Developing Fish Monitoring Methods on Southern Oregon Reefs

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1. Introduction

Oregon’s nearshore environment and the living marine resources that depend upon it are facing increasing human pressures. Emphasis and effort on nearshore fisheries has increased in recent years with the development of the live-fish fishery and reductions in offshore fishing opportunities (e.g., 2006 and 2008 salmon closures, federally-designated Rockfish Conservation Areas, Essential Fish Habitat, and Habitat Areas of Particular Concern). Significant non-fishery pressures also exist, including coastal land development, destructive land use practices, wave energy development, dredge material disposal, oil spills, and global warming, all of which can compromise the health and viability of the nearshore ecosystem and have cumulative effects on marine ecosystems. Recently, unprecedented hypoxic events have been observed in shallow shelf waters off the central Oregon coast (2002 - 2006), resulting in localized mass mortality of sessile marine species. These events are under active investigation by oceanographers and ecologists from Oregon State University and the Oregon Department of Fish and Wildlife’s (ODFW) Marine Habitat Project (Freeland, et al. 2003, Huyer 2003, Grantham et al. 2004, Chan et al. 2008). The cause of these hypoxic events is unknown, as is the possible spatial extent, intensity, frequency, and ecological effects of future events.

Oregon’s nearshore rocky reef habitats and their associated biological communities are highly valuable ecologically, economically, and aesthetically. These nearshore reefs support diverse and productive communities, but are limited in spatial extent. Fishing pressure on these reefs can be intense, particularly on reefs close to port. Numerous commercially and recreationally valuable fish species are found primarily, or only, on nearshore rocky reefs or other rocky substrate. These include species such as greenlings and lingcod (Family Hexagrammidae), quillback rockfish (*Sebastes maliger*), China rockfish (*S. nebulosus*), black rockfish (*S. melanops*), and blue rockfish (*S. mystinus*). In addition, nearshore rocky reefs are utilized by juveniles of other species that are more frequently fished farther offshore, including species such as canary rockfish (*S. pinniger*) and yelloweye rockfish (*S. ruberrimus*) that have been designated as “depleted” by the National Marine Fisheries Service. Most nearshore fish species have not had quantitative stock assessments, yet they are subject to substantial and increasing fishing pressure.

To address the problem of managing data-poor fisheries occurring on Oregon’s nearshore reefs, ODFW’s Marine Habitat Project (MHP) has been developing fisheries-independent, non-extractive methods for assessing reef fishes since 1995. Methods were developed for very shallow water (< 20 meters) using SCUBA surveys from 1995-1997. We obtained a remotely operated vehicle (ROV) in 1998 and have since continued method development in more challenging deeper waters (~ 20-60 meters).

The MHP's overall objectives are to:

1. Facilitate inventory of nearshore rocky reefs off of Oregon using remote sensing (e.g., high-resolution multibeam bathymetry and sidescan sonar) and subsequent habitat interpretation
2. Ground-truth remote sensing data and habitat interpretations using *in situ* methods (e.g., ROV, SCUBA, drop-camera)
3. Document and quantify seafloor biota (e.g., invertebrates, algae) and collect habitat-specific fish density data using *in situ* methods
4. Statistically characterize species-specific habitat associations for rocky reef fish species
5. Use the information gained from #1-4 to conduct habitat-based stock assessments (planned)
6. Monitor the distribution and abundance of target fish species through time (planned)

To date, we have made progress on objectives 1-4. We have either mapped or facilitated mapping of eight reef complexes using sidescan sonar and/or multi-beam bathymetry at resolutions believed to be indicative of fish habitat. The sum of these mapping efforts is 175 km^2 of seafloor, which comprises approximately 5% of Oregon's Territorial Sea. At four of these reef complexes (Cape Perpetua, Siletz Reef, Orford Reef, and Redfish Rocks), we have conducted ROV surveys to ground-truth remote sensing data, document fish densities and seafloor communities, and assess fish-habitat associations (Fox et al. 1999, Fox et al. 2000, Amend et al. 2001, Merems 2003, Weeks and Merems 2004, Weeks et al. 2005, Weeks et al. 2007, Donnellan et al in prep). During 2006 we conducted a pilot study to determine the feasibility of conducting ROV surveys off of small vessels at Orford Reef (Weeks et al. 2007).

The nearshore reefs on the southern Oregon coast, including Orford Reef and Redfish Rocks, have some of the most diverse and abundant biological communities in state waters. These reefs are also subject to locally intense fishing pressure. For example, Orford Reef is the principal fishing location for commercial fishing vessels out of Port Orford that target nearshore species (e.g., rockfish, sea urchins). The lucrative and relatively recent live fish fishery in Port Orford is similar to the fishery in California, which is known to have depleted nearshore groundfish populations (including rockfishes, kelp greenlings, cabezon). Accordingly, characterizing the habitat and biota of these south coast reefs has been and remains a high priority for ODFW. In this report we describe our recent work at Redfish Rocks.

Our primary objectives at Redfish Rocks were to: 1) ground-truth remote sensing data; 2) characterize benthic habitat; 3) describe and quantify fish communities, and 4) analyze fish-habitat associations. The Redfish Rocks vicinity was surveyed in 1995 using sidescan sonar by ODFW and data were interpreted by the Geological Survey of Canada (Fox et al. 1998). Multibeam bathymetry data were not available for the Redfish Rocks area prior to our ROV survey of Redfish Rocks, but these data were collected during July 2008 (Sullivan, unpublished data) through a companion State Wildlife Grant to the Port

Orford Ocean Resource Team (POORT). Therefore, in effect we ground-truthed 13-year old sidescan sonar survey and, *a priori*, POORT's multibeam bathymetry survey.

2. Materials and Methods

2.1 Survey Design

Redfish Rocks is located just south of Port Orford on Oregon's south coast (Figure 1-2). Our survey objective was to collect as much ROV video footage in rocky habitat as possible in the vicinity of Redfish Rocks. Raw and interpreted sidescan sonar data (Fox et al. 1998) were used to guide the placement of ROV transect lines. The sidescan survey footprint covered most, but not all, of the area that we desired to survey. To equally distribute sampling effort within the survey area, we chose a systematic survey approach and planned parallel ROV survey lines that were spaced 100 meters apart and centered around the emergent rocks of Redfish Rocks reef. Transects were oriented parallel to the general direction of the bathymetric contours (NW to SE), and transects were planned in water depths between 18 - 26 meters. The linear distance of planned transects was 35,500 meters. In the field, the determination of which of the planned transects to survey and the order in which they were completed was based on environmental conditions (e.g., water current strength, underwater visibility) that varied across the study area, and on the desire for representative spatial coverage of the study area.

2.2 Field Survey Equipment Components and Configuration

2.2.1 Vessel Specifications and Description

We contracted with Tekna Diving Services, operated by John Cheesman, for the vessel C/V SEASPORTS 1, a 27 foot Boston Whaler with twin four stroke 225 horsepower Yamaha outboard motors (Figure 3). The C/V SEASPORTS 1 was equipped with a davit and 12 VDC winch capable of lifting 500 pounds. The electric winch spool was filled with 250 feet of 1/4 inch galvanized cable. For our electric power needs two generators were secured on the bow. One supplied the 120 VAC and the other 240 VAC. Tekna Diving Services provided the captain and deckhand.

2.2.2 ROV specifications and Description

We used a Phantom HD2+2 ROV manufactured by Deep Ocean Engineering (D.O.E.) (Figure 4). The primary components mounted on or inside the ROV included:

1. video camera 1 (Sony EVI-330 standard definition 460(H) x 350(V) line digital video camera), mounted as a forward-looking primary camera
2. video camera 2 (DEEPSEA Power & Light Multi SeaCam 1050 standard definition video camera), mounted as a secondary forward-looking camera
3. video camera 3 (DEEPSEA Power & Light Multi SeaCam 1060 standard definition video camera), mounted as a downward-looking camera
4. depth pressure sensor

5. compass (D.O.E. PSE 424 r2)
6. digital multi-frequency imaging sonar (Imagenex model 881A)
7. two D.O.E. 15mW red lasers, mounted on top of the camera housing and aligned parallel at approximately 10 cm apart (to provide a reference scale)
8. digital multi-frequency imaging sonar (Imagenex model 881A)
9. two 200-watt MSR lights (Nuytco Research Limited model Newtlite)
10. tracking multibeacon

The primary topside components used for ROV navigation included:

1. Acoustic navigation system (Offshore Research Equipment TrackPoint II) which includes a hydrophone model 4610B
2. On-Screen Display video overlay (D.O.E. OSD-379)
3. KVH 1000Fluxgate compass
4. Furuno GP-37 dGPS
5. Sony DSR-45 Digital Video Cassette Recorder (2)
6. Horita GPS3 Time Code Generator/Reader (2)

Two video monitors on the survey vessel displayed a live feed from the cameras. The main monitor displayed cam #1 and #2, and the second monitor displayed cam #3. Data streams were instantaneously overlaid onto the video, including Universal Time Code (UTC), ROV depth, ROV heading, main camera tilt, and main camera ranging altimeter. These data were then displayed on the main monitor. Camera #3 had only UTC overlaid onto the video.

2.3 ROV Operations

The configuration and operation (including deployment and retrieval) of the ROV was similar to previous surveys (e.g., Amend et al. 2001, Weeks et al. 2006). In brief, during survey operations the ROV was tethered to a “clump weight” that weighed 135 kilograms and was suspended by the vessel’s davit on ¼” cable (Figure 6). The clump weight was deployed off the side of the boat and would trail to the side and aft of the vessel. The clump weight was lowered to a depth five to ten meters, depending on the bottom relief, above the seafloor and the ROV. The ROV was flown behind or to one side (or both) of the clump weight. To standardize the visual survey as much as possible, we attempted to “fly” the ROV at a speed of 25cm/second to 50cm/second and at a height off the bottom of one meter. However, in practicality it was challenging to maintain this speed and altitude due to factors such as poor underwater visibility, strong currents, and pilot fatigue. The angle of the main camera was set to 30 degrees from horizontal to standardize the field of view of resultant video footage.

The acoustic tracking system monitored the location of the ROV during surveying operations. In brief, the tracking system sends out a sound pulse from a boat-mounted hydrophone that is picked up by a beacon on the ROV. The beacon then responds with a sound pulse that is received by the hydrophone. The hydrophone monitors the time it took to send the pulse to the beacon and receive the pulse back from the beacon. The tracking system then divides the time by two to calculate the amount of time it takes the pulse takes to travel from the beacon to the hydrophone. Based on the speed of sound in salt water, it calculates the distance from the boat to the ROV. The tracking system also calculates the angle at which the return pulse was received by the hydrophone. The hydrophone contains pitch and roll sensors that compensate, to some extent, for movement of the boat. By knowing both the distance and angle of the ROV to the boat, the tracking system calculates the depth and geographic position of the ROV.

2.4 Field Data Acquisition Methods

Three types of data were collected by the ROV and navigation system during the survey: telemetry, acoustic navigation, and video. Telemetry data was gathered by instruments aboard the ROV. Telemetry data consisted of ROV depth, main camera tilt angle, and distance from the main camera to the substrate (to a point just above the laser beams). Acoustic navigation data included the position of the ROV, boat, and clump weight. The telemetry and acoustic navigation data were logged using HYPACK MAX Survey 6.2a software (©Coastal Oceanographics, Inc.). The acoustic navigation data and ROV position and depth data were logged by HYPACK MAX Survey every two seconds (a rate dictated by the TrackPoint II system). The digital video footage from the ROV's main and downward cameras was converted to an analog signal in order to pass through the umbilical cable, and was then converted back to a digital signal and recorded by two digital decks (Sony DSR-45) onto MiniDV cassettes. The video quality was significantly reduced due to this analog to digital conversion. A Universal Time Code (UTC) stamp was overlaid onto the video footage and the videotape's audio track by a Horita GPS3 and Sony DSR-45. The GPS3 and HYPACK received the UTC from the GPS, which was later matched to the time with which HYPACK tags its data strings.

2.5 Data Post-processing

The acoustic navigation data logged by HYPACK MAX Survey required post-processing for quality control purposes. First, the geographic outliers that were not eliminated by the TrackPoint II unit filters in real-time needed to be removed from the electronic data file. We used HYPACKs' Single Beam Editor to aid in identification of outliers. Because of the problems with the navigation system (and possibly other factors) during this survey, we set a higher outlier threshold than used in previous surveys (≥ 5 m change in geographic position within a 2-second period). An outlier threshold of ≥ 2 m within a 2 second period was used for outlier identification in previous surveys. For depth outliers, we used a change in depth of ≥ 1m within a 2-second period. After removing outliers, the navigation data files were smoothed and ROV positional data were interpolated (from 2-seconds to 1-second frequency to relate to video footage data) using Generic Mapping Tools sample1d software (GMT©, Paul Wessel and Walter H. F. Smith). This software interpolated the point data using an akima spline. The positional data were further smoothed using a 7-point moving average.

Video footage on MiniDV cassette was digitally transferred to a computer hard drive as an uncompressed Audio Video Interleave (AVI) data file using Adobe Premiere Pro CS3 software.

To link geographic position data from the navigation system to habitat and organism data recorded during review of video footage, we used Microsoft Access 2003 software to create a relational database based on time.

2.5.1 Video Review Configuration

Video footage was reviewed on a Microsoft Windows XP-based desktop computer equipped with a 19" LCD monitor. Adobe Premiere software was used to review video footage for habitat and organism data. During video review, discrete events such as the presence of a fish or a change in habitat type were recorded to the nearest second into an Access relational database. The UTC stamp associated with these events was obtained from the AVI file's audio track by configuring Premiere to output the digital audio signal to an external device (a Canopus ADVC-300 digital/analog audio-video converter). From the ADVC-300, the analog audio was sent to a Horita Time Code Wedge (TCW-50). In response to an event that occurred in the video footage, the TCW-50 captured the UTC stamp from the audio track when the pre-programmed keys of a keypad (P.I. Engineering X-Keys Pad) were punched. These keys were programmed with substrate types and fish taxonomic categories. When a programmed key was punched, the UTC field and data field were automatically entered into the Access database. The video footage was reviewed separately for habitat classification and fish identification and enumeration.

2.5.2 Habitat Classification

We used a dynamic segmentation habitat classification method based primarily on Fox et al. (1998), with some of the modifications reported by Fox et al. (1996) and Merems (2002). In brief, this method consists of assigning primary and secondary habitat types chosen from a pre-determined list to sequentially describe discrete non-overlapping "segments" of a transect. However, in an attempt to both streamline the review process and increase the repeatability of habitat interpretations, we made several modifications to Fox et al's (1998) methods. These modifications included:

1. Only primary substrates were recorded; secondary substrates were not recorded.
2. No measures of relief were recorded.
3. We revised the list of substrate types used to categorize the seafloor (Table 1). Specifically, the level and sloping bedrock substrate category was merged into a single "bedrock" category, and "shell hash" was added to the list.
4. No minimum length of time was used to define a habitat segment (10 seconds of continuous footage was the previous threshold).
5. The downward camera was used to determine substrate type when the main camera lost sight of the bottom. This change in habitat video review was implemented to allow use to obtain as much ground truthing data as possible.

Primary substrate was assigned to transect segments using the following protocol. As the video was reviewed, a new habitat segment was initiated every time a different substrate type exceeded 50% of the bottom of the video review monitor's screen (the start/end line). For example, if the entire view video screen was filled with sand, and a patch of bedrock entered the view from the top of the screen and progressed to the bottom of the screen, a new habitat segment was initiated once the bedrock covered a majority of the bottom of the screen. If there were multiple habitats observed at the same time, the one that occupied the most of the start/end line was the one that determined the habitat segment assigned at that time. If the seafloor substrate could not be observed using the main or downward camera, a habitat data "gap" was assigned instead of a substrate value. The playback speed of the video for habitat classification review was 29.97 frames per second (drop-frame timecode) or slower when needed to differentiate habitat types. The video review process for assigning habitat types took one person approximately three hours for every hour of video reviewed.

Because ROV transects were not randomly placed within the study area, we did not statistically estimate total percent cover by habitat type for the entire reef complex.

We compared the fine-scale habitat classifications derived from ROV video review with large-scale habitat classifications derived from interpretation of sidescan sonar data collected in 1995 (Fox et al. 1998). This analysis was similar to that of Weeks et al. (2007) for an ROV survey at Orford Reef. To facilitate this approach, ROV video observation transects data were overlaid on polygons of habitat types interpreted from the sidescan imagery. The along-transect spacing between geographic point data for video habitat observations was not standardized (i.e., some areas were highly "oversampled" and some were "undersampled" due to ROV speed over bottom and ROV course reversals), therefore only a qualitative visual comparison was conducted.

2.5.3 Finfish Identification and Enumeration

Nineteen species of finfish and seven fish groupings were identified and enumerated during video review (Table 2). Rockfish that could not be identified to species were recorded as an unidentified rockfish species. "Juvenile" rockfish were defined as rockfish that were smaller than 250mm, and these were recorded without a reference to their species. Flatfish were also counted, but not identified to species, and were recorded as unidentified flatfish. An "unidentified sculpin" group included members of the family Cottidae other than cabezon. We are certain that we routinely missed observations of very small and/or cryptic fish species.

Only footage from the ROV's forward-facing main video camera was used during video review for finfish, with the exception that footage from the downward camera was used (if possible) if it was useful to confirm identification of a fish observed by the main camera. Using Premiere, a line graphic depicting the "80% mark" (Figure 6) was superimposed on the video footage during review to distinguish the 80 percent mark of the field of view (Figure 6). The 80% mark was established as a boundary because the upper portion of the camera's field of view was beyond the practical limits of underwater visibility (Amend et al. 2001). For a fish to be counted, any portion of that fish must have appeared below the 80% mark on the screen. The fish information was recorded when the video reviewer was able to first count and identify the fish. The fish taxa and fish count for each observation were recorded with an associated UTC stamp into the Access database using the X-Keys Pad and Time code Wedge. During the fish count process the video was played back 29.97 frames/second (drop-frame timecode) or slower when needed to count and identify fish. The video review process for finfish took approximately two hours for every hour of video footage.

Because we were primarily interested in rocky reef-associated fishes, and in the interest of minimizing time spent reviewing video footage of sandy habitats, only segments of the ROV transects that occurred primarily over rocky habitat were reviewed for fish identification and enumeration. These segments were chosen by selecting continuous sections of transects that were determined to be rocky, as determined from substrate data recorded during the ROV video review. Data were viewed in GIS to identify and extract segments for which sand was not the predominant habitat.

3. Results

3.1 At-Sea Summary

We conducted ROV survey operations on 3 trips to Port Orford totaling 8 field days: April 2-4, May 9-11, and May 27-28. Field days ranged from 2-15 hours long, for a total of 51.5 hours spent on the water. Approximately 12 hours of this total was spent commuting to/from Port Orford and Redfish Rocks. We surveyed 11 transect lines totaling a distance of 42,500 meters (Figure 7) and acquired 20.5 hours of video footage from the ROV (10.25 hours each from the main and downward cameras). The total transect distance recorded by the navigation system was likely an overestimate due to problems with the ROV navigation system (see below).

The weather and sea conditions were generally good during ROV surveys, but suitable weather “windows” were short (1-3 days) and several field days were terminated early due to unfavorable survey conditions (e.g., increased winds, sea state, poor underwater visibility). In-water environmental conditions such as underwater visibility and water current strength sometimes varied substantially in time within a day or a trip, and varied in space within the study area at a given time. Strong water currents were encountered during most field days, and the current field was highly variable at times (e.g., “swirly” around emergent rocks, and going opposite directions on the north side versus the south side of Redfish Rocks proper. We did not survey amongst the emergent rocks because ocean conditions were not favorable for navigating the ROV within this highly complex area of submerged pinnacles, and the navigation system (critical for navigating in complex areas) was not functioning properly (see below).

We encountered several problems during the course of this survey that resulted in erratic ROV flight and imprecise and inaccurate positional data output by the acoustic tracking system. These problems were reflected in the jaggedness of the resultant processed survey lines (Figure 7). The primary problem that resulted in erratic ROV flight was the unusually strong currents of up to 2 to 3 knots that we encountered regularly. On the north side of Redfish Rocks the current ran from south to north following the bottom contour. On the south side the flow direction was reversed, and the currents ran from north to south. We attempted to fly the ROV against the current because that approach generally offers the best control (i.e., no loss of steerage). At times, flying against the current resulted in the ROV moving forward at a very slow speed, or slowly forward with left, right, and backwards movements. These left, right, and backward movements would push the ROV off plane at extreme angles. Flying the ROV with the strong currents often resulted in exceeding acceptable survey speeds (i.e. > ~100 cm/s), a loss of steerage (and thus control), and undesirable orientation of the ROV that resulted in extreme downward (up to 60 degrees) or sideways angles. It was unclear exactly which factor (or combination of factors) was responsible for the poor tracking performance, but we identified several possible explanations in the "Discussion" (section 4, below).

The problems with erratic ROV flight and poor positional data also affected the quality and usefulness of the resultant video footage. The extreme ROV angles encountered during this survey often caused the main camera to be oriented more downwards then forwards, which negatively affected the field of view required to review the video footage for fish density estimation. Unfortunately, the poor positional data output from the navigation system also prevented us from conducting both fine-scale ground-truthing of remote sensing data and analysis of relationships between fish species and sidescan sonar data.

3.2 Habitat Classification

Of the 42,500 meters of actual ROV transect coverage, substrate data was interpreted for 37,140 meters. The majority of the transect segments that were surveyed occurred primarily in the northern and southern fringes of the study area, where sand was the predominant habitat (Figure 8a). Unlike the sand-dominated transects in the north, the southern transects were interspersed with bedrock. Transects located closer to the interior of the reef were more typical of the complex rocky environment found at this reef, with frequent transitions between bedrock, boulder, and cobble-gravel habitats. The deepest and longest transect had the most habitat diversity, traversing sand to the north and south with its interior segmented by large boulder, bedrock and cobble-gravel.

GIS-based visual overlay analysis of the substrate interpretations from the ROV video and sidescan sonar survey illuminated both consistencies and inconsistencies between the two classifications (Figure 8b). Overall, there was substantial agreement between the ROV and sidescan interpretations at the scale of the study area. The habitat type with the most consistent agreement between the two datasets was sand. ROV video observation data classified as sand generally occurred where the sidescan imagery was also classified as sand. The boulder classifications also were generally consistent, primarily for small boulder habitat. Cobble and gravel habitats were also fairly consistently interpreted between surveys.

There were also areas of significant disagreement between the two habitat interpretations. Bedrock habitat had the least agreement between the two datasets, and was classified less frequently in the sidescan imagery than for the ROV observation data. There were also a number of discrepancies between habitat classified as sand during the ROV survey but classified as bedrock or boulder from the sidescan sonar interpretation. There were also numerous areas of disagreement in the boulder classification, as expected, because the size distinction between small and large boulders differed between the interpretation methods for the two datasets (a threshold of 1 versus 2 meters diameter for the ROV and sidescan interpretation, respectively).

3.3 Finfish Identification and Enumeration

Of the 42,500 meters of transect lines surveyed by ROV at Redfish Rocks, approximately half was over sandy habitat, and half of the remaining non-sand footage was unusable for fish density quantification due to limited visibility and extreme camera angles (resulting from strong currents affecting the ROV's trim). Nevertheless, we were able to identify, enumerate, and assess fish-habitat associations for a significant portion of the resultant video footage.

During video review for finfish, we enumerated 489 individual fish comprised of 9 taxa identified to species and 6 species groups (Figure 9). Approximately 33% of the total ROV video footage (6 hours and 20 minutes) was selected for review, which covered approximately 20,014 meters of transects (Figure 10a-f).

Of these 489 individuals, blue rockfish were the most abundant species observed (30%; n = 149), followed closely by black rockfish (28%; n = 138). Both black rockfish and blue rockfish were consistently observed clustered into groups, as expected due to their schooling nature, and were primarily observed in bedrock and large boulder habitat (Figures 10a and b, and 11a). The relative abundance of substrate type observations coincident with fish video review is shown in Figure 12 as a basis for interpretation of species-habitat relationships.

Canary rockfish were observed infrequently (n = 23), and most if not all of these fish appeared to be less than 36 cm in total length (determined by the presence of a black spot on the dorsal fin). Canary rockfish, also a schooling species, were observed in only a few locations, either as solitary individuals or in small groups, and on one occasion, a small school (Figure 10c). They occurred primarily in large and small boulder habitat (Figure 11a) that fringed the core bedrock reef area of Redfish Rocks.

Demersal rockfish such as China, Copper, Quillback, and Vermilion, were rarely observed (n = 4, 2, 4, and 1, respectively). These fish were observed primarily in bedrock and large boulder habitat (Figures 10d and 11b).

Many of the individual fish that were classified as "unidentified fish" and "unidentified rockfish" were observed above the seafloor and were probably black rockfish or blue rockfish. However, identification of these individuals could not be confirmed due to underwater visibility, distance of the fish from the camera, and the generally poor quality of standard-definition video footage that underwent conversion from digital to analog to digital format. Unidentified rockfish were observed clustered in two general locations, primarily near where black rockfish and blue rockfish were observed (Figure 10a and 10e) in large boulder and bedrock habitat (Figure 11d)

Kelp greenlings were relatively abundant (n = 49; Figure 9) during the survey. Individuals were more uniformly spaced than the other species observed (Figure 10f), and they occurred over every habitat type, though were most prevalent in bedrock and small boulder habitats (Figures 10f and 11c). These observations are consistent with observations at Siletz Reef (Merems, 2003). Lingcod were few in number but were observed using various habitats (Figures 10f and 12c).

4. Discussion

The Redfish Rocks reef complex had the greatest vertical relief that we have observed during ROV surveys to date. This relief made flying and navigating the ROV in a safe and effective manner challenging, and this was made all the more challenging by the problems that we encountered with the ROV's tracking system. The often-extreme angles of the ROV's orientation during this survey were likely a significant contributing factor to the poor positional data. The ROV orientation is critical because the tracking system assumes that the locator multibeacon on the ROV is mounted and oriented vertically. Because the tracking system calculates the depression angle of the acoustic signal sent from the ROV to the hydrophone, the tracking system will miscalculate the depression angle if the ROV is not level, and will then incorrectly geo-locate the ROV.

Another contributing factor to the poor positioning may have been the increased frequency of our survey vessel's pitch and roll relative to larger boats that we have used for ROV surveys in the past. Because the tracking system's hydrophone is fixed to the side of the boat in a vertical orientation and extends deeper than the keel of the vessel, the hydrophone travels a greater distance (and at a greater speed) than the vessel when the boat pitches and rolls. This increased pitch and roll may have compounded any miscalculations of the depression angle, which would have further contributed to erroneous positional data. The hydrophone is also equipped with pitch and roll sensors, but these may not have been functioning correctly, or the speed and acceleration at which the boat pitched and rolled may have exceeded the capabilities of these sensors to accurately compensate.

The effects of the possible contributing factors described above were reflected in the erratic track lines (even after smoothing during post-processing). Curiously, the unprocessed ROV track lines had arcing patterns that depicted movement. The ROV video footage did not show this arcing movement, so we concluded that it was an artifact of the tracking system and not an accurate depiction of the path of the ROV.

The ROV tracking system that we used is 20 years old and is no longer officially supported by the manufacturer. We strongly suspect that hardware malfunctions associated with aging components could be a primary factor that contributed to the poor tracking performance. Upon investigating the tracking issue, the hydrophone was disassembled and corrosion of the circuit boards was observed. An attempt was made to clean the corrosion off but no improvement was noticeable after servicing. We are continuing our efforts to correct the tracking problems.

Unfortunately the problems with the ROV tracking system significantly affected our ability to consistently collect quality data. The navigational issues caused by this problem made it very difficult to stay on transect during the survey and avoid obstacles. We did not survey in the most complex portion of the study area due to the elevated risk of damaging or losing the ROV because we would not have known precisely where the ROV was in relation to the vessel and rock pinnacles. Between the problems with the navigation system and the strong underwater currents, we were able to salvage much of the video footage obtained, however.

We felt that the revised habitat classification system that we used accomplished the goal of streamlining the review process and increasing the repeatability of habitat interpretations. The downside of this method was that by only assigning primary habitat, the reviewer was limited to coarsely describing what type of habitat was observed. However, if secondary habitats were also recorded during the review process, the reviewer would have more descriptive power to interpret the habitat resulting in a finer scale of interpretation. An example of this was when 75% of the view was sand and the other 25% was small boulder. Using our latest method, small boulders would not have been recorded present, yet those small boulders may have been an important component of the habitat for fish species that may have been observed at that location. However, despite the increased information obtained by identifying secondary habitats, the repeatability of interpretations by independent observers would likely be low, but this deserves further quantitative investigation.

Because of the modification to the past protocol for habitat interpretation that disallowed interpretation of habitats in habitat “gaps” (previously defined as when the main camera of the ROV lost the “ideal” field of view for more than 10 seconds), we were able to document more habitat area that would have otherwise been possible. Although this footage was not useful for fish density quantification, it was possible to interpret substrate type rather easily. In future analyses, we need to account for oversampling and undersampling of substrate observations by either standardizing the survey speed of the ROV or post-processing the data so that observation points are equidistant.

Our results in the comparison between the ROV-derived substrate interpretations versus the sidescan sonar interpretations were similar to those of Weeks et al. (2007). In addition to the likely classification errors inherent in both interpretations (particularly within transitional habitats and boulder habitat consisting of boulders near the distinction threshold of 2 meters), large-scale inconsistencies were attributable, at least in part, to differences in the classification system used for each dataset. Conversely, at fine scales many inconsistencies were attributable to differences in the scale at which the habitats were interpreted. Differences in boulder classification between the ROV and sidescan interpretations were discussed in depth by Weeks et al. (2007). The disagreement between bedrock habitats was noted for the comparison at Orford Reef as well (Weeks et al. 2007).

These disagreements are probably best explained by differences in the scale at which features were delineated. At the broader, landscape scale of the sidescan interpretation it was possible to delineate very large features over the expanse of the imagery, such as boulders greater than 2 meters in diameter from bedrock. In the video interpretation however, the field of view was restrained to < 3 meters, so it was not possible to see the boundaries or edges of rock structures, and therefore not possible to differentiate between a very large boulder (>3m) and a large mass of bedrock. By default, large rock structures greater than 3m in size were classified as bedrock in the video observation data, while some of this habitat was classified as boulder in the sidescan imagery. This was apparent upon visual examination of the southwestern portion of the survey area where two large boulder habitat sidescan patches coincided with bedrock from the video observations.

There was also a discrepancy between bedrock or boulder and sand, where the observation data indicated sand while the sidescan imagery indicated bedrock or boulder. This might be attributed to wave and current energies occurring over the course of over decade in this shallow, highly dynamic nearshore environment, which likely has transported sediments and may have covered low-relief bedrock with sand. Given that the sidescan data were collected 13 years ago, and having experienced the extreme surges and currents during this ROV survey, it is plausible that we may have documented localized changes in the substrate at this reef.

In the case of discerning boulder from bedrock, the scale at which habitats are delineated is relevant. Given the broader ‘field of view’ in the sidescan imagery, the complexities of characteristics between bedrock and boulder are perhaps more readily discernable at the scale of 10’s of meters. Video observations, however, which occur at the scale of meter and sub-meter allows for the detection of more frequent and subtle changes in substrate type that would otherwise be undetectable. Both are valid and can be used simultaneously to help explain fish-habitat relationships.

A more appropriate analysis for documenting change in substrate configuration over time would be to compare the older sidescan imagery with current sidescan or multibeam backscatter imagery. It is to our advantage that a multibeam bathymetry survey of Redfish Rocks reef has recently been completed under a companion grant conducted by the Port Orford community based group, POORT. Backscatter data from this survey will provide the basis for such a comparison.

Because of the problems with the positional inaccuracy of the navigation system and the strong currents that affected the quality of the ROV video footage, we were limited in what we could do with the fish data. However, we were able to acquire more information from the video than we originally anticipated (post-survey), such as fish community composition and relative abundance, and species- habitat relationships. These analyses, in particular the strong affinity for boulder habitat by canary rockfish, will be useful for management purposes. Our observations of fish-habitat associations and spatial patterns (e.g., aggregated versus more uniform spacing) were also generally consistent with a previous survey at distant Siletz Reef (Merems, 2003).

5. Lessons Learned

During the course of our recent surveys at Orford Reef (2006) and Redfish Rocks (2008), we learned several valuable lessons that will aid our success with future surveys:

1. *Conduct surveys only in areas that have been previously surveyed using multibeam bathymetry.* We did not have multibeam data during the 2008 survey of Redfish Rocks, which made pre-planning survey transects difficult and, given the extreme high relief of the seafloor in this area, made ROV navigation hazardous.
2. *Ensure the navigation equipment is functioning properly*. We have been actively working on troubleshooting our ROV's navigation system, and the problem may be solved. The system can only be tested under actual survey conditions (i.e., not in a swimming pool or shallow embayment), so the trial and error feedback loop is protracted and dependent upon getting at-sea time. However, we tested different software configurations while conducting an opportunistic survey aboard the R/V Elakha in July, and the navigation system appeared to be functioning properly at the end of the survey day. We have another cruise coming up on the Elakha in early August, and will either confirm that the problem is solved or continue troubleshooting. We are also actively pursuing borrowing or leasing an identical navigation system to take with us as a spare in order to isolate the problem, if it still exists.
3. *Determine the size of the smallest vessel that we can use as a survey platform*. We have determined the answer to this after our surveys at Orford Reef and Redfish Rocks. The 27' vessel we used at Redfish Rocks is the absolute smallest vessel that we can use as a survey platform. A larger boat is desirable both for additional working space and greater resistance to pitching/rolling/yawing due to short-period wind waves (which can make working on deck more hazardous and the ROV positional accuracy worse).
4. *Be as familiar as possible with weather and ocean patterns in survey locations.* Data for ocean surface currents are now available online, and we can use this information for trip planning purposes to determine probable current strength on the seafloor.
5. *Conduct surveys in the summer or early fall*. Weather, sea, and oceanographic conditions are most favorable and predictable during this period before October. We did not have experience with conducting spring surveys until 2008 at Redfish Rocks. However, the weather and sea conditions were unusual from fall 2007 to spring 2008 (our past Redfish Rocks survey window) by many accounts, so

survey conditions may have been unusually challenging relative to more “typical” conditions.

6. *Charter a liveaboard vessel when conducting surveys of distant locations.* Contracting a liveaboard boat (on which personnel remain throughout the survey to work, sleep, and eat) will reduce “overhead” of commute time to and from survey sites, but generally will be more expensive to charter than day boats.

5. Literature Cited

Amend, M., Fox, D.S., Romsos, C. 2001. 2001 Nearshore rocky reef assessment ROV Survey (pdf). Newport, OR: Oregon Department of Fish and Wildlife. 33 pp.

Chan, F., J. A. Barth, J. Lubchenco, A. Kirincich, H. Weeks, W. T. Peterson, B. A. Menge. 2008. Emergence of Anoxia in the California Current Large Marine Ecosystem. Science. Vol. 319. no. 5865, p. 920. DOI: 10.1126/science.1149016
Fox 1996

Fox, D.; Amend, M.; Merems, A.; Miller, B; Golden, J. 1998. 1998 Nearshore rocky reef assessment. Newport, OR: OR Dept of Fish & Wildlife. 54 pp.

Fox, D.; Amend, M; Merems. 1999. 1999 Nearshore rocky reef assessment. Newport, OR: OR Dept of Fish & Wildlife. 40 pp.

Fox, D.S.; Amend, M.; Merems, A.; Appy, M. 2000. 2000 Nearshore rocky reef assessment. Newport, OR (pdf): Oregon Department of Fish and Wildlife. 32 pp.

Freeland, H.J., G. Gatien, A. Huyer and R.L. Smith. 2003 Cold halocline in the northern California Current: an invasion of subarctic water. Geophysical Research Letters. 30(3): 1141, doi: 10.1029/2002GL016663, 2003.

Grantham, B.A, F. Chan, K.J. Nielsen, D.S. Fox, J.A. Barth, A. Huyer, J. Lubchenco and B.A. Menge. 2004. Upwelling-driven nearshore hypoxia signals ecosystem and oceanographic changes in the northeast Pacific. Nature. 429: 749 – 754.

Huyer, A. 2003. Preface to special section on enhanced subarctic influence in the California Current, 2002. Geophysical Research Letters. 30(15): 8019, doi: 10.1029/2003GL017724

Merems, A. 2003. 2002 Nearshore rocky reef assessment, ROV Survey (pdf). Newport, OR: Oregon Department of Fish and Wildlife. 24 pp.

Weeks, H and A. Merems. 2004. 2003 Nearshore Rocky Reef Habitat and Fish Survey, and Multi-Year Summary (pdf). Final Report for 2003-04 Grant. Cooperative Agreement No. 001-3176C-Fish. Oregon Department of Fish and Wilflife. 13 pp.

Weeks, H., Merems, A., and Miller, B., 2005. 2004 Nearshore Rocky Reef Habitat and Fish Survey, and Multi-Year Summary. Final Report for 2004-2005 Grant. Cooperative Agreement No. PS05035. Oregon Department of Fish and Wilflife. 10 pp.

Weeks, H.; Merems, A.; Miller, B. 2007. 2006 Orford Reef pilot ROV survey. Newport, OR: OR Department of Fish and Wildlife. 27 pp.

Table 1. Description of habitat categories used in the Redfish Rocks ROV Survey.

Substrate	Interpretation
Bedrock	Outcrop of rock > 3m
Large Boulder	grain size 1-3 m diameter; (include angular blocks broken off from bedrock)
Small Boulder	grain size 0.25 - 1 m
Cobble	grain size 6.4 - 25.6 cm
Gravel & Pebble	grain size 2-64 mm
Sand	grain size 0.06 - 2 mm
Crevice	>1m high x 1-3m wide (drainage ditch)
Vertical	>5m high & > 80 degrees vertical (wall)
Hash	small broken bits of shells

Table 2. Species and generalized taxonomic groups that were searched for during finfish video review.

Species

Black Rockfish (*Sebastes melanops*)
Blue Rockfish (*S. mystinus*)
Canary Rockfish (*S. pinniger*)
Rosethorn Rockfish (*S. helvomaculatus*)
Yelloweye Rockfish (*S. ruberrimus*)
Yellowtail Rockfish (*S. flavidus*)
Copper Rockfish (*S. caurinus*)
China Rockfish (*S. nebulosus*)
Vermilion Rockfish (*S. miniatus*)
Quillback Rockfish (*S. maliger*)
Tiger Rockfish (*S. nigrocinctus*)
Brown Rockfish (*S. auriculatus*)
Kelp Greenling (*Hexagrammos decagrammus*)
Lingcod (*Ophiodon elongatus*)
Painted Greenling (*Oxylebius pictus*)
Cabezon (*Scorpaenichthys marmoratus*)
Wolfeel (*Anarrhichthys ocellatus*)
Spotted Ratfish (*Hydrolagus colliei*)
Pacific Halibut (*Hippoglossus stenolepis*)

Generalized Fish Groups

Eelpout" (several possible families)
Flatfish (Pleuronectiformes)
Juvenile Rockfish
Rockfish Species (Genus *Sebastes*)
Sculpin (Cottidae)
Surf Perch (Embiotocidae)
Unidentified Fish

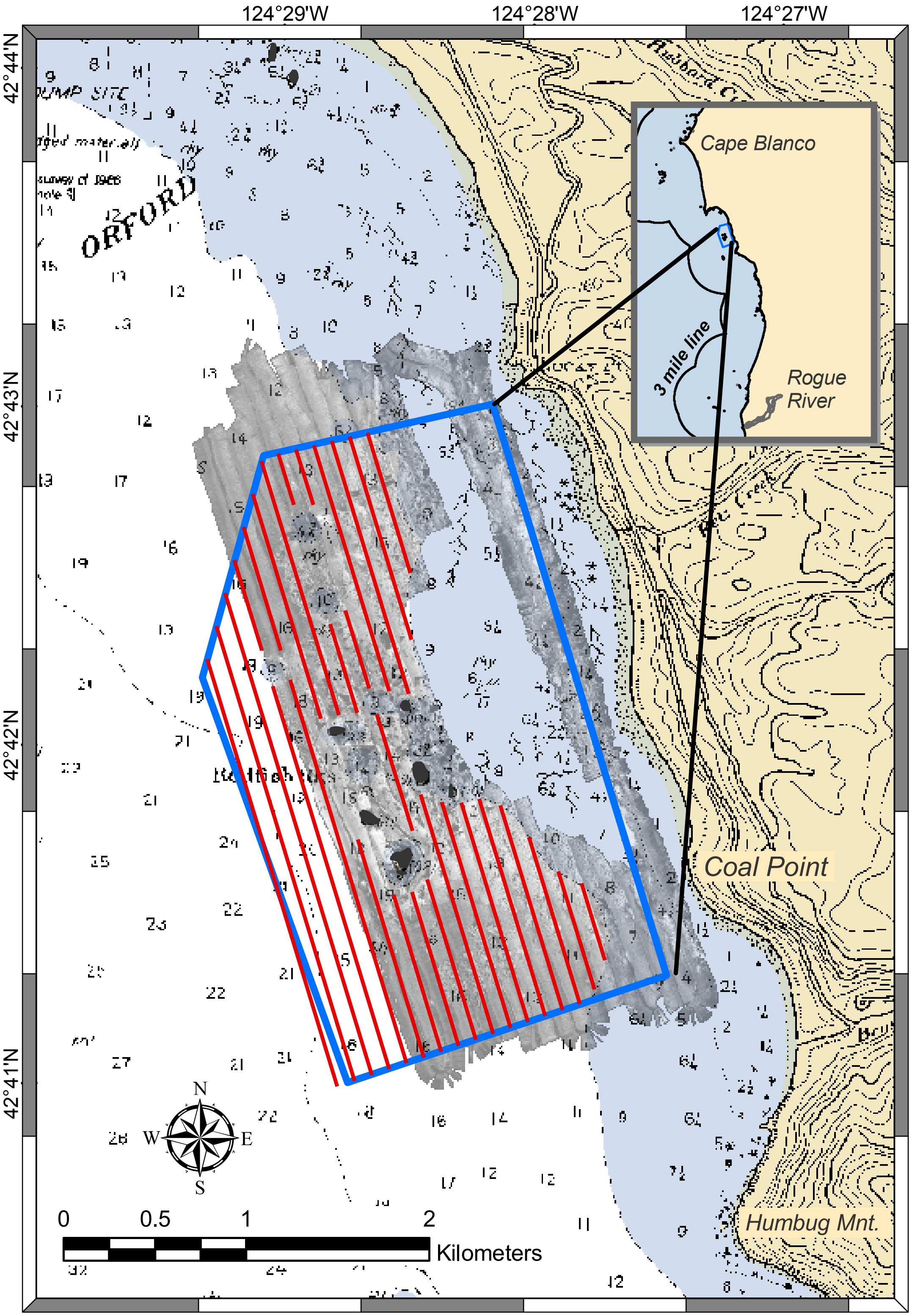

Figure 1. Map of Redfish Rocks Reef with planned ROV survey transects situated within planned multibeam bathymetry survey area, overlaid on sidescan sonar imagery.

Figure 2. Redfish Rocks, looking west from a turnout on Highway 101.

Figure 3. The 27’ Boston Whaler Seasports I that was chartered for the Redfish Rocks survey.

Figure 4. Deep Ocean Engineering Phantom HD 2+2 ROV.

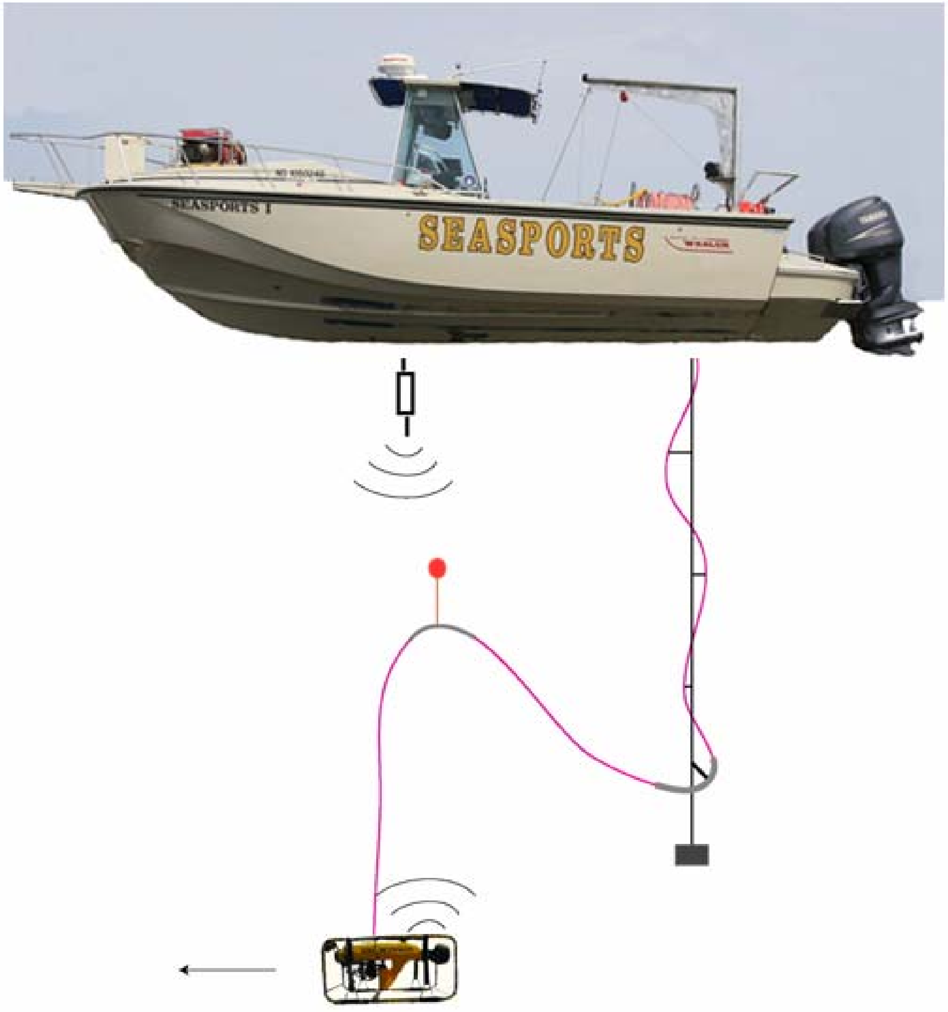

Figure 5. Schematic of the configuration ROV and vessel in survey mode, with the ROV, clump weight, and hydrophone deployed.

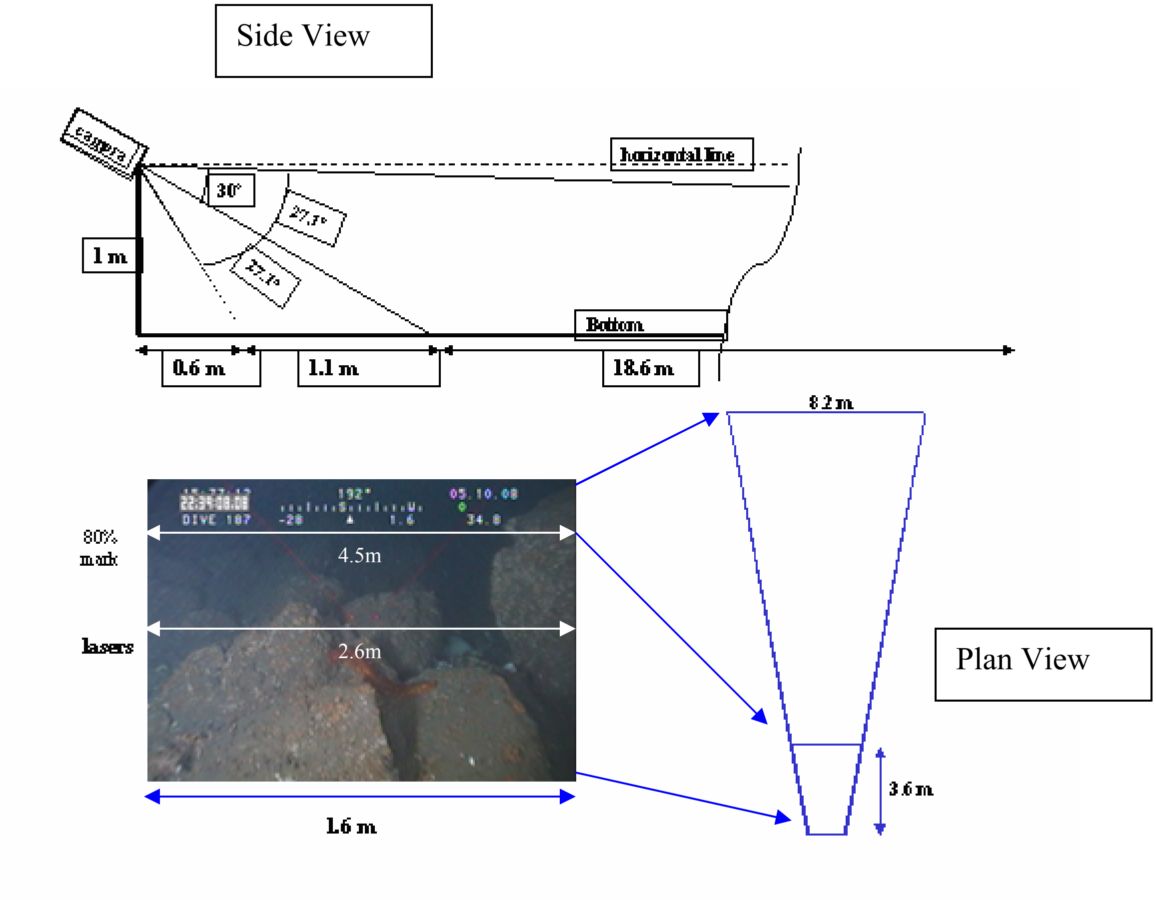

Figure 6. Schematic representations of the ROV camera's field of view. The Side View shows the vertical view angles (for the Sony EVI-330 in an underwater housing) and the distances extending along the bottom in the field of view, based on a camera height of 1 m above the bottom. Note that the top of the view extends out 18.6 m from the camera, explaining why we chose to disregard the top 20% of the video's view. The Plan View shows the area encompassed by the field of view and the calculated widths of the video image at the bottom of the view, at the point where the lasers appear in the view, and at the top of 80% of the view area. The view area is a trapezoid with a lower base of 1.6 m, and upper base of 4.5 m, a height of 3.6 m, and a surface area of 11 m^2. In this example, we use 4.5 m as the transect width.