A Pilot Study Using a Remotely Operated Vehicle (ROV) to Observe Inshore Rockfish (*Sebastes spp.*) in the Southern Strait of Georgia, March 3-11, 2005

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A PILOT STUDY USING A REMOTELY OPERATED VEHICLE (ROV) TO OBSERVE INSHORE ROCKFISH (*Sebastes spp.)* IN THE SOUTHERN STRAIT OF GEORGIA, MARCH 3-11, 2005

by

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ABSTRACT

Martin, J.C., Lacko, L.C. and Yamanaka, K.L. 2006. A pilot study using a Remotely Operated Vehicle (ROV) to observe inshore rockfish (*Sebastes spp.*) in the southern Strait of Georgia, March 3-11, 2005. Can Tech. Rep. Fish. Aquat. Sci. 2663: vi + 36 p.

Inshore rockfish (*Sebastes spp*) have been the subject of increased conservation efforts in recent years. Part of these efforts include the identification of inshore rockfish habitat areas coastwide and the selection of some of these areas to close off from fishing (Rockfish Conservation Areas, RCAs). A model of rockfish habitat has recently been developed which combines fishery data with a measure of benthic complexity attained through the use of high-resolution bathymetry. In this study, a small ROV was used in the Southern Strait of Georgia to test the reliability of the habitat model for determining rockfish habitat, as well as to provide further visual estimates of abundance for stock assessment. Results suggest that the model of rockfish habitat used for the creation of RCAs in the southern Strait of Georgia selects both areas with higher densities of inshore rockfish and more high relief habitat.

RÉSUMÉ

Martin, J.C., Lacko, L.C. and Yamanaka, K.L. 2006. A pilot study using a Remotely Operated Vehicle (ROV) to observe inshore rockfish (*Sebastes spp.*) in the southern Strait of Georgia, March 3-11, 2005. Can Tech. Rep. Fish. Aquat. Sci. 2663: vi + 36 p.

Les sébastes côtiers (*Sebastes* spp.) ont fait l'objet d'efforts de conservation accrus dans les dernières années. Dans le cadre de ces activités, on a notamment repéré des zones d'habitat côtier des sébastes tout le long du littoral et sélectionné certaines de ces zones en vue d'y interdire la pêche de ces poissons (aires de conservation des sébastes). Un modèle de l'habitat des sébastes combinant des données sur les pêches et une mesure de la complexité du fond marin, obtenue par bathymétrie haute résolution, a été récemment élaboré. Dans la présente étude, on a utilisé un petit véhicule téléguidé dans le sud du détroit de Géorgie pour vérifier si le modèle permet de repérer l'habitat des sébastes de façon fiable, et pour obtenir de nouvelles estimations visuelles de l'abondance des poissons en vue de l'évaluation des stocks. Les résultats laissent entendre que le modèle de l'habitat des sébastes utilisé pour la création des aires de conservation des sébastes dans le sud du détroit de Géorgie sélectionne les zones renfermant les plus fortes densités de sébastes côtiers ainsi que les zones présentant les plus fortes proportions de relief fort.

1.0 INTRODUCTION

Inshore rockfish are an assemblage of six *Sebastes* species; yelloweye (*S. ruberimus*), copper (*S. caurinus*), tiger (*S. nigrocinctus*), china (*S. nebulosus*), quillback (*S. maliger*) and black (*S. melanops*). They inhabit rocky reefs in shallow water from Alaska to California (Hart 1973). These species have been the target of recreational and commercial fishing activity for well over a century and have likely always been a significant component of First Nations fisheries (Love *et al* 2002). Currently these stocks are at low levels of abundance within the Strait of Georgia (Yamanaka and Lacko 2001).

As part of a conservation strategy for inshore rockfish, a series of Rockfish Conservation Areas (RCAs) have been implemented since 2001. These RCAs are closed to types of fishing that may affect inshore rockfish and are designed to ensure the protection of the population by setting aside a percentage of the coastwide habitat from fishing pressure. Previous area closures were made using fisheries landing data coupled with the solicitation of stakeholder advice and input. With an eventual goal of the closure of up to 30% of rockfish habitat in the Strait of Georgia, future RCAs are to be selected using an interpretive model of habitat complexity in concert with fishing data and stakeholder consultations.

Inshore rockfish habitat is characterized by high-relief rocky reefs, rocky complexes, boulder fields, vertical walls, overhangs and crevices. In general, most inshore rockfish are commonly found in these rocky habitats in waters down to 200 m in depth. In the absence of interpreted multibeam bathymetry for the whole coast, an inshore rockfish habitat model (a.k.a. “the green blob") was developed in a Geographic Information System (GIS) using bathymetric line data from digitized nautical charts and fishery catch and location data. This coastwide habitat model was created originally to identify areas of optimal habitat required to design effective Rockfish Conservation Areas (RCAs). The merger of two components comprise the inshore rockfish habitat model: a benthic complexity analysis and a fishery catch per unit effort (CPUE) data density analysis.

The benthic complexity analysis used, followed a step by step procedure described by Ardron (2002), based on the Terrain Analysis work of Impeitro and Kvitek (2002). The analysis reveals areas of physical complexity based on calculating the density of the second derivative of the slope of exaggerated depth. The bathymetry line data used in the analysis will limit the scale and accuracy of the complexity results (Ardron 2002). The Department created a benthic complexity model using the digitized Canadian Hydrographic Service (CHS) chart bathymetry line data in order to obtain the highest degree of accuracy. The electronic CHS chart line data did vary in scale and coverage so a 500 m buffer was added to the model polygons to account for uncertainty in the results.

In addition to the complexity analysis, a fishery CPUE data density analysis was conducted to develop areas of high rockfish catch density. Base data included inshore rockfish catch (pieces) per set location (1996-2003) from the ZN and C licensed fisheries, the recreational fishery and the observed L licensed fishery. The analysis reveals areas of high fishing success by calculating the density of catch rates at set locations. As with the complexity model, the level of coverage and accuracy of the data limits the results of this model.

Given that the results of each analysis are limited by the base data, merging the two analyses provides a more comprehensive coverage of the coast.

This study had several goals:

1. To test the ability of our models to accurately identify rockfish habitat.
2. To further provide rockfish density and abundance estimates in the southern Strait of Georgia

In February and March of 2005, we employed a small ROV to perform transects off the eastern side of Gabriola Island. Calculated densities were compared between areas with varying degrees of benthic complexity (the core data for the current habitat selection model) and then between the areas of 'rockfish habitat' and 'non rockfish habitat' as selected by final model using benthic complexity combined with fishing data. Densities were also compared between a number of microscale habitats as observed from the ROV.

2.0 METHODOLOGY

2.1 Site Selection

The study site was a depth-constrained 5x6 km grid off the eastern side of Gabriola Island, in the southern Strait of Georgia, in the approximate area of Thrasher Rock (Figure 1). Survey blocks measured 500m square, and only those with a majority of depth deeper than 10 m and shallower than 200m were used. The benthic complexity index used 5 m resolution bathymetric data, and calculated the rate of change of the slope. The blocks were then classified as having low, medium or high benthic complexity. Of the 120 blocks in the survey grid, 24 were too shallow or too deep to survey with the ROV. Of the remaining 96 blocks, 64 were 'low', 22 were 'medium' and 10 were 'high'. All 10 high-complexity blocks were selected for survey, along with 20 of the medium blocks and 20 of the 'low' blocks (Table 1).

2.2 Field Methodology

A Vancouver Island-based Seaeye Falcon ROV was used for the survey. This particular vehicle was chosen because of its combination of small size, ease of deployment from a small vessel, powerful thrusters and high resolution digital video capabilities (Figure 2). The vehicle was equipped with two halogen floodlights, a camera housing capable of 180° vertical tilt, and a small combination manipulator claw/rope cutter. Propulsion was provided by 4 vectored, variable-speed thrusters as well as a vertical thruster. To enable quantitative work, a pair of green lasers were mounted inside the frame of the ROV, powered by a submersible battery unit (A.G.O. Environmental Ltd.). These were configured in such a manner that the beams were parallel, spaced 20cm apart, and pointed downwards at an angle of approximately 34° from the horizontal. The lasers allowed the width of the camera's field of view to be measured during transects. A

Seabird Model 39 Temperature-Depth recorder (Seabird Instruments, Inc.) was also mounted on the frame.

Work was conducted from the *FV Mariko*, a 38-foot wooden and fibreglass commercial hook and line fishing vessel (Figure 2).

Prior to each transect, a direction of travel was chosen to enable the transect to pass entirely through the survey block. The ROV was deployed while the vessel was underway at 0.5-1.0 kts, so that the entire block could be transected.

A davit was rigged over the starboard side of the deck to facilitate deployment of the vehicle. During deployment, a clump weight weighing approximately 82 kg and secured to a length of 5/8 inch nylon line, marked every 10 m, was lowered to a depth of approximately 3 m. The umbilical for the ROV was secured to the line above the clump weight using nylon cable ties, allowing approximately 20 m of umbilical between the weight and the vehicle. The clump weight was lowered, with the ROV following aft of it, to within 10 m of the bottom as determined by the vessel's echo sounder. The umbilical was secured to the nylon line at 5m intervals with cable ties to prevent excessive drag from cable streaming. the transect started when the ROV reached the bottom,.

The survey grid was displayed on a laptop in the wheelhouse, and a connection to a WAAS-enabled GPS enabled the position of the vessel to be monitored in realtime by both the skipper of the vessel and the pilot of the ROV. Times on the computer and the video recording deck were synchronized to the time signal from the GPS. Vessel tracks were streamed directly to shapefiles in ArcMap 9.0 and archived.

2.3 Video Review

Video from the ROV was recorded on a Sony GV-D1000 recorder, on MiniDV cassettes, taking input directly from the control console of the ROV. The control console for the ROV included a video overlay, which provided data on compass heading, depth, camera angle, and time. The video tape was reviewed with a Sony DSR-30 MiniDV recording/editing deck and a PC utilizing DV-Log software (Freeware developed by Peter Withler at Pacific Eumetrics for the Department of Fisheries and Oceans). Time stamps in DV-Log were synchronized to the time stamp coded in the MiniDV cassettes.

Habitat descriptors were recorded as per Martin and Yamanaka (2004) in DV-Log (Appendix 2). Fish were identified to lowest possible taxonomic level and measured where possible. Only the fish that passed through the horizontal line formed by the lasers were recorded and used in the analyses. This criterion was established because the width of the field of view can only be delineated at the point where the laser dots appeared on screen. Other fish were recorded, but were given a notation of "NTC" in the database to indicate they had passed outside the measured field of view or 'strip'.

Videos were reviewed to determine mean field of view for the camera over each transect. Starting at the beginning of each transect, the distance between the lasers on the video review screen were measured every 30 seconds. The lasers are separated by 20 cm, and the screen is 25 cm across, therefore a simple relationship between on-screen laser separation and the total field of view of the camera can be estimated. Mean width of the field of view varied between transects depending on factors such as available light, the amount of suspended particular matter, camera angle, distance off the sea floor and benthic relief (Table 2).

2.4 Calculation of Track Length

The ROV used for this survey was not equipped with an acoustic tracking system. Since the use of a clump weight resulted in a vertical angle of the ROV tether, with a relatively short length of umbilical trailing from the clump weight, the vessel position was used as a proxy for ROV position on the seafloor. Shapefiles recorded from vessel tracks were cropped to the length of the recorded video transect, and then measured using ARCGIS (Table 3). The total length of each type of habitat along the transect was also calculated (Table 3).

2.5 Calculation of Area Covered

The area swept by the camera was calculated by substrate type using the following equation:

$$A_x = \left(L_x \overline{F}\right)$$

Where A_x is the area covered by substrate type x, L_x = total length of substrate type x along transect (in meters) and $\overline{F}$ is the mean width of the field of view for that particular transect.

2.6 Calculation of Fish Density

Using the area swept as derived above, fish density estimates were calculated. Mean density estimates were calculated for each species by substrate type and reported as number of fish km^{-2} using the formula:

$$D_{sx} = \frac{n_s}{A_x}$$

where D_{sx} = Density per substrate type *x* for a given species *s* (fish m^{-2}), *n* = number of fish observed of species *s* over that substrate, and A_x= Area of a given habitat type swept.

2.5 Statistical Methods

Tests for statistical difference in fish density among categories of primary substrate, benthic complexity and inshore rockfish habitat model were conducted. For the comparisons of densities in low versus medium complexity areas and areas of ‘rockfish habitat’ versus ‘non rockfish habitat’, Mann-Whitney U-tests tests were performed, which compare the median values of two distributions. For comparisons of species densites by primary substrate type, Kruskal-Wallis tests were performed. When differences were detected, a Mann-Whitney U-test was performed to identify differences by substrate type.

3.0 RESULTS

3.1 Deployment Success

Though the survey was planned to dive on areas of ‘low’, ‘medium’ and ‘high’ complexity, none of the blocks of ‘high’ complexity could be surveyed with the ROV. On the first attempt to survey a block of ‘high’ complexity, the steep slope coupled with currents made transects with the clump weight and the ROV very difficult. Based on this first experience, and cautious on-site appraisal of further ‘high’ complexity areas, only ‘low’ and ‘medium’ areas were surveyed to avoid damaging the ROV or fouling the vessel’s prop with the umbilical. Based on sonar, these ‘high” complexity areas were confirmed to be areas of vertical walls and very steep terrain.

3.2 Transect lengths and area swept

A total of 24 transects were conducted over the course of the survey (Table 1). The transects ranged in length from 55 m for transect 6, which was aborted, to 683 m for transect 15. Mean transect length was 457 m, with a standard error of 35 m. During transects, the width of the camera’s field of view varied from a minimum of 1.29 m during transect 20 to a maximum of 5.59 m during transect 1. Mean width of the camera’s field of view was 2.71 m, with a standard error of 0.24. A summary of the mean width of the camera field of view (Table 2) and the length of all habitat types (Table 3) are presented, with the total area viewed by the ROV being 29049 m^2.

3.3 Fish Counts

A total of 1290 fish sightings were recorded along the 24 transects of the survey (Table 4). Of these, 105 were identifiable rockfish species such as greenstriped (*Sebastes elongatus*, n = 52), quillback (*Sebastes maliger*, n = 38), Puget Sound (*Sebastes emphaeus*, n = 5) yelloweye (*Sebastes ruberrimus*, n = 5), copper (*Sebastes caurinus*, n = 4) and rosethorn (*Sebastes helvomaculatus,* n = 1) and a further 14 were unidentified rockfish. 1171 fish were other groundfish species, with the most common being Pacific hake (*Merluccius productus*, n = 388), spotted ratfish (*Hydrolagus colliei*, n = 225), unidentified flatfishes (Order Pleuronectiformes, n = 108) and unidentified codfishes (family Gadidae, n = 28).

Greenstriped and quillback rockfishes both occurred in 11 of the 24 transects, while yelloweye rockfish occurred in only 3 transects, Puget Sound and copper rockfishes occurred in only one transect.

3.4 Depth and Temperature Distributions of Fish Observations

Depth distribution statistics were computed over all transects, by species group (Table 5) and by species (Table 6).

Transect depths ranged from a minimum of 12 m to a maximum of 208 m, with a median depth of 98 m (Table 5). Fish were observed at depths ranging from 20 m to 207 m, with the median depth for observations 86 m (Table 5). Rockfish were observed at depths ranging from 23 m to 193 m with a median depth of 100 m. Depth distributions for individual species are shown in Table 6.

Temperature values associated with each observation and the summary statistics for their distributions are included in Table 7.

3.5 Spatial distributions of Fish Observations

Bubbleplots show the spatial distribution of fish density of the major species of rockfish and groundfish observed over the course of the survey (Figures 3 and 4). Depth distribution by species are evident.

Pacific hake distribution over the survey area was limited to only a few transects, despite being the most numerous fish encountered.

3.6 Microscale habitat proportions

The percent makeup of the primary substrates varied greatly between transects conducted over the course of the survey (Table 8). ‘Mud’ was the most common substrate encountered (33.4% of the total) followed by ‘Mixed coarse’ (27.8%), ‘Bedrock’ (20.1%) and ‘Sand’ (18.5%). ‘Boulder’ and ‘Cobble’ were each present in very small amounts (0.1% each) while no ‘Gravel’ areas were encountered. Because of this, when comparisons of fish densities related to primary substrate were made, only those over ‘Bedrock’, ‘Mixed Coarse’, ‘Sand’ and ‘Mud’ were included. The number of different substrates encountered on a single transect also varied. Transects 15, 18, 21 and 22 each only had one primary substrate type along them, compared to a maximum of 4 primary substrate types over transects 2, 16 and 24 (Table 3).

Percentage of habitat within areas of varying complexity was also compared. A total of 56.9% of the habitat surveyed was within blocks classified as ‘Low’ complexity, while the remaining 43.1% was within ‘Medium’ blocks. In addition, percentage of habitat inside and outside the combined complexity-fishing data areas was compared, and found to be almost equal, with approximately 50.5% of surveyed habitat falling within the area shown by the model to be inshore rockfish habitat, and 49.5% of the surveyed habitat occurring outside (Table 8).

3.7 Habitat associations and substrate-dependant density estimates

Estimates of fish density (individuals per square metre) were calculated for each species by benthic complexity (‘low’ or ‘medium’) by ‘Inshore Rockfish Habitat” (‘Habitat’ or ‘non-habitat’ areas). A breakdown of calculated mean fish densities over complexity/habitat categories and habitat types is presented in Table 9. Since nonparametric statistical tests (Mann-Whitney U) were used to compare distributions of density, median fish densities are also presented (Table 10).

3.7.1 Complexity-dependant density

Boxplots comparing distributions of density in ‘low’ versus ‘medium’ complexity are presented in Figure 5.

Among rockfish, highest mean densities were observed for greenstriped rockfish, with a density of 3080 individuals km^{-2} in low-complexity areas, compared to 1626 fish km^{-2} in medium-complexity areas. The difference between densities over the two levels of complexity was not significant (U = 66, p = 0.84). Quillback rockfish were observed at a mean density of 835 fish km^{-2} in low-complexity areas compared to 811 fish km^{-2} in the medium-complexity areas, a difference which was not statistically significant (U = 66.5, p = 0.84). The other rockfish species were observed in numbers too small to make a meaningful comparison of density between complexity levels.

Among other groundfish, by far the highest mean density was that of Pacific hake with a density of 28842 fish km^{-2} in low complexity areas, compared with only 275 fish km^{-2} in medium-complexity areas but this difference was not statistically significant (U = 68.5, p = 0.93). Flatfish were present at mean densities of 6944 fish km^{-2} in low complexity areas compared to 2878 fish km^{-2} in areas of medium complexity. This difference was not statistically significant though it was the most striking of any of the tested differences in density (U = 91, p = 0.23). Spotted ratfish were observed at a mean density of 6573 fish km^{-2} in the low-complexity areas, compared to 5965 fish km^{-2} in the medium-complexity areas. This difference was not statistically significant (U = 67, p = 0.89). Eelpout were observed at a mean density of 1750 fish km^{-2} in low-complexity areas, compared to 153 fish km^{-2} in medium-complexity areas, and this difference was also not statistically significant (U = 66, p = 0.84). Lingcod were observed at a density of 828 fish km^{-2} in areas of medium complexity, compared to 654 fish km^{-2} in areas of low complexity. This difference was not statistically significant (U = 63, p = 0.71)

3.7.2 Density in 'rockfish habitat' and 'non rockfish habitat' areas

Boxplots comparing distributions of density within 'rockfish habitat' and 'non rockfish habitat' are preented in Figure 6. Mann-Whitney U tests were used to test for significant differences.

Among rockfish, highest densities were observed for greenstriped rockfish, with a calculated mean density of 3953 fish km^{-2} in areas of 'non rockfish habitat' compared to a density of 363 fish km^{-2} in areas of 'rockfish habitat'. The difference in densities between these areas was statistically significant (U = 36.5, p = 0.024). Quillback rockfish were observed at a mean density of 1125 fish km^{-2} in areas or 'rockfish habitat', compared to 530 fish km^{-2} in 'non rockfish habitat' areas. The difference in densities between these areas was not significant (U = 55, p = 0.24). The other rockfish species were observed in numbers too small to make a meaningful comparison.

Among other groundfish, highest mean density was that of Pacific hake with a density of 29029 fish km^{-2} in areas of 'rockfish habitat'. Hake were absent from the areas of 'non-rockfish habitat'. This difference in densities was not statistically significant at the level of $p < 0.05$. Spotted ratfish were observed at a mean density of 8003 fish km^{-2} in areas of 'non rockfish habitat' compared to 3602 fish km^{-2} in areas of 'rockfish habitat', a difference which was statistically significant (U = 34, p = 0.018). Flatfish were observed at a mean density of 6420 fish km^{-2} in 'non rockfish habitat' compared to 3280 fish km^{-2} within 'rockfish habitat', a difference which was not statistically significant (U = 71, p = 0.77). Eelpout were observed at a mean density of 1514 fish km^{-2} in areas of 'non-rockfish habitat' compared to 438 fish km^{-2} in areas of 'rockfish habitat', a difference which was not statistically significant (U = 70, p = 0.73). Lingcod were observed at a mean density of 834 fish km^{-2} in areas of 'non-rockfish habitat' compared to 523 fish km^{-2} in areas of 'rockfish habitat', a difference which was not statistically significant (U = 73, p = 0.85).

3.7.3 Microscale habitat-dependant density

Boxplots comparing distributions of density for rockfish (Figure 7) and groundfish (Figure 8) over the four most common types of primary substrate are presented.

Among rockfish, the highest mean densities were found for greenstriped rockfish, which were calculated as 61,970 fish km^{-2} over cobble bottom, 14,635 fish km^{-2} over 'mixed coarse', 3205 fish km^{-2} over 'bedrock' and 793 fish km^{-2} over 'mud'. Quillback rockfish densities were 4023 fish km^{-2} over 'bedrock', 352 fish km^{-2} over 'mixed coarse', 156 fish km^{-2} over 'sand' and 86 fish km^{-2} over 'mud'. Other rockfish species were observed in numbers less than 5 individuals (Table 9).

Among other groundfish, the highest densities were reported for flatfish. Due to the uncertainties in identification of flatfish with the poor visibility often encountered, only densities of lumped flatfish observations were analysed. Mean density of all flatfish observed over 'boulder' habitat were calculated as 75008 fish km^{-2}, while density was 6721 fish km^{-2} over 'mud', 3196 fish km^{-2} over 'mixed coarse', 1628 fish km^{-2} over 'sand' and 774 fish km^{-2} over 'bedrock'. Mean densities of Pacific hake were 27485 fish km^{-2} over 'mixed coarse', 16625 fish km^{-2} over 'mud' and 10166 fish km^{-2} over 'bedrock'. Mean densities of lingcod were 24859 fish km^{-2} over 'boulder' habitat, 1525 fish km^{-2} over 'bedrock', 785 fish km^{-2} over 'mixed coarse' and 462 fish km^{-2} over 'mud'. Mean densities of spotted ratfish were 8038 fish km^{-2} over 'mud', 1628 fish km^{-2} over 'mixed coarse' and 2536 fish km^{-2} over 'bedrock' and 910 fish km^{-2} over 'sand'. Eelpout were only seen over 'mud', with a mean density of 1669 fish km^{-2}. Gadids were only observed over 'bedrock', with a mean density of 918 fish km^{-2}.

Distributions of density of each species by the four most common habitat types were compared (Figures 7 and 8) and tested statistically using Kruskal-Wallis nonparametric tests. This showed that the significant difference was between densities of quillback rockfish over 'bedrock' and 'mud' (H = 14.6, p = 0.002). A pairwise comparison of these densities was found to be statistically different (U = 59.5, p < 0.01). Though many apparent trends were seen in the data, pairwise comparisons were not significant.

3.8 Proportion of microscale habitat in categories of complexity and modeled habitat

As a further means of determining the ability of both methods to represent rockfish habitat, the proportions of 'bedrock', 'mixed coarse', 'sand' and 'mud' per transect were compared (Figures 9 and 10).

For comparisons between 'low' and 'medium' complexity (Figure 9), percentage of 'bedrock' habitat observed tended to be higher in areas of 'low' complexity, though median values were almost identical. The median percentage of 'mixed coarse' was higher in areas of 'medium' complexity, and that of 'sand' was higher in areas of 'low' complexity and absent in areas of 'medium' complexity. Median percentage of 'mud' cover was seen to be slightly higher in areas of 'medium' complexity, but the range of percentages was greater than in the other comparisons.

For comparisons between 'rockfish habitat' and 'non-rockfish habitat' (Figure 10), median percentage of 'bedrock' was higher in areas of 'rockfish habitat'. Median percentage of 'mixed coarse' was higher in areas of 'non-rockfish habitat'. Median percentages of 'sand' were 0 in both areas, but the 3rd quartile and 90th percentiles were higher in areas of 'rockfish habitat'. Median percentages of 'mud' were higher in areas of 'non-rockfish habitat'.

These comparisons suggest that the differentiation of 'rockfish habitat' from 'non-rockfish habitat' by the merging of fishing data with an analysis of benthic complexity was a better predictor of both higher proportions of bedrock and lower proportions of mud, which in turn suggests that this is a better predictor of areas of rockfish habitat than benthic complexity alone.

4.0 DISCUSSION AND CONCLUSIONS

The 2005 survey provided a valuable opportunity to assess the utility of small ROVs for the study of inshore rockfish habitat and populations. We were able to survey depths in excess of SCUBA divers and the towed video camera system used previously by Martin and Yamanaka (2004). The mean depth of transects over the 2005 survey was comparable to that of the manned submersible surveys conducted in both 2003 and 2005, while expense and overall logistics are considerably less.

Although a total of 24 transects were conducted, the number of fish observed, especially rockfish, was relatively low. Only greenstriped rockfish (n = 44) and quillback rockfish (n = 32) were observed in numbers greater than 5 individuals. In this study, quillback rockfish stocks in the southern Strait of Georgia are at low densities (849 per sqkm), although their optimal habitats could not be surveyed with the ROV. Over much of the survey, visibility was poor both in the water column and on the bottom, due to the late winter/early spring phytoplankton bloom, which arrived earlier than anticipated. This may also have contributed to the low numbers of fish observed.

One consideration that needs to be addressed in interpretation of the results is that of some fish being frightened by the approach of the ROV. If a fish darts away from the field of view before it passes the line marked by the lasers, it is not counted. This may be a problem for some groundfish species, though we have not observed such avoidance behaviour from inshore rockfish during submersible surveys.

This survey was designed to examine the density of inshore rockfish over three levels of 'benthic complexity', given as the rate at which the slope of the bathymetry changed. Though it proved impossible to survey the areas of 'high' complexity, a total of 24 transects were conducted in survey blocks of 'low' and 'medium' complexity. There were no statistically significant differences between densities of either rockfish or groundfish species over these two categories, despite some apparent trends. This suggests that the use of a benthic complexity model alone may not be a good method of identifying inshore rockfish habitat. Areas of 'high' complexity were not surveyed and it is possible that significant differences between ‘high’ and ‘low’ complexity may have been detected.

Relative density of fish species was also examined between areas identified as ‘inshore rockfish habitat’, and outside areas. “Habitat” was defined using a combination of benthic complexity and fishery landing data. Greenstriped rockfish and spotted ratfish were significantly more abundant areas outside of rockfish habitat. Although quillback rockfish were found at twice the density in rockfish habitat, this difference was not significant. The differences in density between ‘habitat’ and ‘non-habitat’ provide evidence that the combination of benthic complexity analysis and fishery data is superior to benthic complexity alone. While this complexity-fishing model is based on extensive fisheries data, there is comparatively little fishery data in the southern Strait of Georgia. For this reason, the complexity-fishing model is likely a better predictor of inshore rockfish habitat along other areas of the coast where there is more fishing activity.

Fish density over the four most prevalent benthic substrate types (‘bedrock’, ‘mixed coarse’, ‘sand’ and ‘mud’) was not found to differ significantly, with the exception of quillback rockfish, which was found at significantly higher densities over ‘bedrock’ than over ‘mud’. These data are difficult to interpret, as numbers of fish in the analysis is small and split over four different categories rather than two as in the previous analyses. However it should be emphasized that this method of categorizing habitat is only used with direct observations, while the models of ‘complexity’ and ‘habitat’ are interpreted models based on remote sensing (i.e. multibeam bathymetry). As such, the observed microscale habitat could be used in conjunction with fish densities to determine if the merging of fishing data with benthic complexity was a better means of habitat identification that complexity alone. Analyses of both fish density and microscale habitat in these classed areas suggest that the inclusion of fishing data, results in more accurate identification of rockfish habitat.

While the ROV survey provided a comparison between several different methods of identifying rockfish habitat, the other objective was to provide further density data for inshore rockfish species in the southern Strait of Georgia. While densities were determined for several species of inshore rockfish using the three methods outlined, overall numbers observed were quite low. For example, a survey using a towed video camera undertaken in June of 2003 (Martin and Yamanaka 2004) observed a total of 85 quillback rockfish over 16 transects, while this survey counted 32 fish over 11 transects. This difference is even more striking when transect length is taken into consideration; mean transect length for the 2003 survey was 398 m while in 2005 it was 457 m.

Densities reported for quillback rockfish over bedrock from this survey were approximately one third of the densities reported from the 2003 towed video camera survey (Martin and Yamanaka 2004, Table 11). However, it is difficult to directly compare these densities because a calibrated comparison of the two methods has not been attempted. Certainly, the mean depths of the two surveys differed considerably, with the 2003 survey having a mean depth of approximately 30 m (Martin and Yamanaka 2004) and the 2005 survey having a mean depth of 104 m. In fact, only 25% of the transects during the 2005 survey were conducted at depths of less than 50 m (Table 5). However, due to the increased control afforded by the ROV compared to the towed camera, we believe that density estimates obtained using the ROV are generally more likely to be accurate than those obtained using the towed camera.

Overall, the ROV proved to be a promising platform for conducting rockfish research. Difficulties encountered surveying areas of high relief could be minimized or eliminated by the utilization of a different deployment strategy. For example, the use of an ROV mounted Ultra-Short Baseline (USBL) tracking system would allow tracking of the vehicle independently from the tender vessel, decrease dependence on a weighted umbilical line and allow more manouverability. A vessel fitted with bow thrusters and a shielded propeller would greatly increase the efficiency of station-keeping while conducting transects.

ACKNOWLEDGEMENTS

We would like to thank the following people; Valentyn DeLeeuw and Hilde Harrison of the M/V Mariko, Mike Wood and Andy Clarke of Suboceanic Sciences Canada, Jackie King of the DFO Lingcod Program and Robert Pacunski of the Washington Department of Fish and Wildlife. Janet Lochead and Dana Haggarty reviewed this document.

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Table 1. Transects conducted over the course of the ROV survey from March 3rd to March 11th, 2005.

Date	Transect	Block	Start Time	End Time	Complexity
3/3/2005	1	110	10:58:04	11:22:49	Low
3/3/2005	2	99	11:48:48	12:07:49	Low
3/3/2005	3	63	12:52:01	13:12:15	Medium
3/3/2005	4	51	13:33:53	13:53:07	Medium
3/3/2005	5	39	14:16:26	14:41:12	Medium
3/3/2005	6	38	15:13:50	15:22:00	Medium
3/4/2005	7	35	10:10:07	10:35:23	Low
3/4/2005	8	83	11:49:45	12:10:32	Medium
3/4/2005	9	115	13:03:19	13:33:34	Low
3/4/2005	10	103	13:36:03	13:57:04	Low
3/4/2005	11	118	14:37:10	15:15:30	Medium
3/4/2005	12	105	15:51:05	16:16:35	Low
3/6/2005	13	119	10:02:59	10:14:37	Medium
3/6/2005	14	59 and 60	11:15:22	11:43:10	Medium
3/6/2005	15	18	12:46:55	13:15:37	Medium
3/6/2005	16	19	13:17:20	13:30:51	Medium
3/6/2005	17	42	14:28:27	14:46:08	Low
3/6/2005	18	52	15:31:06	15:45:50	Low
3/6/2005	19	85	16:14:11	16:36:22	Low
3/7/2005	20	91	14:34:10	14:56:24	Low
3/7/2005	21	80	15:18:25	15:38:14	Low
3/7/2005	22	94	16:10:33	16:14:57	Low
3/11/2005	23	99	9:27:56	9:45:38	Low
3/11/2005	24	110	10:02:04	10:23:00	Low

Table 2. Mean, standard deviation and variance of field of view measured for each transect.

Transect	**Field of View (m)**		
	Mean	**Standard Deviation**	**Variance**
1	5.7	2.4	5.5
2	4.8	2.1	4.4
3	4.5	1.4	1.8
4	3.2	2.2	4.7
5	2.3	1.2	1.5
6	2.7	1.3	1.7
7	3.3	2.4	5.5
8	3.1	1.7	2.7
9	1.8	1.2	1.5
10	1.5	0.5	0.2
11	2.6	1.7	2.9
12	1.8	0.8	0.6
13	3.0	2.9	8.2
14	2.9	1.9	3.5
15	2.2	1.2	1.3
16	2.0	1.0	1.1
17	1.9	1.1	1.1
18	1.7	1.1	1.2
19	1.7	0.8	0.6
20	1.3	0.3	0.1
21	1.7	1.1	1.2
22	2.7	0.9	0.8
23	4.4	2.4	5.8
24	2.1	1.1	1.2

Table 3. Total length of each transect as well as length made up of each habitat type

Transect	Total Length (m)	Substrate Coverage Length (m)						
		Bedrock	Boulder	Cobble	Mixed Coarse	Gravel	Sand	Mud
1	368	44	—	—	17	—	307	—
2	512	94	—	—	104	—	166	149
3	542	49	—	—	277	—	216	—
4	366	81	—	—	56	—	—	229
5	632	—	—	—	10	—	—	622
6	55	15	—	—	—	—	—	40
7	575	—	—	—	523	—	24	28
8	335	70	—	—	265	—	—	—
9	526	—	—	—	3	—	—	524
10	528	—	4	—	—	—	—	524
11	654	64	—	12	172	—	106	300
12	425	—	—	—	220	—	—	205
13	232	31	—	—	96	—	—	106
14	591	244	—	—	347	—	—	—
15	683	—	—	—	—	—	—	683
16	331	20	10	—	122	—	—	179
17	324	96	—	—	114	—	—	114
18	352	—	—	—	—	—	—	352
19	621	—	—	—	158	—	463	—
20	581	69	—	—	171	—	—	340
21	624	624	—	—	—	—	—	—
22	75	75	—	—	—	—	—	—
23	457	343	—	—	—	—	114	—
24	588	155	—	—	189	—	106	138

Table 4. Summary of fish species, scientific names, and total number observed over the course of the 2004 ROV survey.

Species Name	Taxonomic Name	Total Number observed
Pacific hake	*Merluccius productus*	388
Unknown fish	Unknown fish	248
Spotted ratfish	*Hydrolagus colliei*	225
Flatfishes	Pleuronectiformes	108
Greenstriped rockfish	*Sebastes elongatus*	52
Quillback rockfish	*Sebastes maliger*	38
Codfishes	Gadidae	28
Rock sole	*Lepidopsetta bilineatus*	24
Eelpouts	Zoarcidae	22
Lingcod	*Ophiodon elongatus*	22
Poachers	Agonidae	21
Pacific cod	*Gadus macrocephalus*	18
Sculpins	Cottidae	15
Unknown Rockfish	Sebastinae	14
Shiner perch	*Cymatogaster aggregata*	12
Pacific herring	*Clupea pallasi*	11
Walleye pollock	*Theragra chalcogramma*	6
Puget sound rockfish	*Sebastes emphaeus*	5
Yelloweye rockfish	*Sebastes ruberrimus*	5
Copper rockfish	*Sebastes caurinus*	4
Dover sole	*Microstomus pacificus*	3
Sablefish	*Anoplopoma fimbria*	3
Skates	Rajidae	3
Blackfin sculpin	*Malacocottus kincaidi*	2
Redstripe Rockfish	*Sebastes proriger*	2
Octopus	Octopoda	2
Pacific halibut	*Hippoglossus stenolepis*	2
Brown cat shark	*Apristurus brunneus*	1
Greenlings	Hexagramminae	1
Longnose skate	*Raja rhina*	1
Pacific lamprey	*Lampetra tridentata*	1
Plainfin Midshipman	*Porichthys notatus*	1
Pricklebacks	Stichaeidae	1
Rosethorn rockfish	*Sebastes helvomaculatus*	1

Table 5. Depth statistics for transects, total fish, all rockfish and other groundfish.

Distributions	Depth (m)					
	Count	Minimum	25%	Median	75%	Maximum
All Transects	19039	12.0	50.9	98.9	162.4	207.5
All Observed Fish	1226	19.8	76.8	85.7	123.0	207.4
All Rockfish	119	23.4	47.0	100.2	153.2	193.2
All Other Groundfish	1107	19.8	77.3	85.5	115.3	207.4

Table 6. Depth statistics for all species of fish observed during transects.

Species	Depth (m)					
	Count	Minimum	25%	Median	75%	Maximum
Pacific Hake	388	64.7	77.3	83.0	85.4	207.1
Spotted Ratfish	222	75.6	113.7	162.4	184.1	207.4
Pleuronectiformes	108	30.4	80.6	96.9	101.9	206.7
Greenstriped rockfish	52	56.5	98.8	133.9	156.5	185.5
Quillback rockfish	37	23.4	25.5	32.6	73.7	171.8
Gadidae	28	83.6	85.0	86.2	89.2	98.1
Rock Sole	24	32.4	50.2	51.3	57.9	90.0
Lingcod	22	23.5	33.5	60.3	108.3	205.8
Zoarcidae	22	47.0	79.2	85.7	97.7	122.9
Agonidae	21	38.4	78.3	83.4	87.4	99.0
Yelloweye rockfish	5	152.5	166.0	181.0	181.4	183.9
Puget Sound rockfish	5	63.2	63.2	63.2	97.8	98.7
Copper rockfish	4	27.7	28.5	29.1	29.5	30.1

Table 7. Temperature statistics for all species of fish observed during transects.

Species	Temperature (°C)					
	Count	Minimum	25%	Median	75%	Maximum
Pacific Hake	388	8.4	8.4	8.4	8.5	9.3
Spotted Ratfish	222	8.4	8.7	8.9	9.2	9.4
Pleuronectiformes	100	8.4	8.5	8.5	8.6	9.3
Greenstriped rockfish	52	8.4	8.6	8.7	8.9	9.2
Quillback rockfish	28	8.4	8.4	8.4	8.8	9.0
Gadidae	28	8.5	8.5	8.5	8.5	8.5
Rock Sole	23	8.4	8.4	8.4	8.4	8.5
Zoarcidae	22	8.4	8.5	8.5	8.5	8.8
Lingcod	20	8.4	8.4	8.5	8.7	9.4
Agonidae	20	8.4	8.4	8.5	8.5	8.6
Yelloweye rockfish	5	8.8	9.1	9.2	9.4	9.4
Puget Sound rockfish	5	8.4	8.4	8.4	8.6	8.6
Copper rockfish	—	—	—	—	—	—

Table 8. Total proportions of habitat observed over all transects.

Substrate Type	**% Total**
Bedrock	20.1
Boulder	0.1
Cobble	0.1
Mixed Coarse	27.8
Gravel	0.0
Sand	18.5
Mud	33.4
Complexity	**% Total**
Low	56.9
Medium	43.1
Habitat Model	**% Total**
Rockfish Habitat	50.5
Non-Rockfish Habitat	49.5

Table 9. Mean densities of fish species over areas of ‘low’/’medium’ benthic complexity, ‘rockfish habitat’ versus ‘non-rockfish habitat’, and over primary substrate types observed on video.

Species	n	Density (Fish / km²)										
		Complexity		Habitat Model		Primary Substrate Type						
		Low	Medium	Outside	Inside	Bedrock	Boulder	Cobble	Mixed Coarse	Gravel	Sand	Mud
Pacific Hake	322	28842	275	29029	0	10166	0	0	27485	—	0	16625
Spotted ratfish	151	6573	5965	8003	3602	2536	0	0	6428	—	910	8038
All Flatfish	122	6944	2878	6420	3280	774	75008	0	3196		1628	6721
Unidentified Flatfishes	98	6703	1483	6267	1903	674	75008	0	3050	—	1628	5608
Greenstriped rockfish	44	3080	1626	3953	363	3205	0	61970	14635	—	0	793
Quillback rockfish	32	835	811	530	1125	4023	0	0	352	—	156	86
Rock sole	24	240	1394	155	1376	57	0	0	146	—	0	1113
Eelpout	22	1750	153	1514	438	0	0	0	0	—	0	1669
Lingcod	20	654	828	834	523	1525	24859	0	785	—	0	462
Gadids	16	1049	0	1049	0	918	0	0	0	—	0	0
Copper rockfish	3	170	0	0	217	563	0	0	0	—	0	0
Yelloweye rockfish	3	195	0	76	151	0	0	0	311	—	0	696
Puget Sound rockfish	2	74	68	74	62	0	0	0	2433	—	0	65
Rosethorn rockfish	1	38	0	38	0	0	0	0	35	—	0	0

Table 10. Median densities of fish species over areas of ‘low’/’medium’ benthic complexity, ‘rockfish habitat’ versus ‘non-rockfish habitat’, and over primary substrate types observed on video.

Species	n	Density (Fish / km²)										
		Complexity		Habitat Model		Primary Substrate Type						
		Low	Medium	Outside	Inside	Bedrock	Boulder	Cobble	Mixed Coarse	Gravel	Sand	Mud
Pacific Hake	322	0	0	0	0	0	0	0	0	—	0	0
Spotted ratfish	151	2468	5525	7209	0	0	0	0	4873	—	0	7414
All Flatfish	122	3246	1601	1939	2513	0	75008	0	1218	—	0	3071
Unidentified Flatfishes	98	2914	1569	1901	1698	0	75008	0	1218	—	0	2394
Greenstriped rockfish	44	0	340	1389	0	0	0	61970	0	—	0	0
Quillback rockfish	32	0	425	0	849	2321	0	0	0	—	0	0
Rock sole	24	0	0	0	0	0	0	0	0	—	0	0
Eelpout	22	0	0	0	0	0	0	0	0	—	0	0
Lingcod	20	0	207	0	0	0	24859	0	0	—	0	0
Gadids	16	0	0	0	0	0	0	0	0	—	0	0
Copper rockfish	3	0	0	0	0	0	0	0	0	—	0	0
Yelloweye rockfish	3	0	0	0	0	0	0	0	0	—	0	0
Puget Sound rockfish	2	0	0	0	0	0	0	0	0	—	0	0
Rosethorn rockfish	1	0	0	0	0	0	0	0	0	—	0	0

Table 11. Comparison of mean density of quillback rockfish over microscale habitat type as estimated during the 2003 towed camera survey and the 2005 ROV survey.

Year	Mean Density (Number per km²)					
	Bedrock	Boulder	Cobble	Mixed Coarse	Sand	Mud
2003	12283	7632	253	405	5506	0
2005	4023	0	0	352	156	96

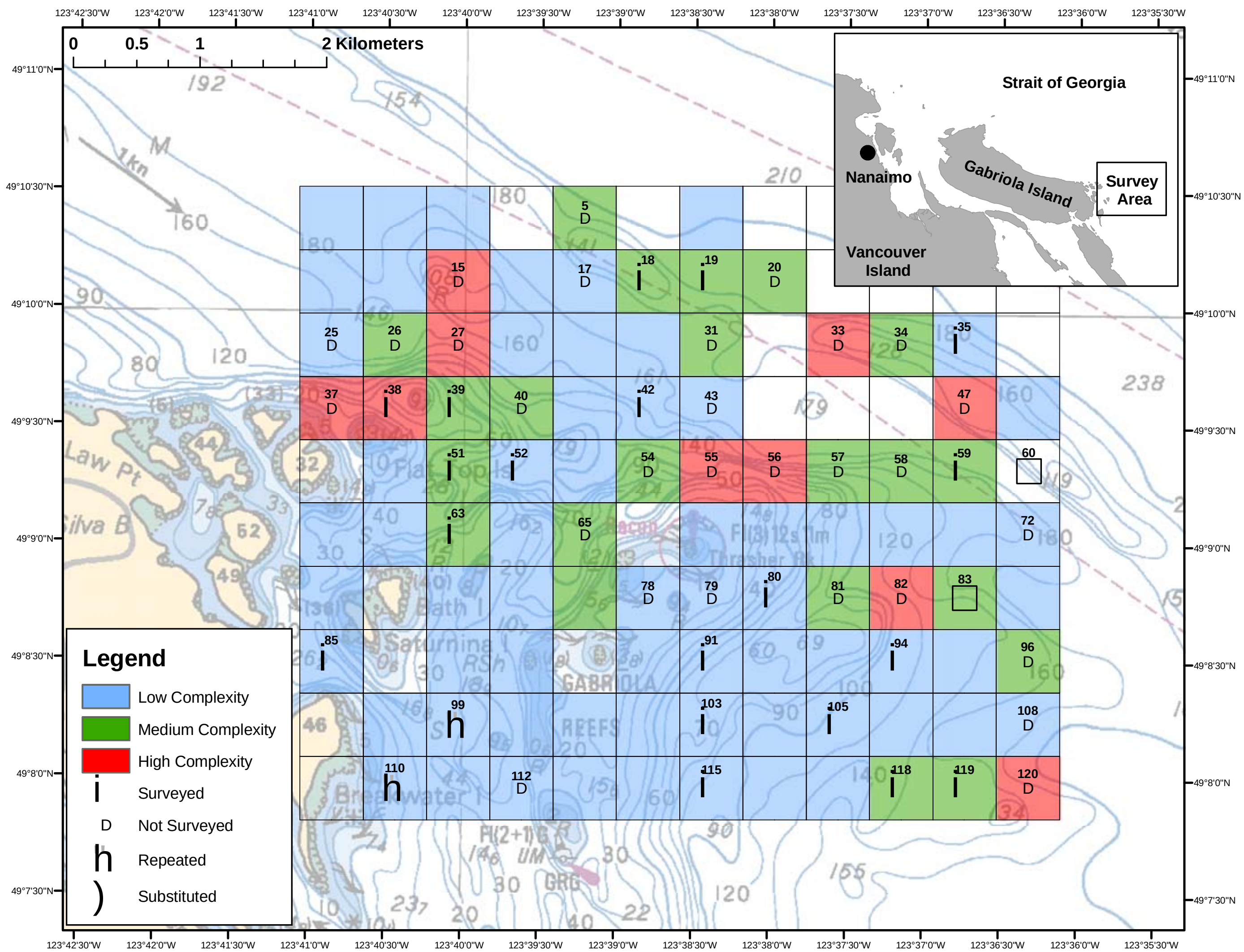

Figure 1. Chart showing general location (inset) and detailed view of the survey area.

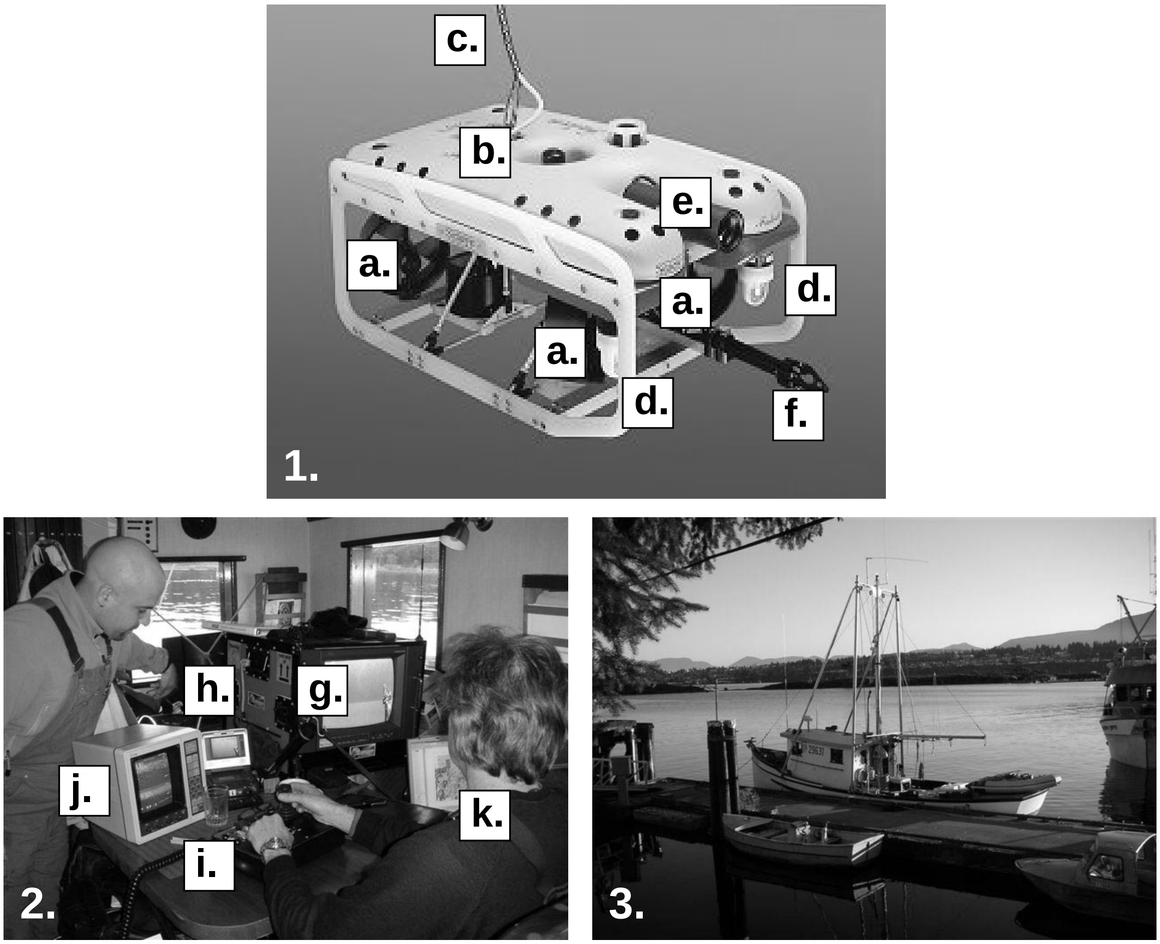

Figure 2. Photographs of the Falcon ROV (1.), the equipment setup (2.) and the F/V Mariko (3.). Important parts are labeled. For the ROV: vectored thrusters (a), vertical thruster (b), umbilical (c), halogen floodlights (d), video camera (e), manipulator (f). For the topsides equipment: video monitor (g), MiniDV recording deck (h), vehicle control console (i), depth sounder (j) and laptop running real-time tracking software (k).

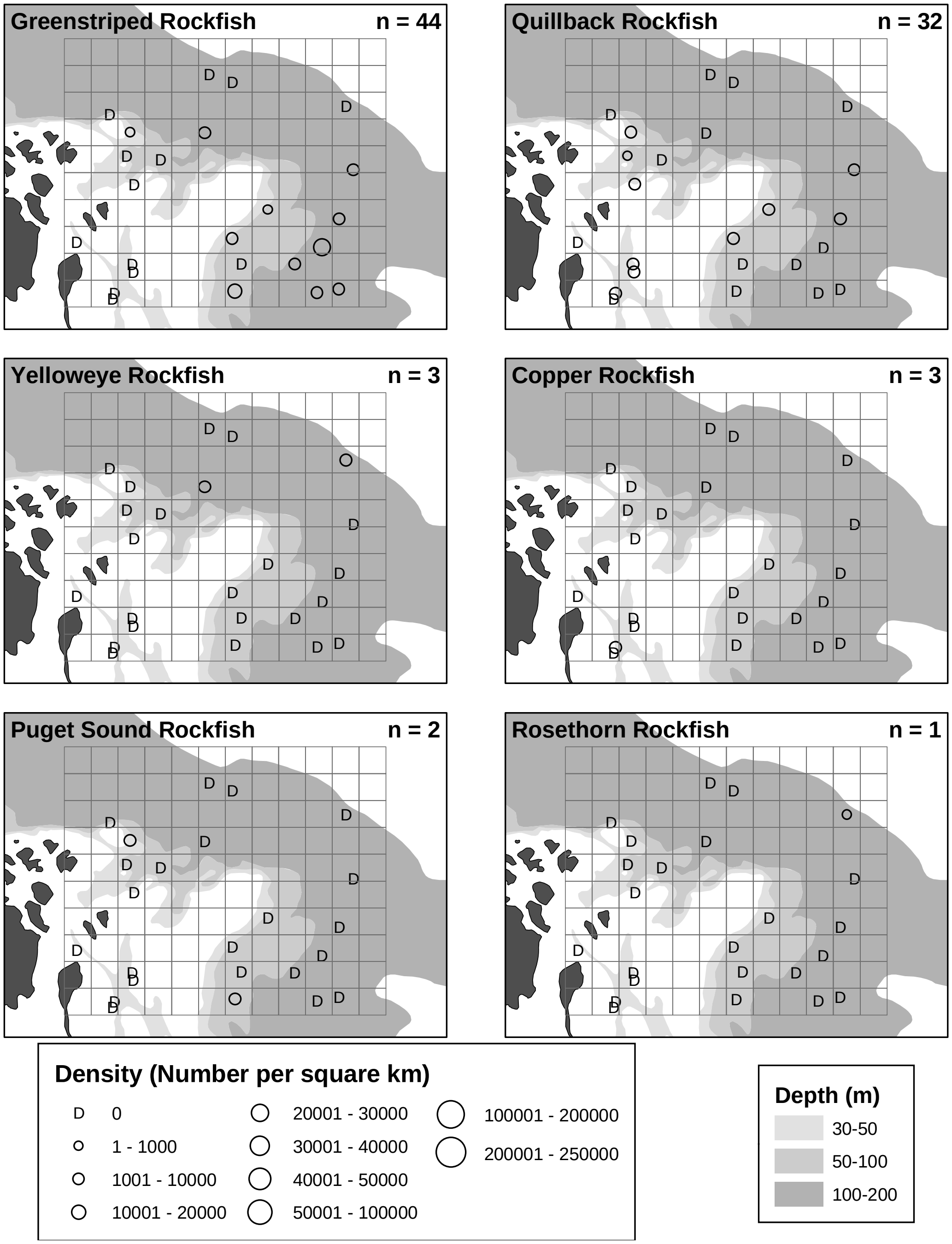

Figure 3. Bubbleplots showing simplified bathymetry and distribution of rockfish densities as observed over the course of ROV transects.

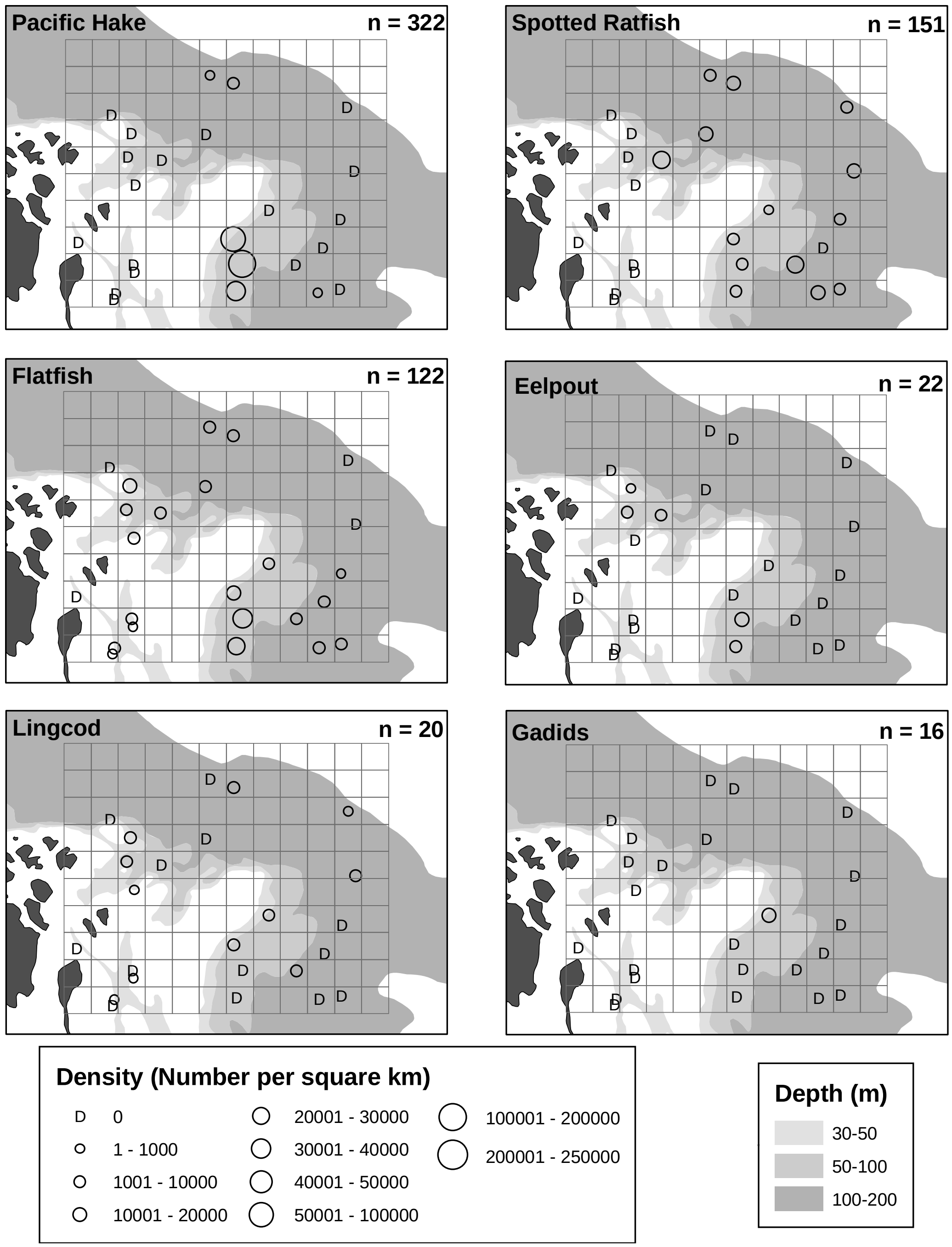

Figure 4. Bubbleplots showing simplified bathymetry and distribution of groundfish densities as observed over the course of ROV transects.

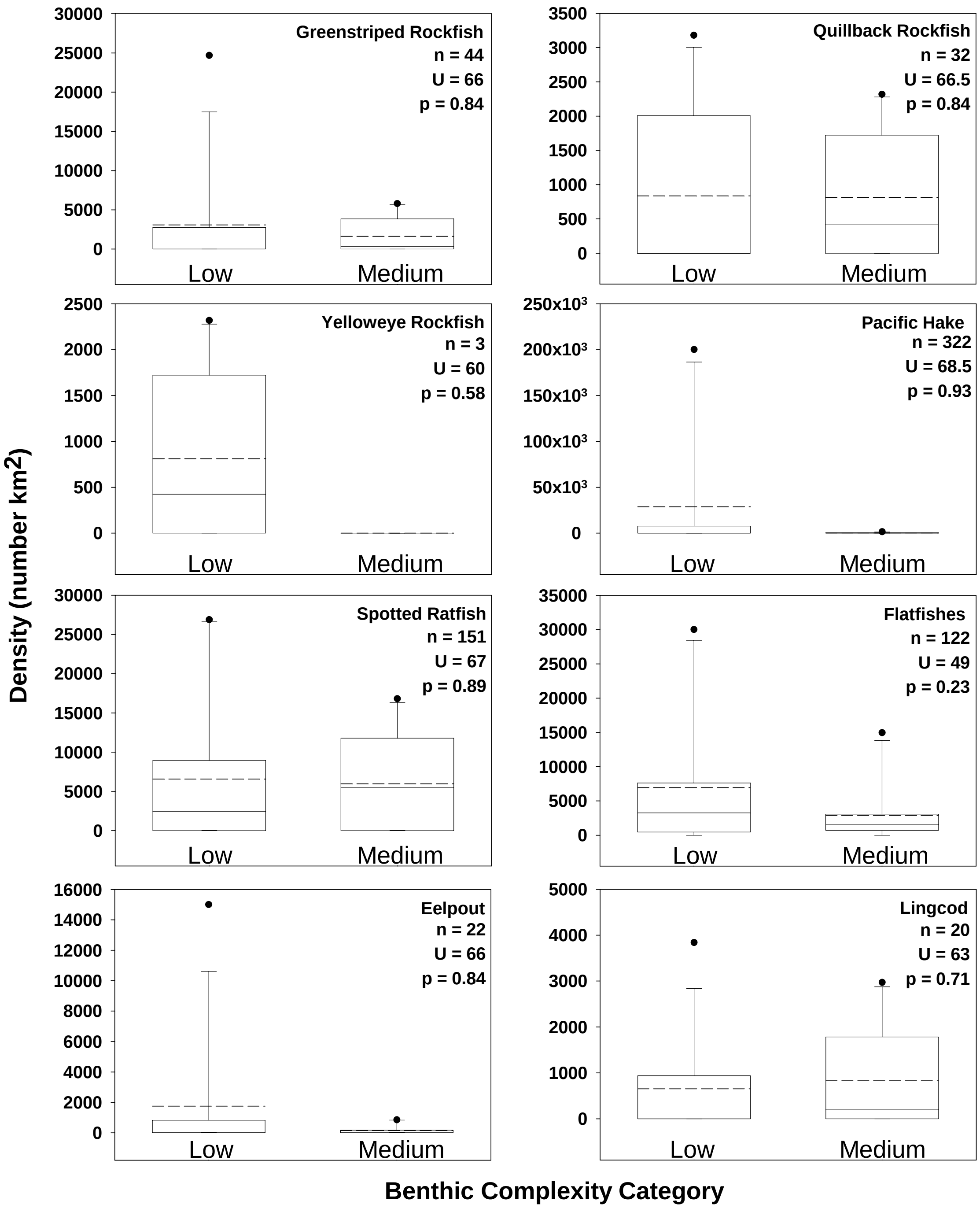

Figure 5. Distributions of fish species density from areas of 'low' and 'medium' benthic complexity. The solid line through each box represents the median value while the 2nd and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 90th and 10th percentiles, and each individual outlier is plotted. Mean values are represented by dashed lines. Mann-Whitney U-test statistics are presented.

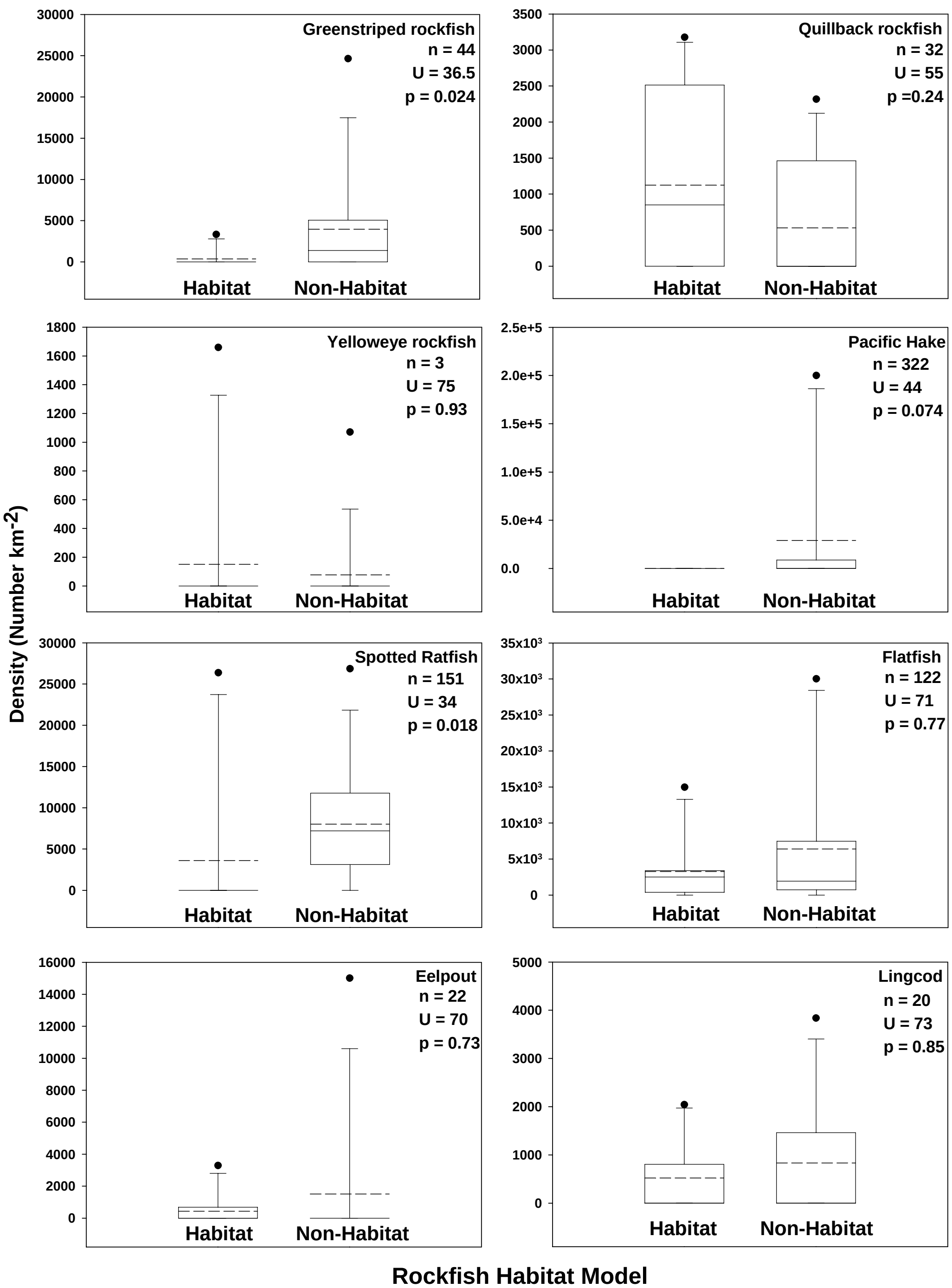

Figure 6. Distributions of fish species density from areas of 'habitat' and 'non habitat' as indicated by the rockfish habitat model. The solid line through each box represents the median value while the 2nd and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 90th and 10th percentiles, and each individual outlier is plotted. Mean values are represented by dashed lines. Mann-Whitney U-test statistics are presented.

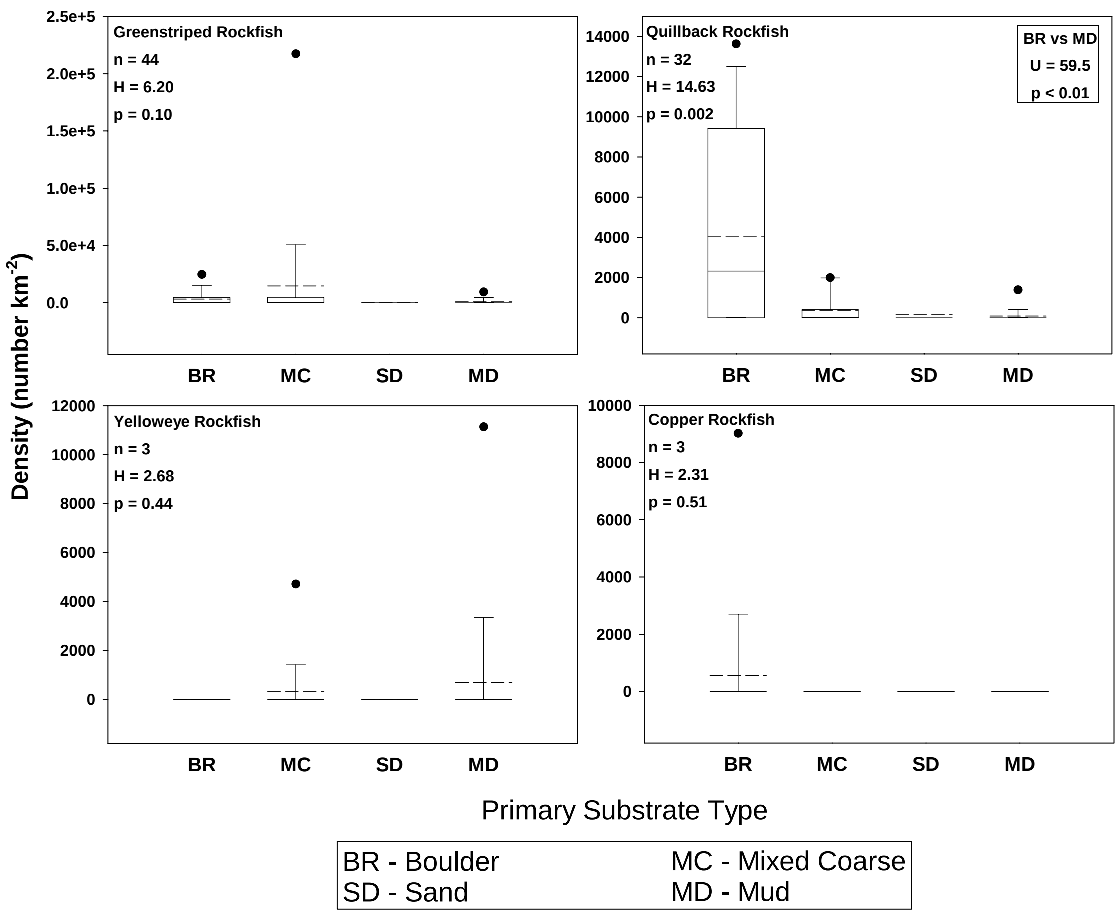

Figure 7. Distributions of rockfish species density from four categories of primary substrate as observed from the ROV. The solid line through each box represents the median value while the 2nd and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 90th and 10th percentiles, and each individual outlier is plotted. Mean values are represented by dashed lines. Kruskal-Wallis test statistics are presented.

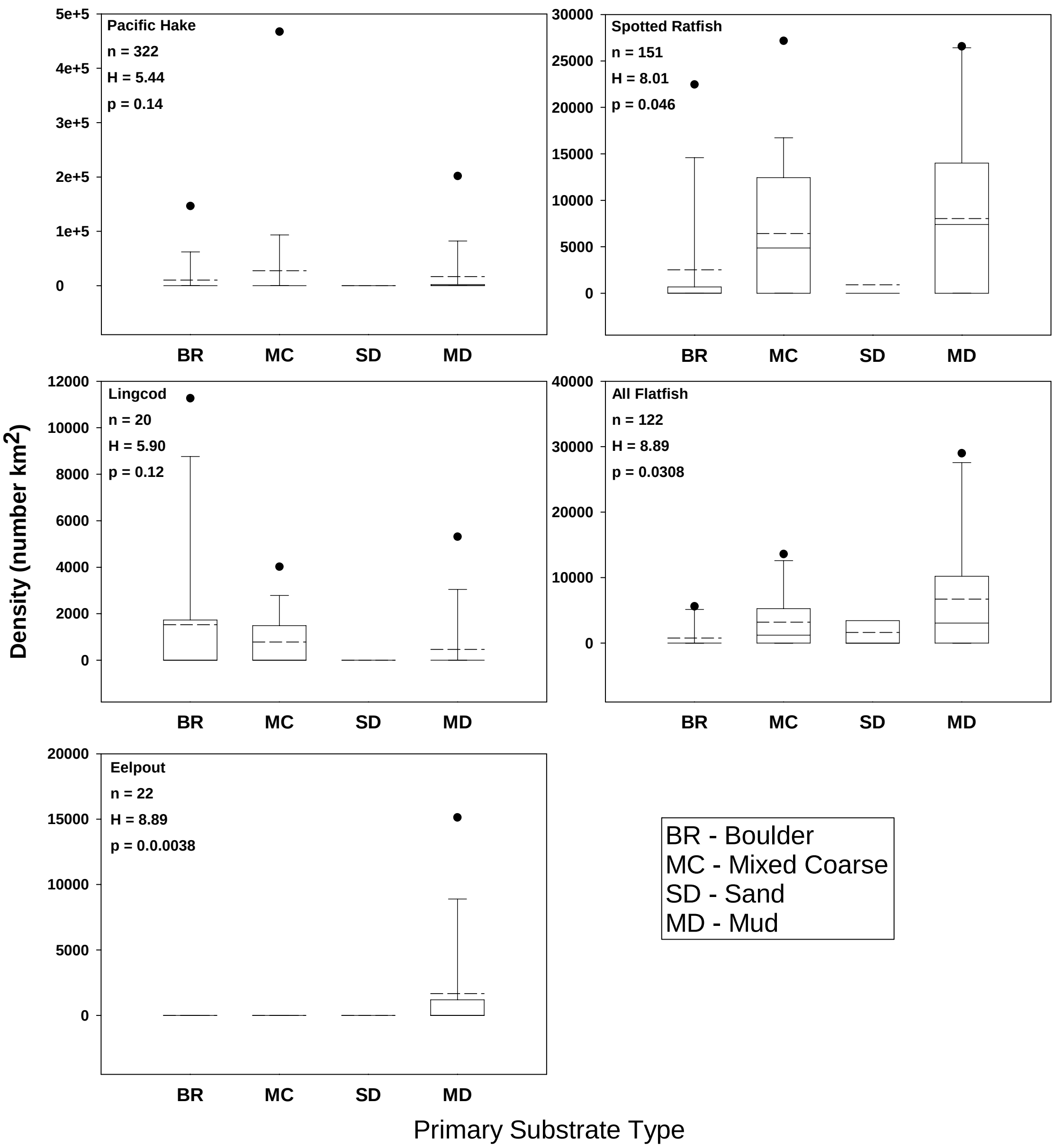

Figure 8. Distributions of groundfish species density from four categories of primary substrate as observed from the ROV. The solid line through each box represents the median value while the 2nd and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 90th and 10th percentiles, and each individual outlier is plotted. Mean values are represented by dashed lines. Kruskal-Wallis test statistics are reported.

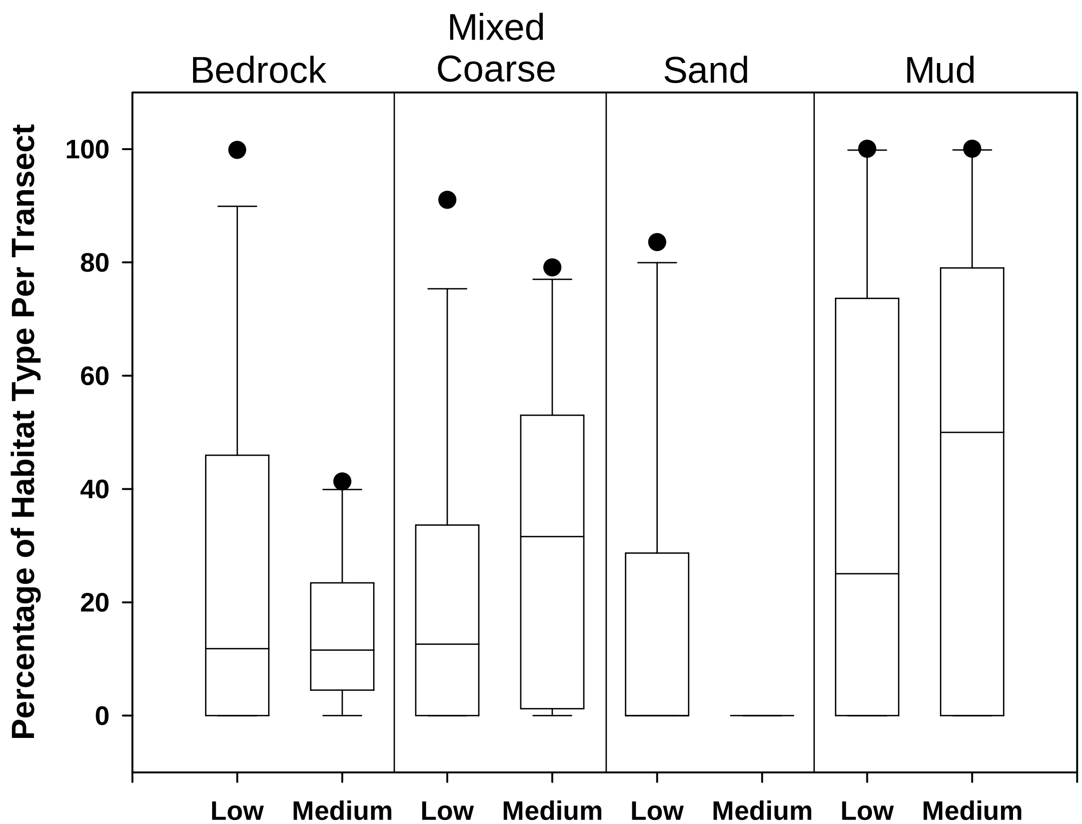

Figure 9. Boxplots showing the distribution of observed microscale habitat by area over transects conducted within areas of 'low' and 'medium' complexity. The solid line through each box represents the median value while the 2nd and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 90th and 10th percentiles, and each individual outlier is plotted.

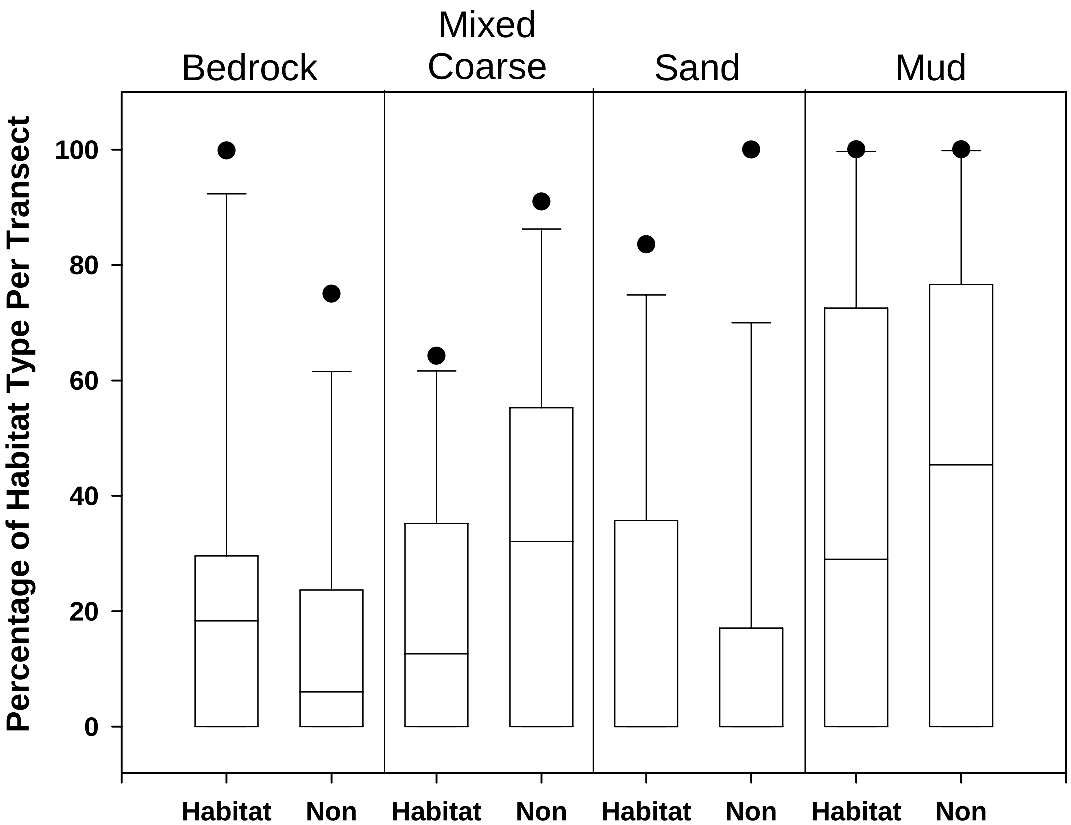

Figure 10. Boxplots showing the distribution of observed microscale habitat by area over transects conducted within areas of ‘rockfish habitat’ and ‘non rockfish habitat’. The solid line through each box represents the median value while the 2nd and 3rd quartiles are indicated by the upper and lower limits of each box. Whiskers above and below each box indicate the 90th and 10th percentiles, and each individual outlier is plotted.

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Appendix. Summary descriptions of transects over the course of the 2005 ROV survey.

Transect	Date	Transect Synopsis
1	3/3/2005	sandy bottom with rocky hilly area in middle. Dense crinoids towards end.
2	3/3/2005	sandy initially, easing gradually to larger cobbles and wrinkled bedrock hills, returning to sand afterwards
3	3/3/2005	mixed coarse with shell, some bedrock. Dense covering of small organisms (scallops or anemones). Large dropoff, followed by rolling muddy bedrock, with urn sponges.
4	3/3/2005	mud-covered bedrock, some wood debris. Few organisms. More mud in deeper area, fewer rocks
5	3/3/2005	muddy bottom with some gravel and protruding bedrock. Small sponges on what may be bioherms. Squat lobsters abound.
6	3/3/2005	heavily sedimented sponge debris. Possible hard bottom underneath. Thick foliose sponges on slope, still covered in mud. Steep rock wall with sponge, high complexity. Almost lost ROV when umbilical and clump weight got snagged.
7	3/4/2005	mud-covered bottom, possibly on mixed coarse substrate. Occasional corals and sponges. Sloping towards end, with boulders
8	3/4/2005	heavily encrusted rolling bedrock, with mud, bryozoans and finger sponges. Steep rock face towards middle.
9	3/4/2005	soft mud/silt with burrows. Occasional boulders
10	3/4/2005	soft silt with burrows, lots of hake/pollock
11	3/4/2005	mud-covered mixed coarse substrate giving way to muddy silt with occasional protruding cobbles and sponges. Later, boulders and more sponges, changing to bedrock ridge alternating with muddy bedrock.
12	3/4/2005	silty mud with borrows and occasional mixed coarse and boulders, with mud cover lessening later on.
13	3/6/2005	mud with sea pens - boulders, sponges later on. Some unidentified rockfish. Aborted halfway because of log boom approaching
14	3/6/2005	rough bottom. Continued into block 60, but didn't denote is as a new transect, because bottom was touch-and-go for the pilot. Primnoa corals, boulders, sponges and rockfish. Great habitat.
15	3/6/2005	mud with some sponges and burrows, and some mixed coarse substrate
16	3/6/2005	muddy, changing to muddy mixed coarse with corals and sponges, then a sheer rock wall, causing aborting of transect
17	3/6/2005	muddy bedrock ridges, followed by muddy flat sloping bedrock with brachipods/scallops and changing to muddy mixed coarse
18	3/6/2005	muddy bottom with burrows and occasional boulders and small sponge bioherms
19	3/6/2005	mud with burrows, mixed coarse bottom with bryozoans. Some mixed coarse covered in mud.
20	3/7/2005	flat muddy bottom with few burrows, more mixed coarse as transect continues, changing to silted bedrock. Possible trawl scar at 6 minutes?
21	3/7/2005	silt-covered bedrock with sponges and dense bryozoan cover. Slopes upwards with increased mixed coarse over bedrock. Ddense sponges and less silt towards end.
22	3/7/2005	currents too strong, and a rock wall approaching caused us to abort after not very long
23	3/11/2005	rolling bedrock with some sand and fuzzy growth and sponges. Dense crinoids on rocks. Muddy flats after rocks with some mixed coarse, possibly some small bioherms
24	3/11/2005	rolling bedrock with some sand and fuzzy growth. Crinoids and sand transitioning to muddy flats before hitting a steeper rocky face followed by rocky flat with dense crinoids. Mud and mixed coarse afterwards, switching to mud with burrrows.

Appendix 2. Habitat descriptor codes used with video review

Codes and descriptions for habitat substrate classifications	
1	Artificial (pilings, tires, ships, etc)
2	Hardpan (e.g. sandstone)
3	Bedrock
4	Boulder (rocks > 25cm)
5	Cobble (6 - 25cm)
6	Mixed Coarse (cobble/gravel/shell)
7	Gravel (small rocks and pebbles 1 - 6cm)
8	Sand (or sand/shell)
9	Mud (or mud/shell)
Codes and descriptions for habitat relief	
1	None (flat or rolling)
2	Low (vertical relief 0.5 - 2m)
3	High (vertical relief > 2m)
4	Steep slope or wall
Codes and descriptions for habitat complexity classifications	
1	Simple (flat/rolling with no crevices)
2	Low (very few crevices)
3	Medium (more than a few but not lots of crevices)
4	High (lots of crevices)
Codes and descriptions for habitat biocover classifications	
1	Bare (<10% cover)
2	Kelp
3	*Ulva spp.*
4	Other algae
5	Algal mat
6	Scallops
7	Barnacles
8	Anemones (mainly *Metridium spp.)*
9	Encrusting organism complex (Psolus spp., barnacles, hydroids, bryozoans, anemones)
10	Eelgrass
11	Opiuroids
12	Tube worms/empty tubes
13	Debris/detritus
14	Sea pens/whips
15	Sponges
99	Unidentified
Codes and descriptions for habitat biocover thickness classifications	
1	0-25% cover
2	26-50% cover
3	51-75% cover
4	76-100% cover