	**1.1**	**2.0**	**34.1**	**16.4**	**8.4**	**6.5**	**7.5**	**9.5**	**0.3**	**4.9**	**3.5**	**0.8**	**2001**
					1.2	*0.3*		*1.7*			*1.0*	*0.4*	*2002*
China rockfish													2000
S. nebulosus	1.1				1.3						0.1		**2001**
													2002
Copper rockfish			2.5	2.3		0.3	1.6			0.4	0.1	0.5	2000
S. caurinus			**10.9**	**1.6**	**0.7**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.3**	**0.2**	**2001**
								0.3		*0.2*	*0.2*		*2002*
Juvenile rockfish					10.2	0.9	23.2	1.5		12.2	4.4	14.7	2000
Sebastes spp.		**36.2**			**6.4**	**0.4**		**5.4**	**3.5**	**26.0**	**1.5**	**0.1**	**2001**
								2.4		*0.4*	*0.2*	*0.1*	*2002*
Kelp greenling	3.0		4.2	2.9	4.0	0.3	0.8	0.4	3.5	1.3	1.7	1.1	2000
Hexagrammos decagrammus	**6.3**	**1.0**	**2.7**	**9.4**	**4.5**	**1.1**	**0.9**	**0.9**	**1.8**	**1.9**	**1.9**	**0.6**	**2001**
						0.3				*0.4*	*0.2*	*0.2*	*2002*
Lingcod	10.5		1.7	5.3	2.2	0.9	2.0	0.4	1.6	1.6	0.4	1.2	2000
Ophiodon elongatus		**2.0**	**1.4**		**0.7**	**1.4**	**0.5**	**1.8**	**0.5**	**0.5**	**0.8**	**0.4**	**2001**
					0.4					*0.2*	*0.5*	*0.6*	*2002*
Quillback rockfish	4.5				1.3	0.6	5.3	1.1	0.6	1.1	0.9	0.9	2000
S. maliger			**4.1**	**1.6**	**5.2**	**0.4**	**0.9**	**3.0**	**0.7**	**2.5**	**1.5**	**1.4**	**2001**
					0.4			*0.3*		*0.4*		*0.6*	*2002*
Wolf-eel							0.4						2000
Anarrhichthys ocellatus									**0.3**		**0.3**	**0.1**	**2001**
													2002
Yelloweye rockfish							0.8		0.3			0.7	2000
S. ruberrimus				**1.6**	**1.9**					**0.4**	**0.3**	**0.2**	**2001**
						0.7					*0.3*	*0.2*	*2002*
Yellowtail rockfish			19.2	1.2	0.4	0.3	4.9		4.5	1.3		1.8	2000
S. flavidus	**1.1**	**8.0**			**14.8**	**0.4**		**1.5**		**0.4**	**0.1**	**0.4**	**2001**
					1.2			*4.8*			*0.2*	*0.2*	*2002*

The following table from Fox et al. (2004) provides mean rocky reef fish densities for three years of ROV sampling at Cape Perpetua and compares the fish densities by years and by transects. The authors suggested that the lower densities observed for a number of the fish species in 2002 was likely related a major hypoxic event detected in that area that year.

Table 6. Mean densities (back transformed from log-transformed data) and p values for 2-way ANOVAS comparing 2000, 2001 and 2002 data by species or groups and transects for seven transect triads on Perpetua Reef. **(Source: Fox et al. 2004a.)**

Species or Group	Back-transformed mean densities (#/100 m^2)				
	2000	2001	2002	p (years)	p (transects)
Total fish	17.62	18.27	3.00	0.004**	0.580
Total Adult Fish	14.18	11.68	2.77	.0037**	0.552
Total Adult Rockfish	11.58	8.08	1.91	.0055**	0.658
Black Rockfish	0.98	1.28	0.17	0.103	0.086
Canary Rockfish	5.06	2.43	0.55	0.001**	0.078
Copper Rockfish	0.47	0.33	0.09	0.103	0.671
Kelp Greenling	1.48	1.15	0.15	0.001**	0.081
Juvenile Rockfish	2.35	6.56	0.29	0.013*	0.459
Lingcod	0.80	1.14	0.22	0.023*	0.987
Quillback Rockfish	1.81	1.45	0.22	0.004**	0.378
Yelloweye Rockfish	0.29	0.17	0.16	0.803	0.873
Yellowtail Rockfish	0.96	0.83	0.54	0.839	0.567

* significant at p<.05

** significant at p<.01

The following tables from Fox et al. (2004) provides mean densities for a number of rocky reef associated fish species observed during ROV surveys in 2001 and 2002 at Siletz Reef. The authors examined potential differences in mean fish densities by depth (Table 7) and by year (Table 8).

Table 7. Descriptive statistics for fish species and groups in deep (30-60 m) and shallow (5-30 m) water on Siletz Reef. Bold type indicates significant difference at $p < 0.05$.

	Deep Water (n=21)		**Shallow Water (n=18)**		
Fish Species or Group	*Mean Density (no. fish / 100m²)*	*Std. Dev.*	*Mean Density (no. fish / 100m²)*	*Std. Dev.*	*p- value*
Benthic fish	1.034	0.532	0.839	0.614	
Schooling fish	1.439	1.463	1.553	2.066	
Total fish	2.908	1.842	3.165	3.395	
Juvenile rockfish	0.352	0.483	0.529	1.258	
Total rockfish	2.556	1.689	2.636	2.549	
Black rockfish	**0.239**	**0.529**	**1.172**	**1.505**	**0.0054**
Blue rockfish	0.697	1.106	0.116	0.184	
Canary rockfish	0.355	0.335	0.234	0.569	
China rockfish	0.003	0.012	0.01	0.031	
Copper rockfish	0.036	0.058	0	0	
Kelp greenling	0.397	0.293	0.441	0.36	
Lingcod	0.251	0.178	0.285	0.251	
Quillback	0.042	0.074	0.003	0.013	
Yelloweye	0.003	0.012	0.0015	0.041	
Yellowtail	0.148	0.377	0.031	0.06	

Table 8. Descriptive statistics for fish species and groups at high and low bottom relief on Siletz Reef. Bold type indicates significant difference between high and low relief at $p < 0.05$.

	High Relief (n=18)		**Low Relief (n=18)**		
Fish Species or Group	*Mean Density (no. fish /100m²)*	*Std. Dev.*	*Mean Density (no. fish / 100m²)*	*Std. Dev.*	*p-value*
Benthic fish	0.993	0.527	0.915	0.634	
Schooling fish	**2.111**	**2.089**	**0.874**	**1.115**	**0.022**
Total fish	4.116	3.149	1.956	1.517	
Juvenile rockfish	**0.786**	**1.223**	**0.080**	**0.111**	**0.001**
Total rockfish	**2.227**	**2.180**	**1.026**	**1.240**	**0.038**
Black rockfish	**1.037**	**1.494**	**0.339**	**0.624**	**0.048**
Blue rockfish	**0.741**	**1.136**	**0.087**	**0.194**	**0.009**
Canary rockfish	0.297	0.558	0.302	0.356	
Kelp greenling	**0.552**	**0.329**	**0.292**	**0.277**	**0.012**
Lingcod	0.284	0.204	0.247	0.230	
Yelloweye	0.006	0.018	0.011	0.038	
Yellowtail	0.036	0.13	0.157	0.396	

The following table from Weeks and Merems (2004) presents density information for rocky reef species observed on ROV transects on rocky reef patches of various sizes at Cape Perpetua from ROV surveys conducted in 2000 to 2003. Note the variability in both density observed as well a presence absence in different years for some species.

Table 3.1 Fish density (no. fish / 100 m^2) by transect on Perpetua Reef for 2000 – 2003. Transects are ordered left to right by increasing patch size. No size data is available for patches 5a and 5b.

	TRANSECT	1.2f	1.4l	1.4x	1.4y	1.4e	3b	1.4t	1.4g	1.4v	1.2i	1.3e	1.1d	1.1c	3a	1.1i	1.2h	1.3a	2d	1.1k	3c	1.2a	1.4a	1.2d	4a	1.4d	2a	1.3b	5a	5b
Year	Patch Size (m2)	25	25	70	70	80	144	360	375	500	550	720	750	1200	1225	1400	1400	2200	3290	3325	3600	4000	6000	7875	10920	12000	12500	30000		
2000	Total Fish	59.91	86.75	15.43	3.67	13.46	130.54	54.50	9.45	30.42	81.62	71.34	44.48	10.29	16.05			10.41		23.54			42.62	21.95			18.60	5.31		
2001							3.21	37.56	21.08	37.51			28.84	51.22	14.79			5.41		7.04	24.07	39.25	25.87		29.25	10.69	12.61	32.53		
2002													5.37	0		6.19	0.94	1.73	12.29	10.73		6.48	2.19	2.70		4.47	4.00	4.01		
2003													6.12	9.87					10.29	9.09		3.2	2.32	4.5		9.07	5.73	9.75	8.86	6.4
2000	Black rockfish	0	0	0	0	0	70.29	1.36	0	0	18.98	1.18	0	0	7.78			0		0.30			5.23	0.10			8.09	0.64		
2001	*Sebastes melanops*						0	0	1.51	12.31			0.44	0.00	1.61			0.86		0.43	0	14.12	2.19		9.29	0.39	2.17	7.30		
2002													0	0		0	0	0	3.60	0.35		0	0	0		0.39	0.64	0.32		
2003													0	0.99					4.12	0		0	0.12	0		2.47	0.22	5.11	1.06	0
2000	Blue rockfish	0	0	0	0	0	0	0	0	0	7.59	0.24	0	0	0			0		0			0.11	0.10			0.00	0.00		
2001	*S. mystinus*						0	0	0	0			0	2.85	0			0		0	0	1.38	2.00		0.58	0.13	0.00	0.88		
2002													0.00	0.00		0	0	0	0.90	0		0	0	0		0.00	0.00	0.48		
2003													0	0					0	0		0	0	0		0.41	0	0	0	0
2000	Brown rockfish	0	0	0	0	0	2.01	0	0	0	1.89	0.24	0.65	0	0.17			0		0.60			0	0.21			0.14	0.00		
2001	*S. auriculatus*						0	0	0	0			0	1.22	0			0		0	0	0	0		0.00	0.00	0.00	0.10		
2002													0	0		0	0	0	0	0.35		1.04	0	0		0.08	0.00	0.08		
2003													0	0					0	0		0	0	0		0	0	0	0	0
2000	Canary rockfish	0	55.21	0	0	0	2.01	34.06	1.05	16.38	5.69	8.95	8.38	7.49	0.33			6.46		9.53			4.88	9.57			3.50	0.81		
2001	*S. pinniger*						0	8.35	0	11.14			9.76	7.32	0.32			1.14		2.77	0	0.34	1.46		1.16	1.11	0.69	0.88		
2002													1.15	0		0	0	0.35	0.60	1.73		0	0	0.13		1.31	0.96	0.40		
2003													0	1.97					0	0		0	0.49	0.56		0.21	0	0	0.21	0
2000	China rockfish	0	0	0	0	0	0	0	1.05	0	0	0	1.29	0	0			0		0			0	0			0.14	0		
2001	*S. nebulosus*						0	0	0	0			0	0	0			0		0	0	0	0		0	0.07	0.00	0.00		
2002													0	0		0	0	0	0	0		0	0	0		0	0	0		
2003													0	0					0	0		0	0	0		0	0	0	0	0
2000	Copper rockfish	0	0	0	0	0	0	10.90	0	1.56	0	0.94	0.65	0.47	0.66			0.36		0.60			0.84	1.25			0.27	0.18		
2001	*S. caurinus*						0	2.50	0	2.34			0	1.63	0			0.29		0	0	2.07	0.36		0.35	0.26	0.10	0.49		
2002													0	0		0	0	0	0	0.35		0.26	0.20	0		0	0.16	0		
2003													0	0					0	0		0	0.12	0		0	0	0	0	0
2000	Quillback rockfish	0	0	0	0	0	0	4.09	0	1.56	1.89	4.48	5.16	0.94	0.66			0.36		2.98			2.50	3.23			1.49	1.44		
2001	*S. maliger*						0.00	0.00	4.52	0.00			1.33	5.29	0.64			0.57		1.07	0	1.72	1.09		0.70	1.50	0.89	1.85		
2002													0.38	0		0	0	0	1.80	0.35		2.59	0.40	0.51		0.23	0	0.56		
2003													1.36	0.99					1.03	1.36		0	0.37	0		0.41	0	0.24	0.07	0
2000	Tiger rockfish	0	0	0	0	0	0	0	0	0	0	0.24	0	0	0			0		0			0	0			0.00	0.00		
2001	*S. nigrocinctus*						0	0	0	0			0	0	0			0		0	0	0	0		0	0.07	0	0.29		
2002													0	0		0	0	0	0	0		0.26	0	0		0	0	0		
2003													0	0					0	0		0	0	0		0	0	0	0	0
2000	Yelloweye rockfish	0	0	0	0	0	0	0	0	1.56	3.80	1.41	1.94	0	0			0		0			0.35	0.84			0.27	0.18		
2001	*S. ruberrimus*						0	0	0	0			0	0.81	0.32			0		0	0	0.34	0		0.23	0.52	0	0.68		
2002													0	0		0	0	0.69	0	0		0.26	0	0.13		0.15	0.32	0.24		
2003													0	0					0	0		0	0	0		0	0	0.12	0.07	0
2000	Yellowtail rockfish	0	0	0	0	0	8.03	0	1.05	0	0	6.35	14.82	0	0			0.36		1.49			0.35	0.21			0.14	0.36		
2001	*S. flavidus*						0	19.20	0	1.17			0.44	4.88	4.50			0.29		0	0	0	1.28		4.88	0.26	0	1.75		
2002													1.15	0		0	0	0	0.30	4.85		0	0.20	0.90		0.85	0.16	0.16		
2003													0	1.97					1.03	0		0	0.24	0		1.03	0	0.71	0.07	0
2000	Juvenile Rockfish	0	31.55	0	0	3.36	36.16	0	0	0	26.57	45.69	6.44	0	3.47			0.36		5.37			25.96	2.81			1.49	0.09		
2001	*Sebastes sp.*						0	0	0	0			10.21	23.17	0			0.86		1.49	12.74	12.05	12.21		3.25	2.22	4.43	14.70		
2002													0	0		1.90	0	0	1.20	2.42		0	0.40	0		0	0.16	0.08		
2003													0	0					0	0		0	0	0		0.31	0	0.24	0.50	0
2000	Kelp greenling	49.92	0	11.02	3.67	6.73	10.04	2.73	6.30	9.36	3.80	1.41	4.51	0.94	1.81			1.07		0.90			1.90	1.25			1.88	0.64		
2001	*Hexagrammos decagrammus*						0	4.17	3.01	2.93			3.99	0.81	3.54			0.29		0.43	0	1.38	1.28		2.55	0.98	1.68	1.07		
2002													0	0		0.95	0	0.35	0	0		0	0.40	0.39		0.15	0.16	0.24		
2003													0	0					0	0		0	0	0		0	0	0	0.21	1.24
2000	Lingcod	9.98	0	2.20	0	3.36	2.01	1.36	0	0	5.69	0.24	0.65	0.47	0.50			1.44		1.79			0.48	1.88			0.81	0.36		
2001	*Ophiodon elongatus*						0	1.67	10.54	5.28			2.22	2.03	1.61			0.86		0.43	0	2.07	1.64		2.67	1.11	0.39	1.17		
2002													0.38	0		0	0	0	0.90	0		1.82	0.20	0.26		0.69	0.48	0.64		
2003													0.00	0					1.03	0		0	0	0		0.52	0.22	0	0.14	0
2000	Flatfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0		0			0	0			0	0		
2001	Pleuronectiformes						0	0	0	0.59			0	0	0			0		0	0	0	0		0	0	0.30	0		
2002													0	0		0	0.94	0	0	0.35		1.04	0.40	0.13		0	0	0		
2003													2.72	0.99					0	6.36		2.67	0.61	0.84		0.72	3.09	0.83	2.69	1.45
2000	Ratfish	0	0	0	0	0	0	0	0	0	5.69	0	0	0	0.33			0		0			0	0.31			0.14	0.54		
2001	*Hydrolagus colliei*						0	0	0	0			0	0	0			0		0	0	2.75	1.09		0	0.65	0.00	0.78		
2002													0	0		0	0	0	2.40	0		0	0	0.13		0.39	0.16	0.40		
2003													0	0					3.09	0		0	0	0.84		0.31	0.88	0.71	0.21	0.21
2000	Spotted Wolf-eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33			0		0			0	0			0.27	0.09		
2001	*Anarhichthys ocellatus*						0	0	0	0			0	0.41	0			0		0	0	0.34	0		0.12	0.26	0	0		
2002													0	0		0	0	0	0	0		0	0	0		0	0	0		
2003													0	0					0	0		0	0	0		0	0	0	0	0

The following table from Weeks and Merems (2004) reported mean fish densities observed during ROV surveys of rocky reefs at Cape Perpetua conducted in August of different years. The authors examined potential differences both for years and for transects similar to the analysis by Fox et al. (2004, Table 6) but added data from 2003 and excluded data from 2002 when a major hypoxia event occurred.

Table 3.2 – Results of ANOVA of fish densities in seven common transects sampled in 2000 – 2003 (2002 excluded).

Species or Group	Back-transformed mean densities (#/100 m^2)						
	Aug 2000	June 2001	Aug 2003	p (years)		p (transects)	
Total Fish	3.03	3.10	2.02	0.0438	*	0.8886	
Total Adult Fish	2.80	2.64	2.02	0.0809		0.7068	
Total Rockfish	2.62	2.30	1.28	0.0134	*	0.6178	
Black Rockfish	0.79	0.82	0.47	0.6438		0.1723	
Canary Rockfish	1.85	1.32	0.25	0.0002	**	0.0374	*
Copper Rockfish	0.40	0.29	0.02	0.0468	*	0.4868	
Quillback Rockfish	1.14	0.95	0.49	0.0473	*	0.3595	
Yelloweye Rockfish	0.29	0.17	0.02	0.3430		0.7612	
Yellowtail Rockfish	0.74	0.64	0.31	0.6389		0.6461	
Juvenile Rockfish	1.37	2.21	0.04	0.0066	**	0.6636	
Kelp Greenling	0.95	0.83	0.00	0.0001	**	0.0362	*
Lingcod	0.56	0.78	0.03	0.0050	**	0.9789	
Flatfish	0.00	0.04	1.08	0.0003	**	0.3971	
Ratfish	0.08	0.20	0.20	0.6268		0.1737	

* significant at p<.05

** significant at p<.01

The following table from Weeks et al. (2007) provides densities of fishes observed during ROV surveys at Orford Reef in 2006 on rocky reefs stratified by depth range. Four 500 m long transects were conducted in each of the depth range "boxes". The table also provides a measure of relative abundance for each species or species group in terms of the percentage that each species/group comprised of the total number of fish observed in that depth range.

Table 3.1 Density and Fish Species Observed During the 2006 Orford Reef Pilot ROV Survey.
Depths reported are based on ROV depth gauge and are not true bottom depths.

	Box 5 (shallow) Mean Depth: 26.0 m Range: 20.9 - 30.1 m			Box 9 (intermediate) Mean Depth: 51.1 m Range: 43.2 - 58.5 m			Box 12 (deep) Mean Depth: 86.3 m Range: 72.1 - 98.7 m		
	number	density (#/100 m^2)	% (of individuals observed in box)	number	density (#/100 m^2)	% (of individuals observed in box)	number	density (#/100 m^2)	% (of individuals observed in box)
All Fishes	122	2.56	100%	302	4.48	100%	53	1.05	100%
Black Rockfish (*Sebastes melanops*)	9	0.19	7.4%	0	0.00	0.0%	0	0.00	0.00%
Blue Rockfish (*S. mystinus*)	46	0.96	37.7%	55	0.82	18.2%	0	0.00	0.00%
Canary Rockfish (*S. pinniger*)	13	0.27	10.7%	0	0.00	0.0%	4	0.08	7.55%
Rosethorn Rockfish (*S. helvomaculatus*)	0	0.00	0.0%	40	0.59	13.2%	4	0.08	7.55%
Yelloweye Rockfish (*S. ruberrimus*)	0	0.00	0.0%	7	0.10	2.3%	0	0.00	0.00%
Yellowtail Rockfish (*S. flavidus*)	0	0.00	0.0%	7	0.10	2.3%	8	0.16	15.09%
Copper Rockfish (*S. caurinus*)	2	0.04	1.6%	2	0.03	0.7%	0	0.00	0.00%
China Rockfish (*S. nebulosus*)	1	0.02	0.8%	9	0.13	3.0%	0	0.00	0.00%
Vermilion Rockfish (*S. miniatus*)	0	0.00	0.0%	6	0.09	2.0%	0	0.00	0.00%
Quillback Rockfish (S. *maliger*)	2	0.04	1.6%	3	0.04	1.0%	0	0.00	0.00%
Unidentified Rockfish	0	0.00	0.0%	6	0.09	2.0%	11	0.22	20.75%
Juvenile Rockfish	12	0.25	9.8%	73	1.08	24.2%	3	0.06	5.66%
Kelp Greenling (*Hexagrammos decagrammus)*	28	0.59	23.0%	54	0.80	17.9%	1	0.02	1.89%
Lingcod (*Ophiodon elongatus)*	2	0.04	1.6%	9	0.13	3.0%	1	0.02	1.89%
Painted Greenling (*Oxylebius pictus*)	0	0.00	0.0%	0	0.00	0.0%	1	0.02	1.89%
Cabezon (*Scorpaenichthys marmoratus)*	1	0.02	0.8%	0	0.00	0.0%	0	0.00	0.00%
Sculpin (Cottidae)	3	0.06	2.5%	5	0.07	1.7%	1	0.02	1.89%
Wolfeel (*Anarrhichthys ocellatus*)	0	0.00	0.0%	1	0.01	0.3%	0	0.00	0.00%
Spotted Ratfish (*Hydrolagus colliei*)	0	0.00	0.0%	0	0.00	0.0%	14	0.28	26.42%
"Eelpout" (several possible families)	0	0.00	0.0%	6	0.09	2.0%	0	0.00	0.00%
Flatfish (Pleuronectiformes)	0	0.00	0.0%	0	0.00	0.0%	1	0.02	1.89%
Unidentified Fish	3	0.06	2.5%	19	0.28	6.3%	4	0.08	7.55%

The following table provides fish densities from ROV surveys that ODFW conducted at rocky reef areas offshore of Otter Rock and Cape Foulweather (Donnellan et al. 2009). The authors noted that they only reported densities for six species and species groups because “not a single observation of yellowtail rockfish, canary rockfish, china rockfish, quillback rockfish, cabezon, sculpin, or spotted ratfish within the video footage deemed useable for fish density estimation” although each of these species were observed during other portions of the survey. It is worth noting that the authors also reported average densities for the six species or species groups for the 10 transects and expanded these density estimates to population estimates for the “statistical populations” within the survey area by multiplying average densities by the extent of rocky reef in the survey area and that they provided standard errors for the density estimates and 80% confidence intervals for the population estimates (see Figure 11 in Donnellan et al. 2009). Although the sampled area with usable footage on transects varied considerably, the authors used transect as the sampling unit for calculations of means, standard errors and confidence intervals.

Table 6. Densities (# fish/100 m^2) for species that were observed at least once during fish transects having > 100m^2 of useable footage. Survey data from 2009 were not included because no estimate of transect area was available. **(Source Donnellan et al. 2009)**

Survey Date	**Dive #**	**Transect #**	**Average Transect Width (m)**	**Transect Area (m^2)**	**Black Rockfish**	**Blue Rockfish**	**Juvenile Rockfish**	**Lingcod**	**Kelp Greenling**	**Unid. Fish sp.**
9/29/2008	249	028	3.5	137					0.73	
9/29/2008	250	020	4.2	362	4.72		0.55	0.55	0.28	0.83
9/29/2008	251	018	4.4	301	0.33		0.33		0.33	
9/29/2008	252	015	4.8	1311	0.69	0.15	0.23	0.15	0.38	0.46
9/29/2008	253	016	5.1	439	0.46				0.23	
9/29/2008	254	012	4.5	638	0.16				0.63	0.47
9/29/2008	255	013	5.3	761	0.13		0.79	0.26		0.13
10/27/2008	264	023	3.2	192	1.44				0.52	0.52
10/27/2008	266	a19	4.7	595	0.34			0.17	0.17	
10/29/2008	279	005	3.9	357			1.68		0.28	0.85

The following two tables are from ODFW (2014). Video lander MaxN abundance metrics for fish is from surveys in rocky reefs at Redfish Rocks and Otter Rock marine reserve and associated marine protected area and comparison areas conducted in 2010 and 2011 in the tables below. The authors did not attempt to evaluate view area of the lander or provide density estimates, rather they report average MaxN/drop for each species along with standard errors.

Table 3. Mean relative abundance (# of fish/ lander drop), followed by standard error within parentheses, of fish observed in Redfish Rocks Marine Reserve (n=122), Marine Protected Area (n=41), Humbug Comparison Area (n=71), and McKenzie Comparison Area (n=103). * denotes a significant difference based on Kruskal-Wallis nonparametric analysis. **(Source: ODFW 2014, p.48)**

Species/group	Redfish Rocks MR	Redfish Rocks MPA	Humbug CA	McKenzie Reef CA
Black Rockfish*	0.53 (0.14)	4.32 (1.02)	0.52 (0.12)	0.44 (0.13)
Blue Rockfish	0.35 (0.13)	0.41 (0.24)	0.27 (0.09)	0.14 (0.06)
Canary Rockfish*	0.25 (0.07)	1.95 (0.59)	0.14 (0.06)	0.01 (0.01)
China Rockfish	0.02 (0.01)	0.12 (0.08)	0 (0)	0.01 (0.01)
Copper Rockfish*	0.22 (0.04)	0.12 (0.05)	0.3 (0.06)	0.27 (0.06)
Kelp Greenling	0.07 (0.02)	0.07 (0.04)	0.1 (0.04)	0.07 (0.02)
Lingcod	0.01 (0.01)	0.27 (0.1)	0 (0)	0 (0)
Quillback Rockfish*	0.04 (0.02)	0.08 (0.08)	0.14 (0.07)	0.04 (0.03)
Sculpin	0.01 (0.01)	0 (0)	0 (0)	0 (0)
Spotted Ratfish	0.1 (0.04)	1.39 (0.71)	0.14 (0.06)	0.04 (0.02)
UNID Juvenile Rockfish	0 (0)	0 (0)	0.09 (0.05)	0.02 (0.02)
Vermilion Rockfish	0.02 (0.02)	0 (0)	0 (0)	0 (0)
Yelloweye Rockfish*	0.02 (0.02)	0 (0)	0 (0)	0.02 (0.02)
Yellowtail Rockfish*	0 (0)	0.21 (0.13)	0 (0)	0 (0)

Table 3. Mean relative abundance (# of fish/ lander drop), followed by standard error within parentheses, of fish observed in Otter Rock Marine Reserve (n=94) and Cape Foulweather Comparison Area (n=74). * indicate a significant difference between the areas based on Mann-Whitney nonparametric analysis. **(Source: ODFW 2014, p. 76)**

Species/group	Otter Rock MR	Cape Foulweather CA
Black Rockfish*	0.245 (0.11)	0.459 (0.154)
Blue Rockfish	0.011 (0.011)	0.054 (0.038)
China Rockfish	0 (0)	0.014 (0.014)
Kelp Greenling*	0.032 (0.018)	0.149 (0.046)
Lingcod*	0 (0)	0.095 (0.034)
Starry Flounder	0.011 (0.011)	0 (0)
UNID Juvenile Rockfish	0 (0)	0.068 (0.068)

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