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Chiswell Ridge Lingcod ROV Survey with Ancillary Population Estimates of Demersal Shelf Rockfish, 2005

by

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Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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by
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ABSTRACT

Current management of lingcod *Ophiodon elongates* and demersal shelf rockfish (DSR) in the Cook Inlet Management Area is based on guideline harvest levels and season restrictions for the commercial fishery and bag limit, size, and seasonal restrictions for the recreational fishery. These management measures are either based on historical harvest levels or are set with consideration to life history traits and do not rely on abundance. The purpose of this survey was to estimate, for the first time, the abundance of lingcod within a section of the North Gulf District in the Cook Inlet Management Area. Chiswell Ridge was selected for this 2005 survey because it is a historically important recreational and commercial harvest area. Lingcod were the focus of this survey but ancillary estimates for DSR were made because both species occupy similar habitats. A closed population was assumed because the Chiswell Ridge is surrounded by relatively deep waters, extending to the lower limit of typical lingcod depth distribution. A neighboring area was also surveyed to compare and investigate variation in density estimates. Strip transects were conducted with a remotely operated vehicle (ROV) to estimate lingcod and DSR abundance within rocky habitats delineated from multi-beam and side-scan sonar data. Significant differences in lingcod density were detected between study areas. Chiswell Ridge abundance estimates were relatively precise for all species; the coefficient of variation for lingcod was 20%, adult yelloweye rockfish *Sebastes ruberrimus* was 15%, and quillback rockfish *Sebastes maliger* was 18%.

Key words: Lingcod *Ophiodon elongates*, yelloweye rockfish *Sebastes ruberrimus*, demersal shelf rockfish (DSR), remotely operated vehicle ROV, transect, Cook Inlet.

INTRODUCTION

The management of many marine groundfish species is complicated by the lack of quantitative assessment data. This is particularly true for lingcod *Ophiodon elongates* and rockfish (*Sebastes* spp.) in the Cook Inlet Management Area. Many traditional sampling methods used to estimate population size or trends are not practical for these species because of their affinity for rocky habitats, and in the case of rockfish, mark–recapture methods utilizing tagging are problematic because they have a closed swim bladder. The lack of assessment information has hindered development of management objectives and reference points. Rockfish exhibit low reproductive rates and are long lived and slow growing, and therefore particularly vulnerable to overexploitation (Adams 1980). Lingcod are more resistant to fishing pressure because they mature earlier, are shorter lived, and are faster growing. Both species have been overfished in many areas within their range and rebuilding depleted populations has taken years or stocks continue to be depressed (Jagielo et al. 1997; Adams et al. 1999; Parker et al. 2000). These issues underscore the need to develop robust assessment methods for these species.

The Chiswell Islands-Chiswell Ridge area has historically accounted for a large proportion of the recreational (Stock and Meyer 2005) and commercial[1] lingcod and demersal shelf rockfish (DSR) harvest in the Cook Inlet Management Area. High recreational lingcod harvest and lack of biological data prompted the Alaska Department of Fish and Game (ADF&G) Division of Sport Fish to conduct a jigging survey in 1998 of index population abundance (Bethe and Meyer 2002). Survey data provided valuable insights into the general distribution of lingcod along the Chiswell Ridge but because no similar surveys have been conducted since 1998, the status of the lingcod population remains unknown.

The density and distribution of benthic fishes are often strongly correlated with habitat type (Phillips 1959; Smith and Forester 1973; Jagielo 1988; O'Connell 1993). For structure-oriented species descriptions of the quantity and spatial distribution of available habitats are important for

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[1] Statewide electronic fish ticket database [Internet]. 1985- . Juneau, AK: Alaska Department of Fish and Game, Division of Commercial Fisheries.

designing surveys, estimating population size, and scaling harvest guidelines based on available habitat. Combining biological data and fish density estimates with the areal extent of available habitat can be an efficient and cost-effective assessment method, and can increase the precision of biomass estimates by focusing sampling effort in a way that minimizes variance within the habitat.

With the knowledge that benthic habitat types can determine groundfish occurrence and distribution, an interest developed in mapping and classifying habitats over broad areas (Able et al. 1987; Yoklavich et al. 2000; Nasby-Lucas et al. 2002). Side-scan and multi-beam sonar have been used extensively to collect the data necessary to characterize mesoscale areas of the seabed. Habitat-based assessments take advantage of the affinity of fishes for particular habitat types by focusing sampling effort in preferred habitats. Habitat-specific density estimates can then be integrated with available habitat area delineated from high-resolution sonar to obtain abundance estimates. This assessment method has become common, especially along the Pacific west coast and in Alaska (O'Connell and Carlile 1993; Fox et al. 2000; Karpov et al. 2001; O'Connell et al. 2003; Yoklavich and O'Connell 2008). Both submersibles and remotely operated vehicles (ROV) have been used to assess rockfish and other groundfish species.

The ADF&G Central Region conducted an ROV pilot survey along Chiswell Ridge in 2004 to develop strip transect sampling methodology and to collect preliminary data on lingcod density and habitat use (Byerly 2005). Based on the results of that survey, an ROV habitat-based survey to assess lingcod abundance was conducted along the Chiswell Ridge in April 2005. Only rocky reef seafloor features were sampled and strip transect density estimates were multiplied by the available rocky habitat to obtain abundance estimates. Dissimilar resolution bathymetry data sets were available for delineating rocky reef features. This influenced both the survey design and postsurvey estimates. The northern half of the ridge had been previously mapped using multi-beam sonar by the National Oceanic and Atmospheric Administration (NOAA). Accurate estimates of the areal extent of available rocky substrate were obtained from these data because of the high resolution of the 2 m gridded bathymetry. However, estimates of the extent of rocky substrate along the southern portion of the ridge were based on low-resolution single-beam and lead-line survey data (50 m gridded bathymetry). Due to the lower resolution of these data, it was probable that other rocky reefs either were undetected or the boundaries of identified reefs were not precisely defined. This area was mapped in 2006 using multi-beam and side-scan sonar to more precisely inventory and delineate available rocky reef features (Byerly et al. 2008). Although the 2005 ROV survey was designed and conducted using earlier habitat delineations based on the low resolution sonar data for the southern Chiswell Ridge, density and population estimates for this report were calculated using updated delineations based on the high resolution sonar data collected in 2006.

OBJECTIVES

The primary objective of this study was to estimate lingcod density and abundance along the Chiswell Ridge using an ROV and produce ancillary estimates of yelloweye rockfish *Sebastes ruberrimus* and quillback rockfish *S. maliger* density and abundance. Yelloweye and quillback rockfish are the most harvested DSR for both commercial and recreational fisheries in the area. A secondary objective was to survey a neighboring area to contrast density and variance estimates to Chiswell Ridge. The habitat-based approach required processing existing single-beam and multi-beam bathymetry data (Byerly 2005, 2007) and was augmented through the collection of new side-scan and multi-beam sonar data (Byerly et al. 2008).

METHODS

SURVEY AREA

Chiswell Ridge is a prominent, relatively shallow seafloor feature in the northern Gulf of Alaska. It is surrounded to the north, east, and west by deep fjords and to the south by the deeper continental shelf (Figure 1). A 100 m contour generally defines the boundary of Chiswell Ridge (Figure 2). Lingcod are typically concentrated in depths less than 100 m. Lingcod in British Columbia are reported to be most common in the upper 50 fathoms (91 m; Hart 1973). A review of area Sport Fish harvest statistics indicated that the majority of the lingcod recreational catch occur in water shallower than 100 m (S. C. Meyer, Sport Fish Biologist, ADF&G, Homer; personal communication). Therefore, the Chiswell Ridge study area boundary was defined by those waters along the ridge within the 100 m contour. No assumptions were made for how DSR were distributed within the study area. Although density and abundance estimates are reported for DSR, their depth distribution may be skewed toward deeper depths than those sampled in this survey.

In addition to Chiswell Ridge, a section of Harris Bay (referred to as Granite I for this report) was surveyed to compare lingcod densities between the 2 areas (Figure 2). Harris Bay lies approximately 15 km west of Chiswell Ridge and is separated by Ailiak Passage at an average depth of 200 m. Granite Island is a prominent feature located in the eastern portion of Harris Bay. Relatively high lingcod densities were observed in the vicinity of Granite I during multiple scuba surveys for black rockfish *S. melanops* from 2001 to 2003. Much of this area had been mapped by NOAA using multi-beam sonar and seafloor features appeared different than those along Chiswell Ridge. These factors combined make this a desirable area to compare lingcod density and variance estimates.

HABITAT DELINEATION AND SURVEY DESIGN

Lingcod abundance and distribution are often correlated with habitat type, with fish occurring most often in rocky substrates (Phillips 1959; Smith and Forester 1973; Jagielo 1988; O'Connell 1993; Byerly 2005). Although lingcod may prefer rocky habitats, they do occur over soft substrates (Jagielo et al. 2003). Anecdotal reports from commercial gillnet and groundfish pot fisheries indicate catches of lingcod occur outside of rocky substrates. Additionally, lingcod trawl fisheries along the Pacific west coast harvest lingcod in habitats that are probably not from higher-relief rocky reef substrates. Nonetheless, only rocky substrates were sampled during this survey with the objective of obtaining higher precision abundance estimates and accepting the bias of not sampling all available habitats. Therefore, the estimates produced here are considered conservative.

In order to delineate rocky substrates, it was necessary to process and analyze many bathymetric data sets. This was done as part of a larger ADF&G Central Region seafloor mapping project. Bathymetry from NOAA hydrographic surveys was the major data source used in this effort. The NOAA Coast Survey has been using multi-beam sonar for charting Alaska waters since 1998. The resolution of these data varies depending on depth, ranging from 2 m horizontal resolution for 100 m of depth to 5 m horizontal resolution for 300 m of depth. In contrast, data collected earlier than 1998 using single-beam sonar or lead-line typically have horizontal resolution varying from 25 m to 500 m depending on when the data were collected, depth, or other factors, such as obtaining higher resolution data for shallow-water hazards. The northern portion of the Chiswell Ridge was mapped by NOAA using multi-beam sonar in 2000 and 2001, but older single-beam and lead-line data collected between 1928 and 1930 were the most recent data available for the southern portion.

Both the multi-beam and single-beam/lead-line data were processed into raster data sets using ESRI Spatial Analyst[2]. The multi-beam data were gridded at 2 m and the single-beam/lead-line data were gridded at 50 m. An inverse distance weighted interpolation method was used to assign depth values to raster cells between data points to retain evidence of rugosity in the benthic terrain. Hillshades of the raster grids were made to enhance the rugose features. The meso-scale rocky features appeared as rugose outcrops or pinnacles and are referred to as rocky reefs throughout this report. Additionally, steep rugose shorelines were identified as probable rocky features. The rugose features were delineated by manually digitizing polygons in ArcGIS. The resulting digitized rocky reef polygons were then compared to available bottom sample data to confirm the existence of hard bottom types.

There were large differences in the precision of rocky reef delineations between the high- and low-resolution data sets (Figure 3). This prompted us to map the southern half of the Chiswell Ridge study area using a combination of side-scan and multi-beam sonar in 2006 (Byerly et al. 2008). This mapping effort provided much higher resolution data with which to delineate rocky reefs and confirmed the lack of rocky reefs outside of the original delineations (Figure 3). The mapping survey occurred after the 2005 ROV survey, which was conducted using rocky reef delineations based on the low-resolution data. The ROV abundance estimates reported here use the new delineations.

Results from the 1998 ADF&G Division of Sport Fish jig survey indicated lingcod catch per unit effort (CPUE) were higher in the southern Chiswell Ridge (Bethe and Meyer 2002). Lingcod encounter rate showed a similar pattern during the 2004 ROV pilot survey (Byerly 2005). Because there were probably differences in lingcod density between the northern and southern portions of the study area, and there were dissimilar data sources for defining rocky substrates, the study area was stratified into the Chiswell North and Chiswell South strata by the boundary, defining the southern edge of the NOAA multi-beam coverage.

A separate stratum was made for the steep-sided rocky substrates along the shoreline within the Chiswell North stratum. This was done because of the steep nature of the seafloor, which made it difficult to precisely digitize polygons around the rocky features. Additionally, it was anticipated that a different ROV deployment method would be needed to maintain a safe working distance between the shoreline and the vessel. The final Chiswell Ridge study area was composed of 3 strata (Chiswell North rocky reef, Chiswell North shoreline, and Chiswell South rocky reef) all within the 100 m contour (Figure 4). The Granite I survey area included the area seaward of Granite I to approximately 5 km east of Granite Cape, all within the 100 m contour.

ROV transect locations for the Chiswell Ridge was selected using stratified random sampling. Granite I locations were selected using simple random sampling. Random sampling points within the rocky reef polygons were chosen using PopTools 3.24 in ArcGIS ArcView 9.1. Because the ROV camera is tilted downward and produces an oblique view of the substrate, it is

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[2] Product names used in this report are included for scientific completeness but do not constitute a product endorsement.

advantageous to pilot the ROV upslope to keep more of the substrate within view. This maximizes the video quality, insures the highest likelihood of detection by enabling interstitial spaces in the substrate to be viewed, and improves the accuracy of transect width measurements. To select upslope transects, a random direction between 0° and 359° was selected for each point. In ArcView, a 0.5 km line oriented in the random direction was laid on and slid over the point until an upslope transect was achieved. If no upslope transect was found, another random direction was selected and the exercise was repeated. All transects terminated near the top of the rocky structure. If the deep end of the line extended outside of the rocky reef polygon, the entire transect was run and the data outside of the polygon was excluded later from the estimate. Transects within the Granite I rocky reef polygons were selected using the same methods. Due to the arbitrary boundary at Granite I, only density estimates are reported.

Granite I and Chiswell North shoreline transects were selected by summing the cumulative length of shoreline as measured in ArcGIS, and randomly selecting points along this distance. Half-kilometer transects were oriented perpendicular to the shoreline and terminated at mean lower low water. Once all planned transect lines were made, they were exported from ArcGIS and imported into the data acquisition software for survey preparation.

FIELD DATA COLLECTION

A Deep Ocean Engineering Phantom HD 2+2 ROV was used for this survey and deployed from the ADF&G R/V *Pandalus* (Figure 5). Additional components were added to increase the functionality of the ROV base system (Appendix A1). The ROV was positioned using an ultrashort baseline (USBL) tracking system, vessel DGPS, vessel heading sensor, and vessel pitch and roll sensor. Hypack Survey software was used for navigating transects and data acquisition (Figure 6). Real-time data acquired included Coordinated Universal Time (UTC), ROV *xy* position calculated in Hypack using the positioning sensors, ROV heading and depth from onboard sensors, and a continuous video record from a forward-looking camera recorded on a mini-DV DVR. UTC was also recorded on a video onscreen display from a time code generator and on the audio channel of tapes, allowing video data to be associated with ROV positions. To measure the size of objects and estimate the width of the transect line, 2 parallel scaling lasers were mounted 10 cm apart and above the video camera housing.

The ROV was deployed using a 200 lb clump weight for rocky reef transects following Amend et al. (2001) and without the clump weight for shoreline transects (Figure 7). Transects were always run up-current and up-slope. Upon arriving at a transect location the vessel captain assessed the drift and if it was favorable for the randomly selected direction the planned line was run. If the current was unfavorable the next random direction was assessed and so forth until a favorable direction was found. In practice, usually the first random direction was chosen. For the rocky reef transects, the ROV was allowed to run out 50 m before the umbilical was clipped into the clump weight line. A trawl float with 2.5 kg of flotation was secured at 25 m to keep the free portion of the umbilical off the bottom. The ROV descended to the bottom, down-current of the planned transect starting point, and was piloted up to the starting point of the transect. The ROV was flown approximately 1 m off the bottom at a target speed of 0.5 knots. A networked computer in the vessel’s wheelhouse allowed the captain to maintain a distance of no more than 40 m to the side or behind the ROV thus keeping it in front and away from the clump weight. Shoreline transects were run in a similar manner except a clump weight was not used and instead the umbilical handler fed and retrieved the umbilical as needed to minimize the amount of free umbilical between the ROV and vessel. All transects were run during daylight hours.

VIDEO REVIEW

A Horita Time Code Wedge was used to capture the time from the video tapes while logging observations during the video review process. All observations were later related to the ROV tracking data in a Microsoft Access database for georeferencing. Video transects were reviewed a minimum of 4 times for 1) video quality evaluation, 2) habitat classification, 3) fish enumeration, and 4) transect width measurements. A subset of transects were reviewed by 2 different viewers to assess between-viewer variability.

Video transect data were first evaluated for image quality based on visibility, erratic vehicle movement, and image loss due to high-relief substrate. Only those video segments that were classified as *Good* by the primary video quality grouping were included in any analysis (Table 1).

Multiple considerations helped determine the most appropriate seafloor classification scheme: 1) comparisons needed to be made with similar research studies along the Pacific west coast and the Gulf of Alaska, 2) factors measured needed to be biologically relevant for determining lingcod and DSR occurrence, distribution, and density, 3) because many other groundfish species would be enumerated, factors measured needed to be biologically relevant to other commercially and recreationally important species, and 4) at least some of the variables considered needed to be measured in a manner that enabled them to be scaled up to remotely sensed data – in particular, multi-beam bathymetry. The classification scheme utilized work from Stein et al. (1992) Yoklavich et al. (2000), and Karpov et al. (2001; Appendix A2). Seafloor features were classified by marking the time at the beginning and end of continuous video segments, along which the feature of interest remained constant for at least 10 sec (Hixon et al. 1991; Stein et al. 1992). Classifications were made for primary and secondary substrate type, vertical relief, crevice size, and crevice density. Primary substrate was defined as the substrate type constituting >50% of the viewing area and the secondary substrate type was defined as the next most dominant substrate type that covered between 20% and 50% of the viewing area (Stein et al. 1992).

Fish observations were recorded as point data. Fish were identified to species or recorded to the lowest possible taxa or convenient grouping (Appendix A3). Although all fish were enumerated, only the species of interest are reported here. Juvenile and adult yelloweye rockfish were enumerated separately. Juveniles were identified according to Love et al. (2002). Fish behavior was categorized at initial sighting to gauge fish response within the detection range of the camera. Response categories followed Adams et al. (1995), including 1) strongly attracted – rapidly moving into the frame; 2) weakly attracted – slowly moving into the frame; 3) no response – no movement; 4) weakly avoided – slowly moving out of frame; and 5) strongly avoided – rapidly moving out of frame. All fish that were strongly attracted to (category 1) or strongly avoided (category 5) the ROV were omitted from the analysis.

Laser separation distance was measured off the video monitor using electronic calipers at 30 sec intervals during the transect width review. If the laser points were not detected at an interval or were at an oblique angle to the substrate, the next closest available laser separation measurement was taken. Once in the database, laser separation measurements were used to calculate transect width (m) as specified below.

DATA PROCESSING AND ANALYTICAL METHODS

To estimate fish density, the area swept by the video camera must be accurately measured. Transect width was estimated using the Canadian perspective grid method (Wakefield and Genin 1987) and transect length measured from the USBL tracking data. The Canadian Perspective Grid method uses horizontal and vertical distances measured by a combination of camera tilt angle; parallel laser point measurements; camera viewing angle in water; and optical specifications of the camera to compute the focal distance and width of the video image, surface area of the seafloor in the image, and height of the camera above the bottom. An inwater calibration exercise was conducted to calculate the necessary parameter estimates (Davis and Tusting 1991). The camera was tilted 24° below the horizon and was assumed to be constant. Transect width was estimated at the 80% height of the video monitor (Fox et al. 2000). Detectability and positive species identification are much lower in the upper 20% of the viewing area because in that portion of the oblique view, fish and other objects are farthest from the camera. Fish observed in the upper 20% of the viewing area were not enumerated unless they did not move and came into view at the 80% mark as the ROV progressed.

ROV tracking data were filtered, interpolated, and smoothed before inclusion into a database. Tracking data were first filtered for outliers using a Hypack single-beam editor. One-second positions were created to relate ROV tracking data to all of the video observation. The USBL tracking system on average records a position every 2 to 3 sec, whereas the video data transcribed during the review process can occur at any second. To relate each video observation with an ROV position, it was necessary to interpolate the ROV tracking data. This was done using linear interpolation on the time and *xyz* positions in *R* statistical software package (ver. 2.11.1). Following interpolation, the data were smoothed using the *R* smooth.spline function (Hastie and Tibshirani 1990). The interpolated smoothed tracking data and video observations were imported into a Microsoft Access database and related by transect identification and time.

ET GeoWizards was used to create and segment transect polylines, and linear referencing in ArcGIS was used to help with calculating transect area and line lengths. ROV *xy* point data were first converted to polyline features. Any transect segments that fell outside of the rocky reef polygons were split at the polygon boundary and eliminated. Calibrated routes were made from the remaining lines. Video observation data were then used to create route events. The route data type accommodates the representation of multiple layers of attributes along a single line feature through the use of dynamic segmentation.

Route events were made for all *Good* video segments and then for each position where transect width measurements were taken so that distance between measurement locations could be calculated (Figure 8). These distances were then exported to the database where the final transect area swept was estimated by calculating the trapezoidal area for each transect width segment using the estimated width from adjacent segments and the distance between them. These were then summed to obtain the transect area sampled. The total available rocky reef area was simply the sum of all the digitized polygons for each stratum.

For Chiswell Ridge, there are 3 strata in the study area; density D and abundance τ were then estimated as:

$$D = \frac{\sum_{x=1}^{3}(D_x A_x)}{\sum_{x=1}^{3} A_x}, \tag{1}$$

$$\tau = \sum_{x=1}^{3} \tau_x , \tag{2}$$

where:

$$D_x = \frac{\sum_{i=1}^{k} c_i}{\sum_{i=1}^{k} a_i}, \tag{3}$$

$$\tau_x = D_x A_x . \tag{4}$$

For each stratum *x*:

A_x = the area (m^2),

τ_x = the number of fish counted for the stratum,

c_i = the number of fish counted for transect *i*,

a_i = the area (m^2) sampled for transect *i*, and

k = the number of transects.

For the Granite I study area, without stratification density D and abundance τ were estimated as:

$$D = \frac{\sum_{i=1}^{k} c_i}{\sum_{i=1}^{k} a_i}, \qquad \tau = D A . \tag{5}$$

A non-parametric bootstrap was used to estimate variance by re-sampling the transects 1,000 times (Efron 1982). Upper and lower 95% confidence intervals were calculated using the percentile method (Efron 1987).

RESULTS

The ROV transect survey was conducted between April 2 to April 7 and April 26 to April 29, 2005. There were 42 transects successfully completed at Chiswell Ridge and 14 completed in the Granite Island study area. Of the 6 planned shoreline transects, 3 were completed. Shoreline transects that were run without the use of a clump weight proved to be difficult due to the influence of drag on the unsecured umbilical. This resulted in either incomplete transects or a high percentage of unusable video due to difficulties piloting the ROV. Because of this, the 3 completed shoreline transects were not included in the analysis and the shoreline stratum was not included in the population estimates.

There were 26,603 m of transect run for both survey areas combined (Table 2). Of this, 8.5% fell outside of the rocky reef polygons and were excluded from the analysis. Of the remaining, 9.2% had bad video quality and were also excluded from the analysis. The final cumulative lengths of transect included were 15,020 m for the Chiswell Ridge study area and 6,036 m for the Granite Island study area. The total area swept for Chiswell Ridge was 23,577 m^2 and 9,641 m^2 for Harris Bay. The number of fish excluded from the analysis based on quick reactions either toward or away from the ROV varied by species (Table 3). The largest percentage excluded was lingcod (13%), followed by 5% of adult yelloweye rockfish, no juvenile yelloweye, and 4% of quillback rockfish.

Lingcod and yelloweye rockfish were patchily distributed among transects with a high frequency of zero counts (Figure 9). Quillback rockfish counts were more evenly distributed, although a high proportion of zero counts still occurred. The spatial distribution of fish within the study areas varied by species (Figures 10 and 11). Lingcod densities were generally higher in the south than the north but were patchily distributed among transects within both strata. All the Granite I transects had relatively low lingcod densities. Adult yelloweye rockfish occurred frequently at transects in the Chiswell Ridge south stratum but occurred both in lower densities and less frequently among transects in Chiswell North or Granite Island. Quillback rockfish were more widely distributed than other species. Their spatial distribution was similar between Granite I and Chiswell North.

The frequency and range of depths sampled appeared to be adequate for yelloweye and quillback rockfish, but under-sampling of shallow depth zones may have occurred for lingcod (Figure 12). Lingcod were observed from 10 m to 100 m with 26% occurring in depths less than 40 m, but sampling effort was skewed toward deeper depths and was relatively low at depths less than 40 m. The distribution of adult yelloweye and quillback rockfish observations were well within the depths sampled and no depth zones appeared to be under-sampled. Although juvenile yelloweye rockfish tended to occur deeper than others, median depth distribution was similar to the median depth sampled. Some sampling occurred outside of the 100 m survey boundary. These portions of the data were removed prior to estimation of population statistics.

Lingcod density and abundance was highest for the Chiswell south strata (Table 4). Density was significantly lower at Granite I (1,037 fish/km^2) than at Chiswell Ridge (3,360 fish/km^2). Lingcod population estimates were relatively precise with the coefficient of variation (CV) 0.20 at Chiswell Ridge and 0.22 at Granite I, and both areas had low estimated bias. Adult yelloweye rockfish density and abundance were similar for both Chiswell strata and were significantly lower at Granite I. Density of juvenile yelloweye rockfish was significantly higher in Chiswell South (1,802 fish/km^2) compared to that of the North (878 fish/km^2) but was similar between Chiswell North and Granite I. Quillback rockfish density and abundance trends were quite different than lingcod or yelloweye rockfish, being lowest in Chiswell South and having nearly identical density estimates between Chiswell North and Granite I strata. Precision was relatively high for Chiswell Ridge yelloweye rockfish (CV = 0.15) and quillback rockfish (CV = 0.18) estimates.

DISCUSSION

This survey produced the first lingcod and DSR population estimates for ADF&G Central Region. These estimates are probably of sufficient precision to reliably monitor local abundance through time. Yelloweye rockfish were estimated with similar precision to line transect submersible survey estimates in the ADF&G Southeast Region, which are used for stock assessment and management. Over the history of that assessment program, coefficient of variations ranged from 11% to 31%.

We designed the survey to estimate the population abundance of lingcod within a shallow bank defining Chiswell Ridge. We assumed minimal emigration and immigration in the survey area. Additional assumptions should be considered when interpreting the results. These can be classified into 2 areas: those associated with transect sampling methodology and those associated with sampling design. Strip transect sampling assumes that 100% of the organisms of interest are observed within the strip width. As with distance sampling, it is also assumed that organisms do not move in response to the presence of the observer prior to detection (the ROV in this case). For strip transect sampling, this refers to fish moving into or out of the transect, not within it. Specific protocols were used to maximize the number of detections during this survey, including transiting up-slope to keep more of the substrate within view and closer to the camera lens, transiting at a slow steady speed, and truncating the vertical field of view to exclude observations that were far away and in the dimly lit upper corners of the video monitor. Detection probably varies with substrate complexity, and because higher densities of both DSR and lingcod are often found in more complex habitats, it is possible that detections were lower in the more complex boulder and basement habitats. Though it is impossible to know what percentage of fish went undetected, our protocols should have minimized the possibility. To address possible responsive movement, fish were categorized by swimming speed and direction of movement. While this classification attempted to separate natural fish movement from responsive movement, it was purely qualitative. However, the nature of the classification scheme made it easy for observers to reasonably differentiate between natural and responsive movement.

Another source of error associated with the sampling methodology was transect width estimation. Laser separation distance was used to estimate transect width. This method works well on flat substrate; however, most of the substrate in this survey was rocky and complex. Video review protocols were established for selecting clear perpendicular laser fixes at defined intervals. Further, transect segments where the substrate disappeared on one side or the other (e.g., traversing a rock wall) were measured and eliminated to avoid overestimation of the viewable transect width. Although these protocols should have increased the accuracy of transect width estimates, there is a measurement error component that remains unquantified.

A strict stratified random sampling design was followed that should have provided unbiased results. Ideally, the direction chosen for running transects would be random, but to balance the logistical needs of piloting the ROV up-current and attempting to obtain the highest quality video and detection rate by piloting up-slope, alternate random directions were chosen in the field to meet these logistical needs. The bias introduced here was probably very small, although it is difficult to evaluate.

Other assumptions associated with the sampling design could potentially have had the most influence on the results. We assumed that (a) all rocky habitats were mapped, (b) fish occurred predominantly in rocky reef habitat, and (c) it was a closed population. The rocky shoreline habitat was difficult to delineate and sample. For this area, we used a different deployment method to maintain a safe working distance off the beach. In practice, operating with the clump weight would probably be more effective for sampling shoreline habitats. This approach will be used in future surveys. Due to sampling difficulties in the field, the shoreline stratum was excluded from the population estimates, resulting in an underestimate of total abundance. During a lingcod jig survey in the same area, CPUE was approximately 2 times greater offshore than along shore (Bethe and Meyer 2002). Although lingcod clearly occur along shoreline habitats, densities were probably lower than rocky reef areas surveyed by the ROV.

The greatest uncertainty regarding survey estimates relates to the closed population assumption. Lingcod have generally been described as sedimentary, ambush, or sit-and-wait predators (Miller and Geibel 1973; Cass et al. 1990; Smith et al. 1990), although anecdotally they may occasionally be active feeders (Star et al. 2004). Lingcod have small home ranges and show strong site fidelity to rocky reefs (Smith et al. 1990; Matthews 1992; Starr et al. 2004; Anthony 2009; Greenley 2009; Tolimieri et al. 2009). Lingcod migrations and movements do occur; however, migrations are generally driven by ontogenetic shifts from juvenile to adult habitats (Forrester 1973; Miller and Geibel 1973; Cass et al. 1990) and seasonal bathymetric shifts associated with shallow-water spawning activities and nest guarding by males (Low and Beamish 1978; Cass et al. 1990). Even as adults, larger lingcod tend to occur in deeper waters, suggesting a further bathymetric shift with ontogeny (Smith et al 1990; Gordon 1994). Conventional tagging studies have shown that most lingcod movement is restricted to small distances (81% to 95% moving < 8.1 km to 10 km), with a small percentage moving moderate distances of up to 50 km and a few to great distances up to hundreds of km (Hart 1943; Chatwin 1958; Cass et al. 1986; Davis 1986; Barss and Demory 1989; Cass et al. 1990; Smith et al. 1990). However, Mathews and LaRiviere (1987) found approximately 50% of 1,692 tagged fish moved > 8.1 km. A common finding in most tagging studies has been that no net movement occurred, although Jagielo (1999) estimated a net offshore movement of lingcod off the Washington coast.

Although many tagging studies report similar movement patterns for lingcod, there appears to be some level of variability, which may be related to the size of fish tagged. Greater movement may occur with larger animals and may be related to sex (Chatwin 1956; Miller and Geibel 1973; Cass et al. 1984) or sexual maturity. Although females tend to disperse into deeper waters following spawning, they may remain in relatively shallow waters throughout the spring and summer and then transition into deeper habitats (Cass et al. 1990).

There have been mixed results for studies addressing off-reef movements. Off-reef forays by lingcod, presumably associated with foraging, have been documented in Southeast Alaska (Starr et al. 2004). In those studies, 10% of acoustically tagged lingcod spent more than 2 weeks outside an acoustic array that encircled 2 rocky pinnacles. Off-reef forays from other acoustic tagging studies have been much shorter in duration (< 1 day) (Bishop et al. 2010; Lee et al. 2011), and others have observed no off-reef movement (Matthews 1992; Yamanaka and Richards 1993). Lingcod also have the ability to home back to rocky habitats even when crossing unsheltered areas to do so. When translocated from rocky reefs, they have homed back distances of 1 to 2.8 km in 33 hours to 60 hours, mostly moving at night (Matthews 1992). The choice of only sampling within the rocky habitats for this survey was done to increase the efficiency of the Chiswell Ridge survey, both in terms of sampling efficiency and increasing precision. Although lingcod prefer rocky habitats, the proportion of the population either residing outside of the Chiswell Ridge rocky reefs or making off-reef forays is unknown. This makes the population estimate conservative for the entire Chiswell Ridge area because density estimates were only scaled up to the available rocky substrates.

Sampling timing may be important when considering lingcod movements. Lingcod may have foraging times that are related to diurnal or tidal cycles (Tolimieri et al. 2009; Beaudreau and Essington 2011) or forage availability (Beaudreau and Essington 2007). These movements may involve off-reefs forays or they may occur within rocky reef structure (Beaudreau and Essington 2011). For studies that have assessed diurnal movement, rates have been higher at night (Mathews 1992; Tolimieri et al. 2009). Because all sampling in this study occurred during daylight and outside of crepuscular hours, any movement due to diurnal effects should have been minimized.

When considering how fish migrations or movements may have influenced the results of this survey, it is important to consider scale, both temporally and spatially. Although lingcod occur at depths > 300 m, they are typically found between 10 m and 100 m (Cass et al. 1990). The Chiswell Ridge study area is surrounded on 3 sides (west, north, and east) by deep fjords with depths ranging from 150 m to 300 m, averaging approximately 220 m. These basins are predominately filled with soft substrate material. To the south, outside the 100 m study area boundary, there is a low slope extending to Amatouli Trough at approximately 240 m. This area appears to have little rocky structure based on the best available single-beam bathymetry. These deeper depths, which are outside of the typical lingcod depth distribution, and the apparent lack of rocky features surrounding the study area probably help to restrict the movement of lingcod and DSR to the Chiswell Ridge. Because lingcod do occur deeper than 100 m and occur outside of rocky substrates, they are fully capable of moving into and out of the Chiswell Ridge study area. The pertinent questions, however, are how much movement could occur, whether there could be net movement into and out of the study area, and the temporal pattern of movement. Understanding these aspects of migration and movement would assist in understanding how well the closed population assumption was satisfied. This in turn would assist in gauging how movement may influence interannual abundance estimates and the ability to detect changes in lingcod abundance along the Chiswell Ridge. Even with the patchy distribution of lingcod, the error for the Chiswell Ridge population estimate was relatively low. Additionally, significant differences in lingcod density were detected in the nearby Granite I study area. This bodes well for being able to detect larger spatial and temporal changes in abundance using this survey methodology. Without empirical data on lingcod movement, it is important to define survey areas in a manner which, with an understanding of lingcod biology, will minimize the influence of fish movement on monitoring population abundance.

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TABLES AND FIGURES

Table 1.–Video quality categories.

Primary grouping	Secondary grouping	Code	Definition
Good	Good	GGF	**G**oing **F**orward
Bad	Good	GRB	**R**esting on **B**ottom
Bad	Good	GRBC	**R**esting on **B**ottom with **C**lose-up image
Bad	Bad	BDO	Going over **D**rop **O**ff
Bad	Bad	BBS	**B**ottom **S**tirrup
Bad	Bad	BLB	**L**ost **B**ottom visual
Bad	Bad	BGB	**G**oing **B**ackwards
Bad	Bad	BRB	**R**esting on **B**ottom
Bad	Bad	BCF	Bad **C**amera **F**ocus
Bad	Bad	BLA	**L**oitering in same **A**rea
Bad	Bad	BPV	**P**oor **V**isibility
Bad	Bad	BRP	**R**e**P**ositioned

Table 2.–Meters of transect line run for each stratum.

		Within rocky reef	
	Total	Good and bad	Good
	m	m	m
Chiswell North	9,103	7,693	7,027
Chiswell South	10,651	8,647	7,993
Harris Bay	6,849	6,397	6,036
Total	26,603	22,737	21,056

Note: Included are total meters run and meters run within rocky reef polygons including good and bad video segments and good video only segments.

Table 3.–Fish counts by reaction category

Reaction	Lingcod	Juvenile yelloweye	Adult yelloweye	Quillback
Quickly toward	12	0	2	3
Slowly toward	8	5	17	4
None	95	35	53	138
Slowly away	5	1	11	11
Quickly away	4	0	2	3
Total	124	41	85	159
Included	108	41	81	153

Note: Only fish that were categorized as slowly toward, none, or slowly away, were included in population estimates.

Table 4.–Fish density $\hat{D}$ (fish km2) and abundance $\hat{\tau}$ estimates for each stratum and study area.

Lingcod	Chiswell North		Chiswell South		Chiswell Ridge		Granite I
	$\hat{D}$	$\hat{\tau}$	$\hat{D}$	$\hat{\tau}$	$\hat{D}$	$\hat{\tau}$	$\hat{D}$
Estimate	2,633	34,924	5,255	47,112	3,690	82,036	1,141
Bootstrap mean	2,696	35,771	5,304	47,549	3,748	83,320	1,145
Bootstrap SD	694	9,203	1,476	13,231	727	16,155	247
LCI	1,416	18,787	2,600	23,309	2,413	53,640	666
UCI	4,108	54,503	8,393	75,241	5,268	117,123	1,614
Estimated bias	64	847	49	437	58	1,284	4
CV	26%	26%	28%	28%	20%	20%	22%

Adult yelloweye rockfish	Chiswell North		Chiswell South		Chiswell Ridge		Granite I
	$\hat{D}$	$\hat{\tau}$	$\hat{D}$	$\hat{\tau}$	$\hat{D}$	$\hat{\tau}$	$\hat{D}$
Estimate	2,828	37,511	3,228	28,940	2,989	66,451	934
Bootstrap mean	2,905	38,544	3,234	28,996	3,038	67,540	951
Bootstrap SD	802	10,644	618	5,543	545	12,119	258
LCI	1,529	20,281	2,131	19,103	2,067	45,946	482
UCI	4,578	60,739	4,562	40,901	4,210	93,594	1,490
Estimated bias	78	1,033	6	55	49	1,089	18
CV	28%	28%	19%	19%	18%	18%	28%

Juvenile yelloweye rockfish	Chiswell North		Chiswell South		Chiswell Ridge		Granite I
	$\hat{D}$	$\hat{\tau}$	$\hat{D}$	$\hat{\tau}$	$\hat{D}$	$\hat{\tau}$	$\hat{D}$
Estimate	878	11,641	1,802	16,153	1,250	27,794	830
Bootstrap mean	868	11,516	1,785	16,006	1,238	27,521	821
Bootstrap SD	271	3,591	402	3,604	225	4,996	304
LCI	391	5,183	1,031	9,241	810	18,006	229
UCI	1,421	18,847	2,619	23,478	1,675	37,242	1,411
Estimated bias	-9	-126	-16	-147	-12	-273	-9
CV	31%	31%	22%	22%	18%	18%	37%

-continued-

Table 4.–Page 2 of 2.

All yelloweye rockfish							
	Chiswell North		Chiswell South		Chiswell Ridge		Granite I
	*D^*	*τ^*	*D^*	*τ^*	*D^*	*τ^*	*D^*
Estimate	3,705	49,152	5,030	45,093	4,239	94,245	1,763
Bootstrap mean	3,773	50,060	5,020	45,001	4,276	95,061	1,772
Bootstrap SD	909	12,064	755	6,770	615	13,675	486
LCI	2,248	29,828	3,621	32,465	3,160	70,248	907
UCI	5,697	75,584	6,561	58,815	5,542	123,215	2,756
Estimated bias	68	908	-10	-92	37	816	9
CV	25%	25%	15%	15%	15%	15%	28%

Quillback rockfish							
	Chiswell North		Chiswell South		Chiswell Ridge		Granite I
	*D^*	*τ^*	*D^*	*τ^*	*D^*	*τ^*	*D^*
Estimate	5,850	77,609	2,928	26,248	4,672	103,857	5,601
Bootstrap mean	5,814	77,127	2,931	26,276	4,651	103,403	5,720
Bootstrap SD	1,345	17,841	450	4,031	824	18,308	1,379
LCI	3,531	46,842	2,101	18,837	3,177	70,637	3,046
UCI	8,768	116,319	3,807	34,127	6,471	143,867	8,436
Estimated bias	-36	-482	3	27	-20	-455	119
CV	23%	23%	15%	15%	18%	18%	25%

Note: Also included are bias and error statistics including upper and lower 95% confidence limits.

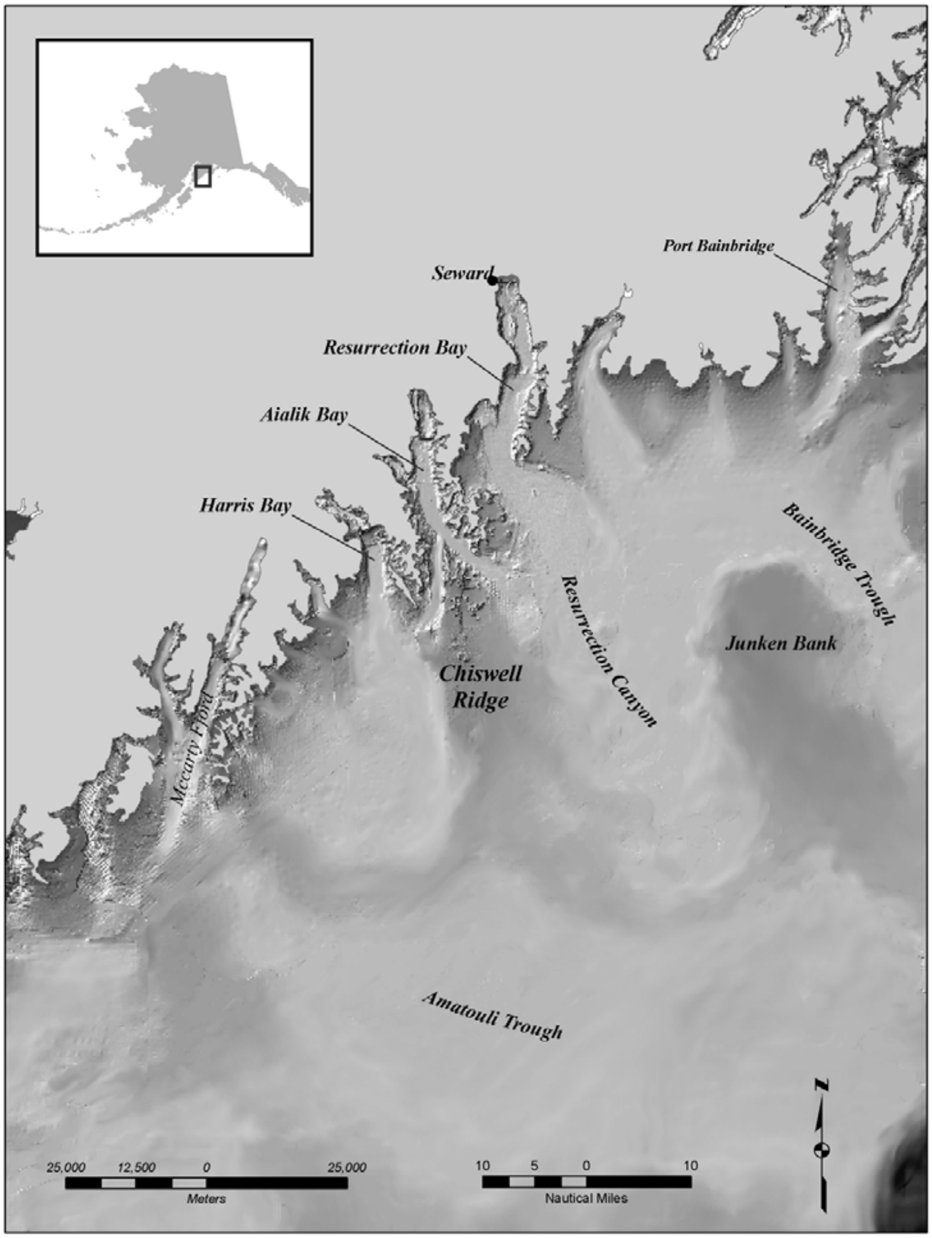

Figure 1.–Chiswell Ridge and the north gulf coast of the Kenai Peninsula with hillshade of bathymetric grid (azimuth = 315° and altitude = 45°).

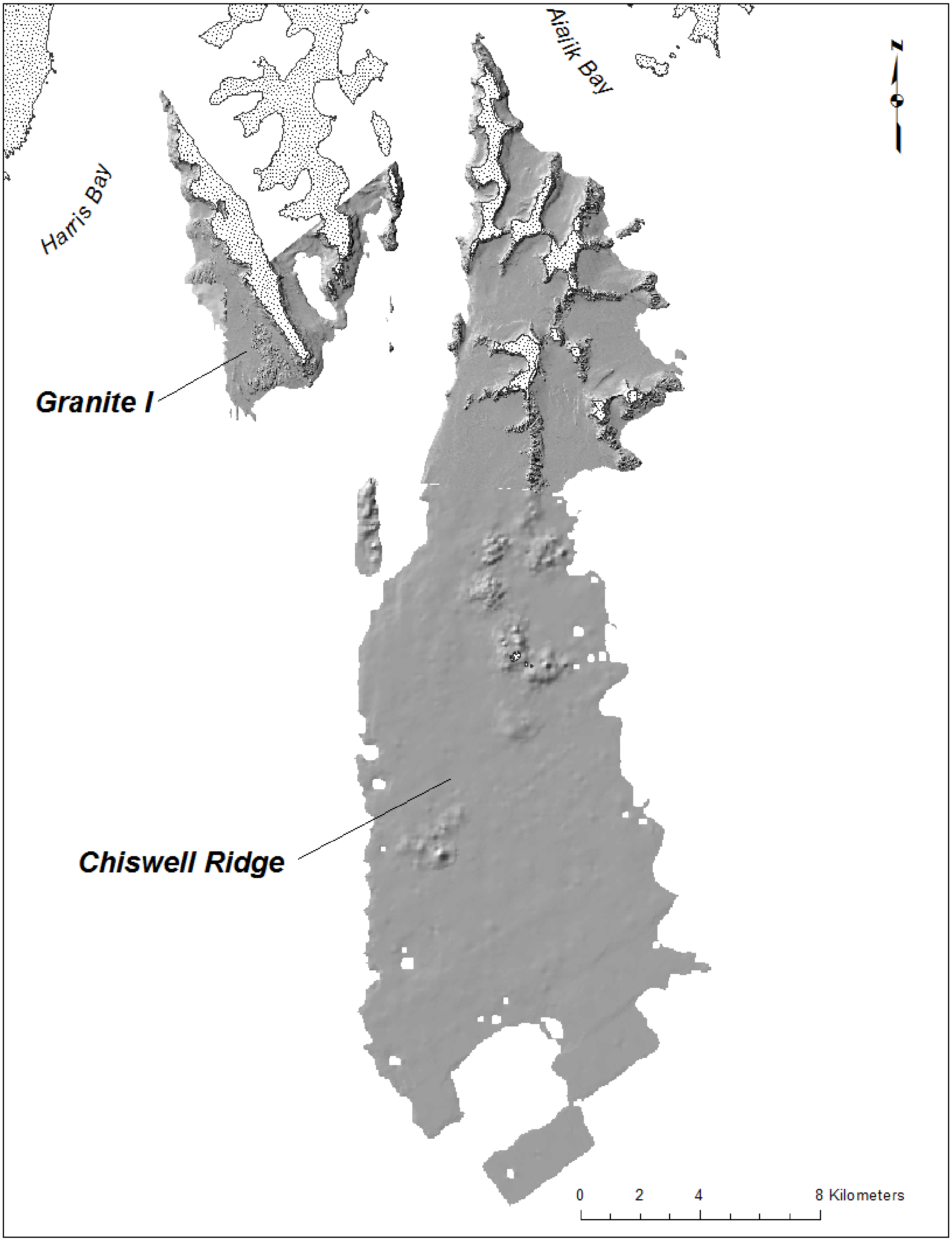

Figure 2.–Chiswell Ridge and Granite Island study areas with hillshade of bathymetric grid (azimuth = 315° and altitude = 45°).

Note: Study area boundaries were defined between mean-lower-low-water and 100 m.

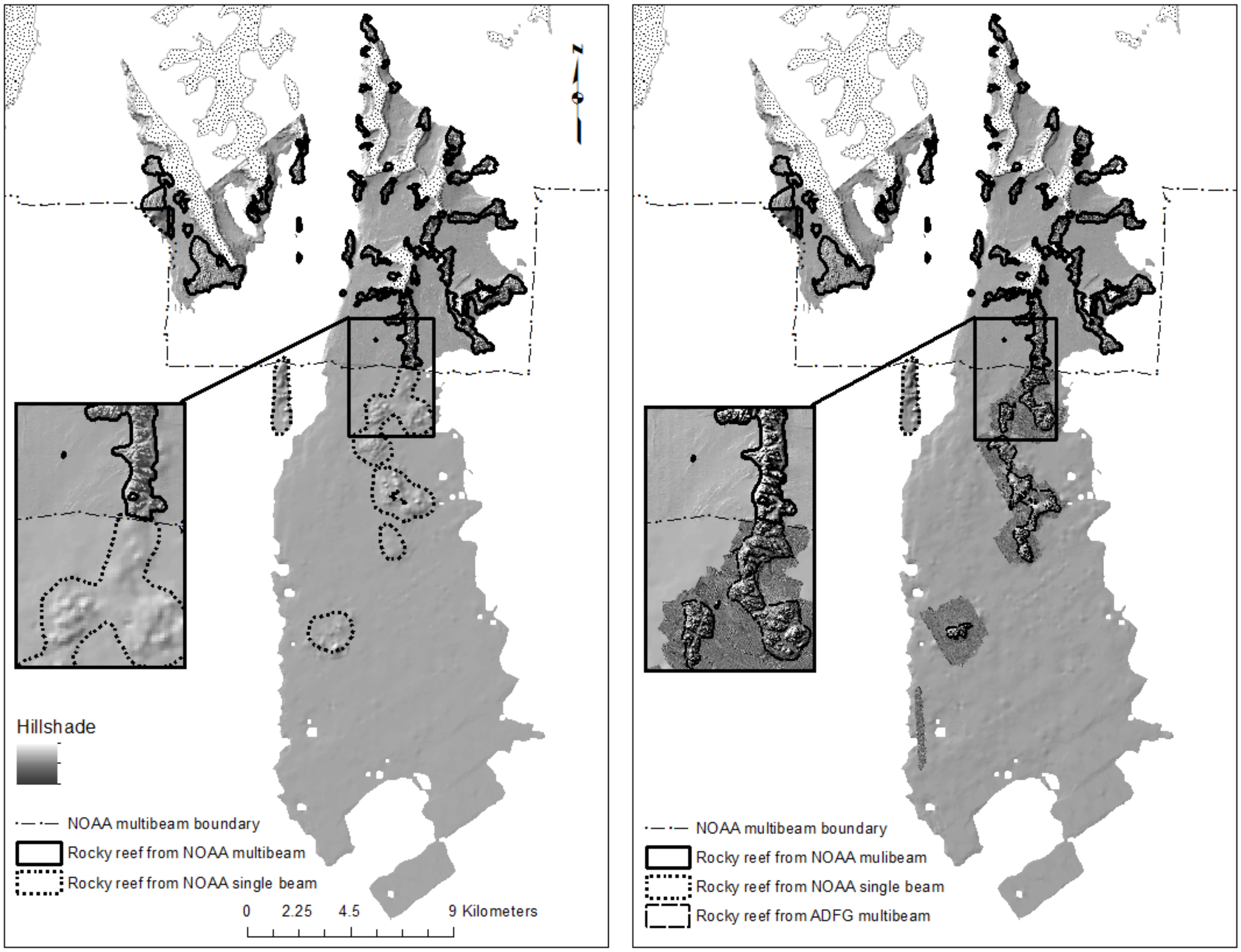

Figure 3.–Hillshaded bathymetry with bathymetry source and rocky reef delineations for the Chiswell Ridge and Granite I study areas with hillshade of bathymetric grid (azimuth = 315° and altitude = 45°).

Note: Panel A shows the difference in resolution between the multi beam available for northern Chiswell Ridge and single-beam bathymetry for the southern. Panel B shows the multi-beam bathymetry collected after the ROV survey in 2006 and refined rocky reef delineation.

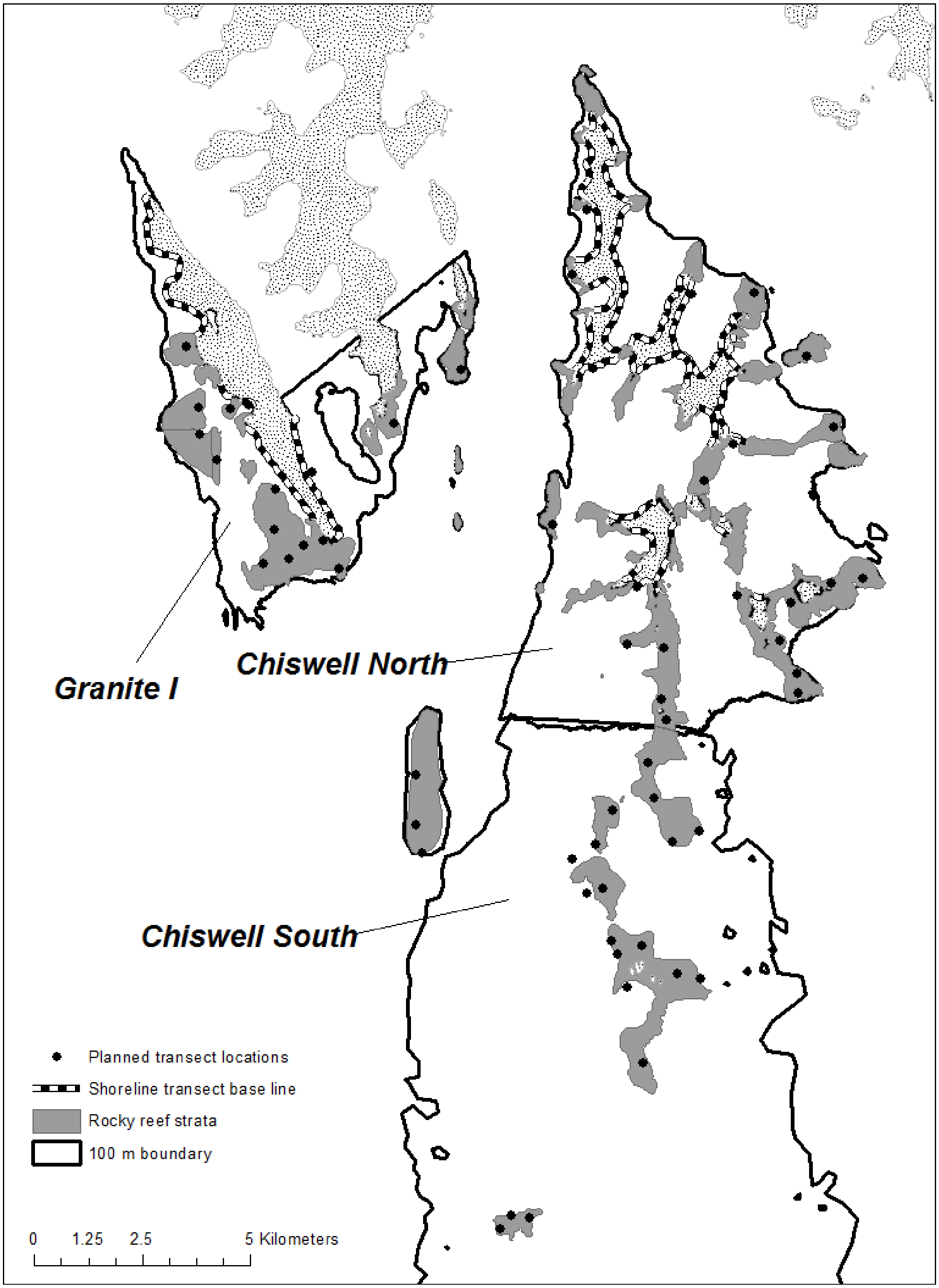

Figure 4.–Study area boundaries, stratification, and transect locations for the Chiswell Ridge and Granite I study areas.

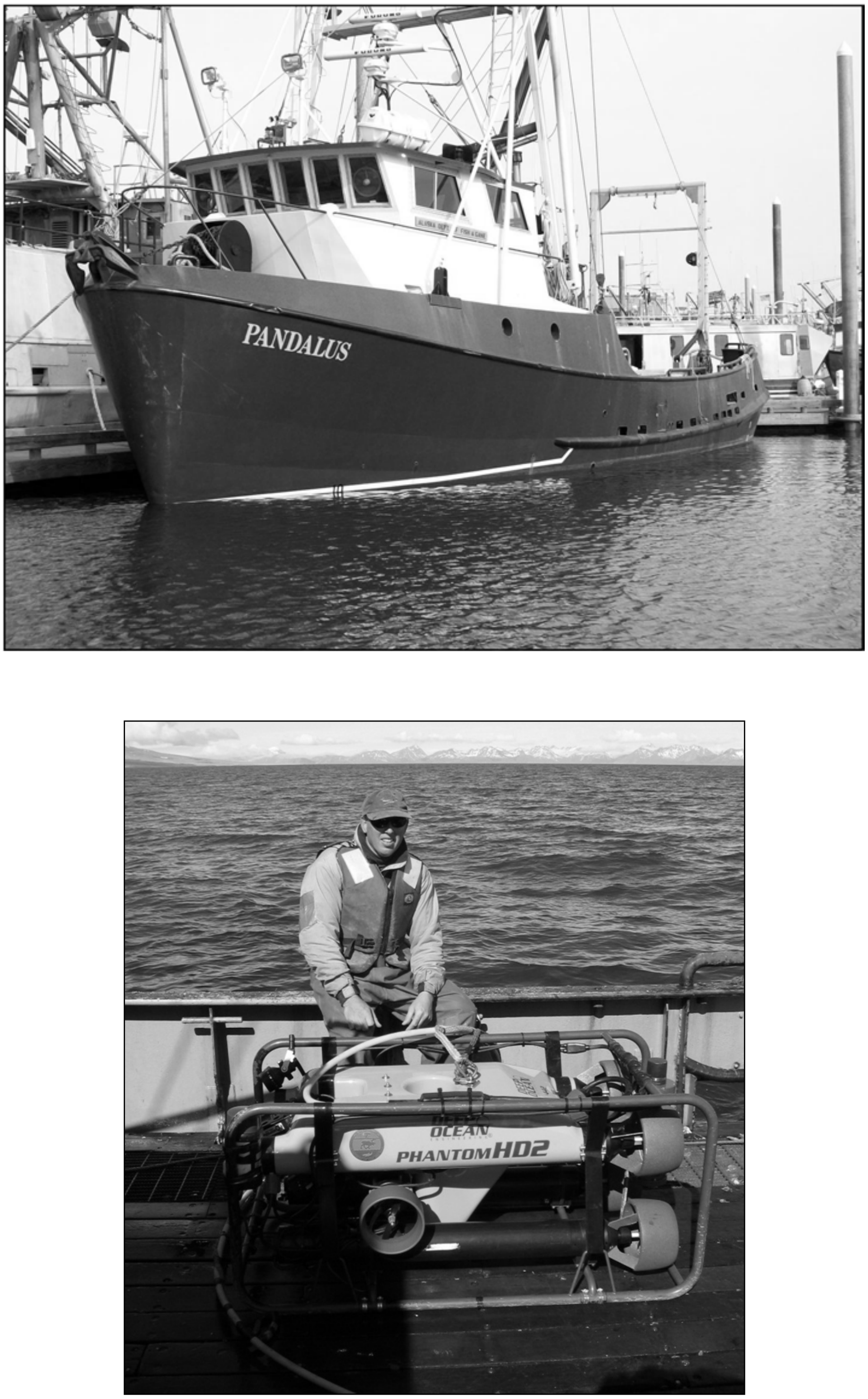

Figure 5.–The R/V Pandalus and Deep Ocean Engineering Phantom HD2+2 ROV used for the survey.

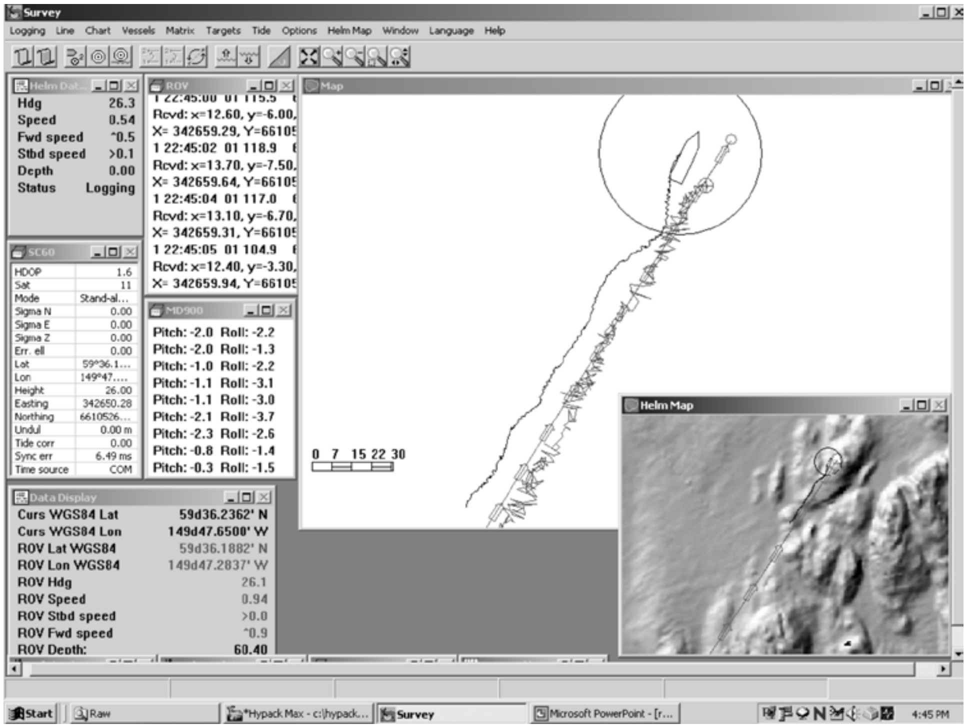

Figure 6.–Computer screen shot of Hypack navigation software used for navigating and data acquisition.

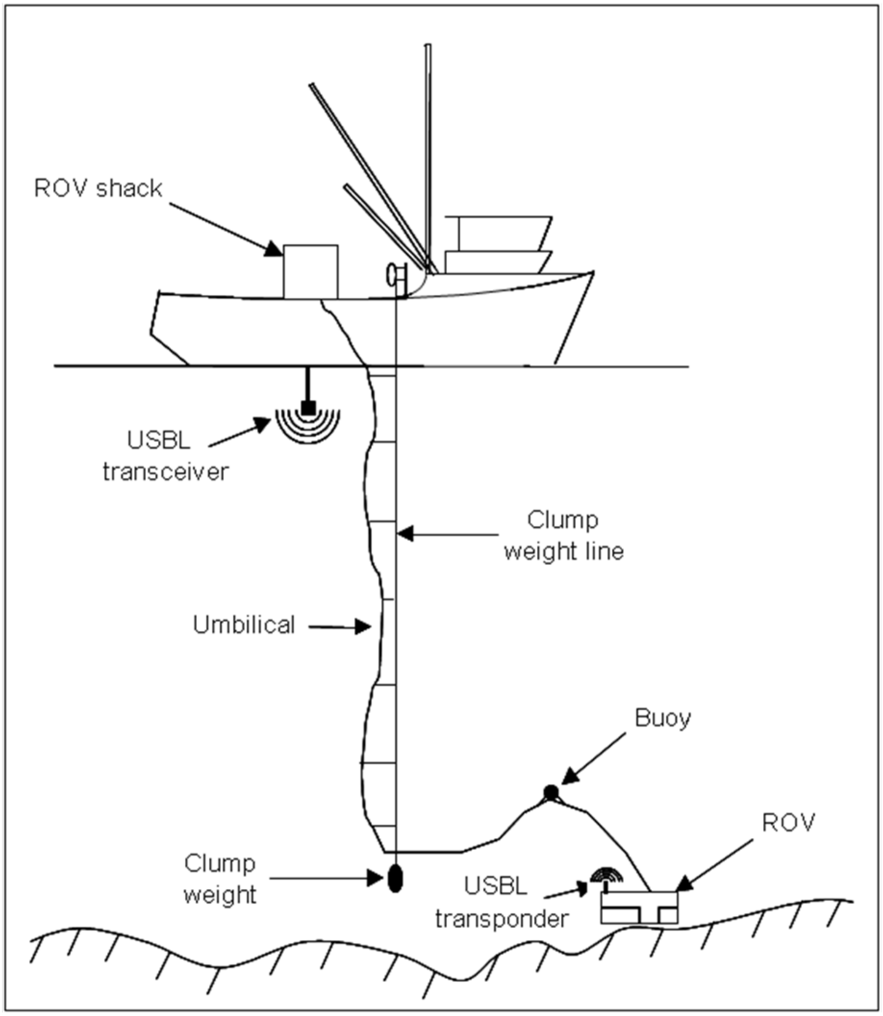

Figure 7.–Schematic of the ROV deployment method.

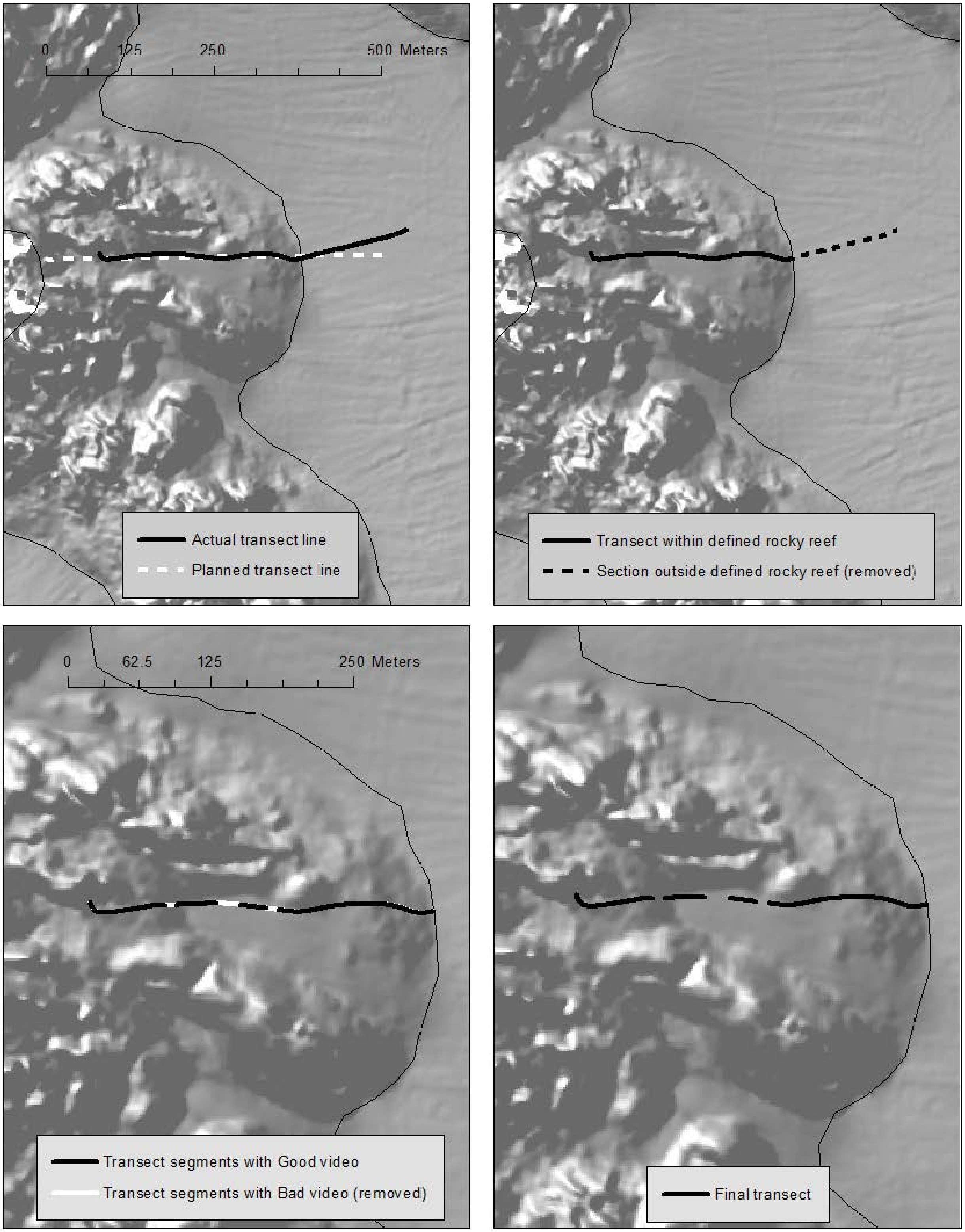

Figure 8.–Example of the methods used to segment out portions of transect that fell outside of the rock reef polygons and those that had bad video segments.

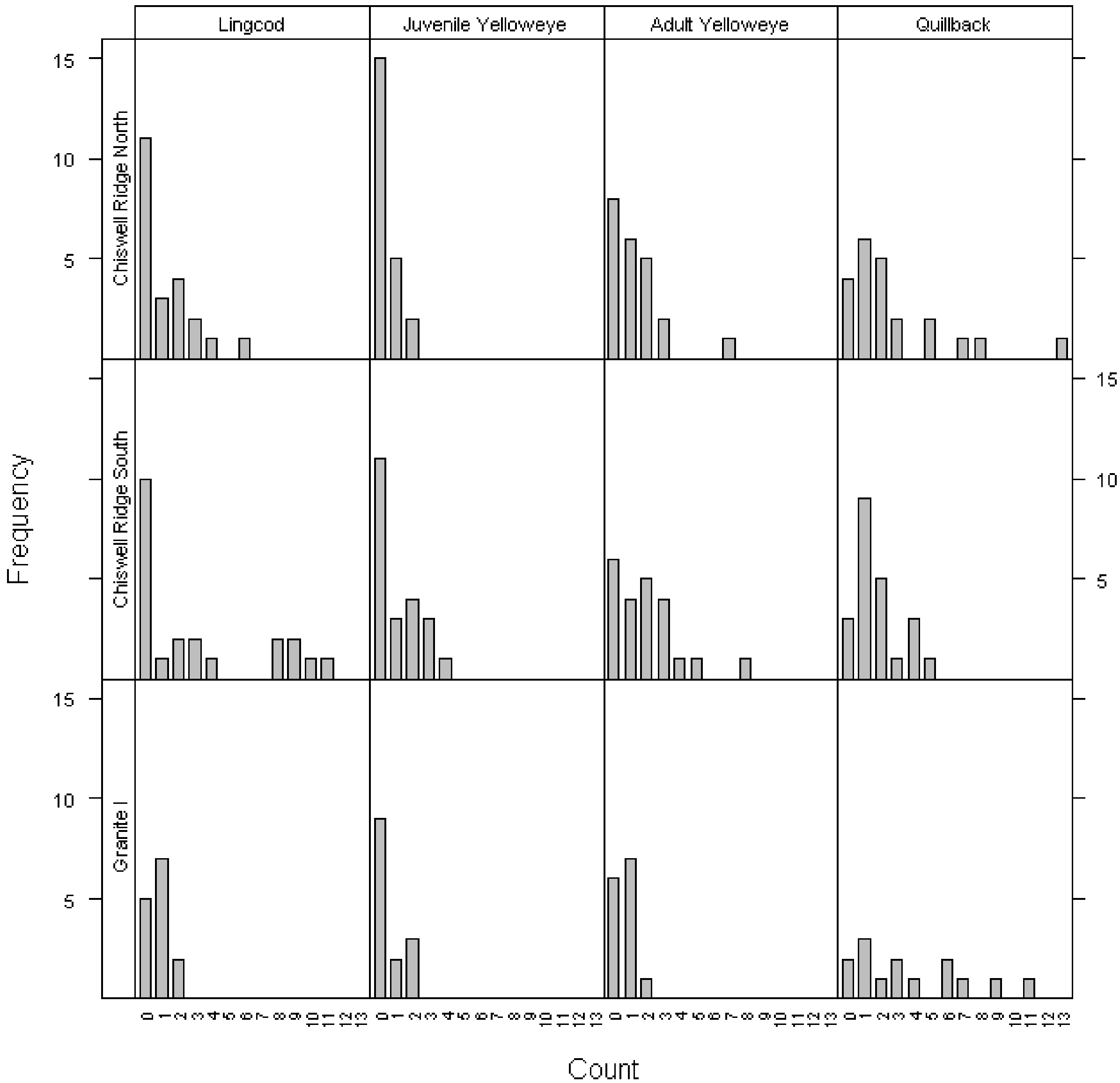

Figure 9.–Frequency of fish counts for each transect by strata and species**.**

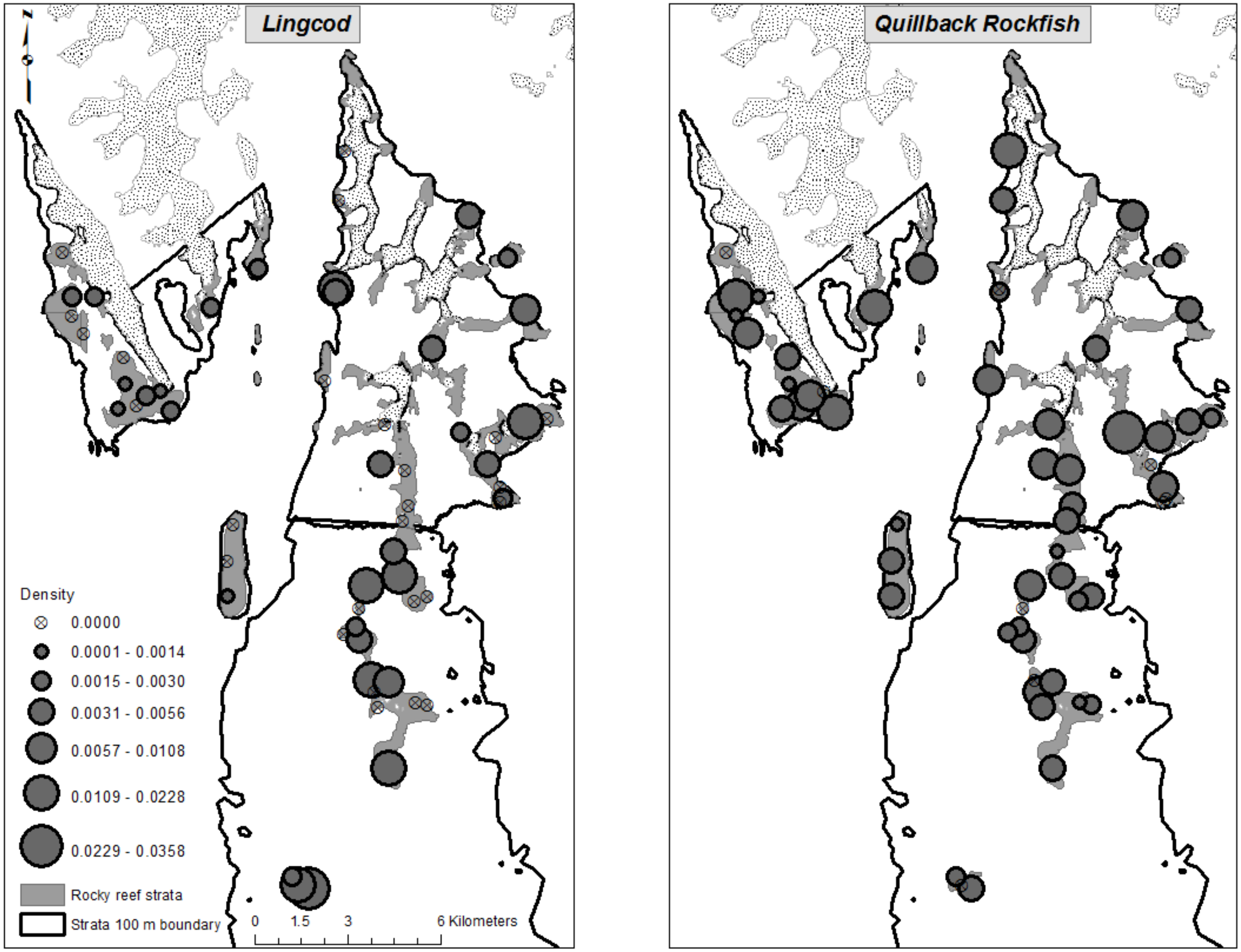

Figure 10.–Distribution of lingcod and quillback rockfish density within the Chiswell Ridge and Granite I study areas.

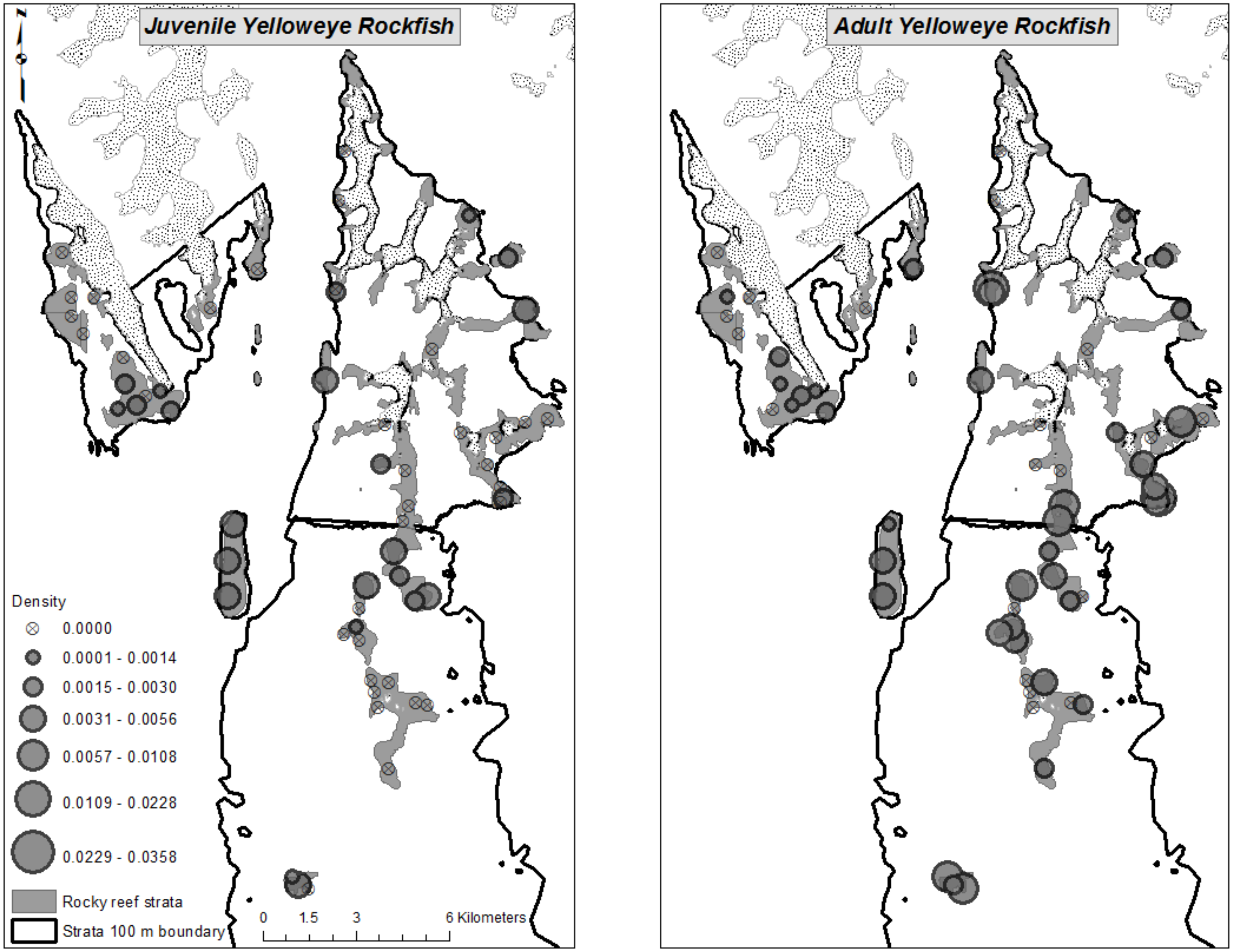

Figure 11.–Distribution of juvenile and adult yelloweye rockfish density within the Chiswell Ridge and Granite I study areas.

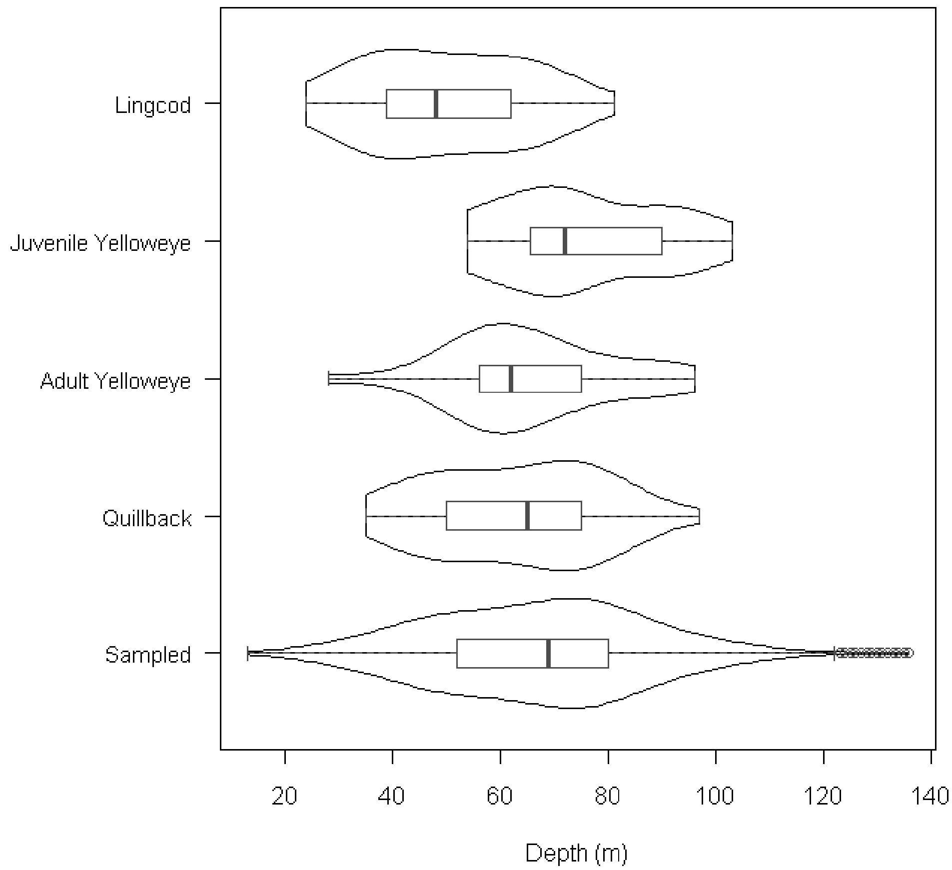

Figure 12.–Violin and box plots of fish observations by depth along with the distribution of sampling effort by depth.

APPENDIX A

Appendix A1.–Components for the ROV system.

Component	Make / Model	Use
ROV		
ROV base system	Deep Ocean Engineering Phantom HD2	Components include two horizontal thrusters and one vertical thruster controlled by a remote control unit, a Sony EVI-330 video camera, two dimmable Deep Sea Power and Light 250-watt halogen lights, a depth pressure sensor, and a fluxgate compass
Additional thrusters		
Horizontal thrusters	Deep Ocean Engineering	Two horizontal thrusters are mounted to the ROV crash frame. The additional thrusters provide twice the forward, reverse, and turning thrust of the ROV base system (HD2+2)
Lateral thruster	Deep Ocean Engineering	The one lateral thruster is mounted below the ROV hull within the crash frame. The additional thruster provides the ability to maneuver the ROV laterally without turning
Video		
On screen display	Deep Ocean Engineering OSD-379	Overlays the following data on the video records; magnetic heading and depth of the ROV, the number of twists in the umbilical cable, date and time code from the time code generator.
Digital video recording deck	Panasonic AG-DV2000P	Digital recording of ROV video on mini-DV
Navigation and tracking		
GPS satellite compass	Furuno SC-60	Vessel heading
DGPS	Trimble Ag132	Vessel positioning
Motion sensor	Applied Geomechanics, MD900-TW	For determining pitch and roll of the research vessel. These measurements are sent to Hypack Survey software to correct vessel motion when calculating ROV position
Ultrashort baseline tracking system	Linkquest Tracklink 1500MA transceiver with TN1500B transponder	For acoustic tracking of the ROV. The slant angle, range, and bearing of the ROV are calculated by the system and output to Hypack Survey software. Hypack then calculates the *x*, *y*, *z* position of the ROV using the latitude and longitude from the GPS and vessel pitch and roll from the motion sensor
Dual-frequency scanning sonar	Tritech Seaking Sonar	Mounted on the front of the ROV inside the crash frame. Can scan 360 degrees or sector scan. Provides the ROV pilot and navigator with images of objects outside of the range of the video camera. Used primarily for enhancing navigation capability and for avoiding obstacles that present dangers to the ROV
Data acquisition		
Scaling lasers	Deep Sea Power and Light, SeaLaser 100	The two lasers are mounted horizontally, 10 cm apart, above the video camera housing. Used for measuring the size of substrate or fish length and for calculating the width of the transect line
Time code generator	Horita GPS3	Captures UTC from GPS and passes it to the on screen display and video recording deck
Programmable keyboard	PI Engineering X-Keys	Use for logging video observations into database
Hypack	Max Lite	Software for survey preparation and data acquisition

Appendix A2.–Habitat classification scheme.

Substrate type	Expanded code	Definition	Description
BLK	Block	Rocks	>= 3 m diam.
LBO	Large boulder	Rocks	1 < 3 m diam.
BAS	Basement	Solid bedrock	
SBO	Small boulder	Rocks	0.25 < 1 m diam.
COB	Cobble	Rocks	64 < 254 mm diam.
MIX	Mixed coarse	Sand and/or gravel and/or shell hash	
PEB	Gravel	Small rocks or pebbles	4 < 64 mm diam.
SND	Sand	Clearly separate grains	< 4 mm diam.
SHE	Shell hash	Area primarily covered with whole or crushed shells	
SOF	Soft	Mud / silt	
Psub	Primary	Substrate type occupies > 50% of the area	
Ssub	Secondary	The next most dominant substrate type that makes up at least 20% of area	

Relief	Expanded code	Definition	Description
NONE	None	0	Maximum vertical relief – not a measure of slope. Important measurement for basement. For rocks, usually relief will be the same as the rock diameter; however, relief may be higher if rocks are piled vertically. Also applies to sand waves.
LOW	Low	< 1 m	
HIGH	High	1–3 m	
STEEP	Steep	> 3 m	

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Crevice size	Expanded code	Definition		Description
ZERO	Zero	0	Smooth surface	If in rocks: 1) occur as voids b/w touching rocks, 2) horizontal space b/w bottom of large or block boulders and sediment. If in basement: 1) crevices must be at least as deep as they are wide, 2) will appear as either cracks, depressions, or folds.
SM	Small	< 0.25 m	Small crevices in either basement or among cobble or small boulder	
MED	Medium	0.25–0.5 m	Most typically in either small to block boulders, or in basement	
LG	Large	> 0.5	Most typically in either large or block boulder fields, or large cracks in basement	

Crevice density	Expanded code	Definition	Description
NONE	None	No crevices	For rocks, crevice density refers to the density of voids, but is related to rock size. For basement, crevice density refers to the number of cracks, depressions, or folds, but is associated with crevice size. For example, if one large (> 0.5 m wide) crack.
FEW	Few	Smaller density of rocks touching, or one > 0.5m crack, depression, or fold in basement (or) few < 0.5m cracks, depressions, or folds in basement.	
MOD	Moderate	Moderate density of above	
ABUN	Abundant	Rock fields with all rocks touching or piled, or in highly fractured or folded basement	

Appendix A3.–Meters of transect line run and area sampled by video quality and habitat type.

		Total	Within rocky reef		
		Good and bad	Good and bad	Good	Good
Strata	Transect	m	m	M	sq m
Chiswell Ridge North	2005R02001	425.8	423.7	402.8	530.5
	2005R02002	496.6	258.1	252.5	363.0
	2005R02003	467.1	450.2	420.9	592.4
	2005R02004	472.9	309.0	266.5	441.4
	2005R02005	340.2	290.5	229.2	299.8
	2005R02019	234.8	234.8	226.1	325.6
	2005R02020	498.2	477.5	455.8	649.9
	2005R02021	517.5	439.1	435.8	649.3
	2005R02024	500.3	132.7	130.0	147.4
	2005R02025	153.3	153.3	115.2	169.2
	2005R02026	464.4	464.4	402.7	659.8
	2005R02029	449.0	449.0	431.0	648.3
	2005R02030	340.4	340.4	321.8	457.1
	2005R02031	295.3	263.6	197.9	238.1
	2005R02032	276.7	276.7	251.8	358.4
	2005R02033	301.2	301.2	233.1	304.5
	2005R02034	508.9	343.6	328.6	459.3
	2005R02043	617.1	498.6	468.3	760.7
	2005R02044	522.6	433.3	405.9	594.6
	2005R02045	513.6	445.8	418.7	655.3
	2005R02047	117.8	117.8	115.0	158.9
	2005R02048	589.3	589.3	517.3	792.9
	Total	9,102.8	7,692.5	7,026.9	10,256.3
Chiswell Ridge South	2005R02006	494.7	310.1	296.1	479.7
	2005R02007	429.7	429.7	385.9	651.8
	2005R02008	494.4	240.5	237.0	382.9
	2005R02009	524.4	524.4	496.6	745.6
	2005R02010	492.8	229.2	202.5	305.7
	2005R02011	517.1	125.3	119.0	201.1
	2005R02012	543.4	543.4	486.3	883.7
	2005R02013	302.3	223.5	204.2	394.1
	2005R02014	507.7	507.7	445.2	832.0
	2005R02015	512.9	359.5	327.4	575.5
	2005R02016	385.6	385.6	349.5	640.4
	2005R02017	618.5	618.5	611.4	1,143.5
	2005R02018	444.5	237.8	216.2	413.8
	2005R02035	196.0	170.0	152.0	229.1
	2005R02036	513.7	513.7	494.7	663.4
	2005R02037	489.8	489.8	480.9	759.6
	2005R02038	537.0	537.0	506.7	908.3
	2005R02039	557.9	444.5	424.0	633.9
	2005R02040	469.3	469.3	452.8	680.2
	2005R02041	568.7	262.7	248.6	321.0
	2005R02042	524.0	524.0	440.3	715.1
	2005R02049	526.3	500.8	415.5	759.9
	Total	10,650.9	8,647.1	7,992.9	13,320.2

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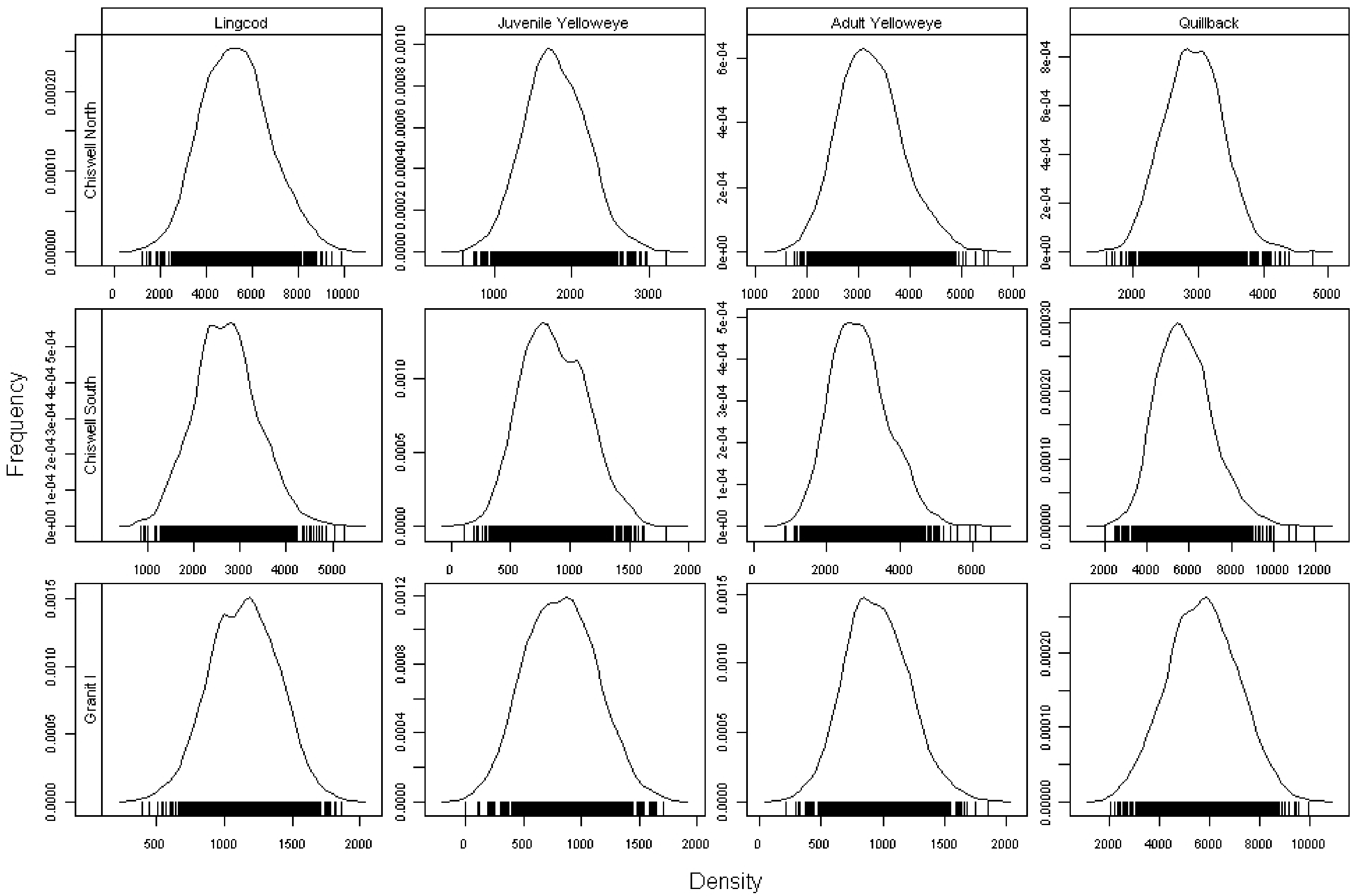
Appendix A3.–Page 2 of 2.

		Total	Within rocky reef		
		Good and bad	Good and bad	Good	Good
Strata	Transect	m	m	m	sq m
Granite I	2005R02027	474.7	409.5	373.2	533.3
	2005R02028	471.2	452.5	419.1	624.5
	2005R02050	510.8	481.1	446.7	673.1
	2005R02051	537.8	537.8	485.7	986.7
	2005R02052	502.1	502.1	459.8	692.9
	2005R02053	489.4	489.4	482.0	763.5
	2005R02054	501.9	466.9	450.7	843.4
	2005R02056	524.1	524.1	478.4	716.6
	2005R02057	517.2	449.6	420.1	620.8
	2005R02058	492.4	257.0	246.5	374.3
	2005R02059	507.6	507.6	499.8	789.9
	2005R02060	519.5	519.5	497.4	788.7
	2005R02061	508.4	508.4	493.8	769.2
	2005R02062	291.9	291.9	282.7	463.7
	Total	6,849.0	6,397.4	6,036.0	9,640.7
	Grand total	26,602.7	22,737.0	21,055.8	33,217.2

Appendix A4.–Species and species groupings for all animals enumerated.

Species or species group	Description
Lingcod	*Ophiodon elongatus*
Pelagic rockfish	
Black rockfish	*Sebastes melanops*
Black / dark rockfish	*Sebastes melanops or S. ciliatus*
Dark / dusky rockfish	*Sebastes ciliatus or S. variabilis*
Dark rockfish	*Sebastes ciliatus*
Dusky rockfish	*Sebastes variabilis*
Yellowtail rockfish	*Sebastes flavidus*
Demersal rockfish	
Canary rockfish	*Sebastes pinniger*
China rockfish	*Sebastes nebulosus*
Quillback rockfish	*Sebastes maliger*
Rosethorn rockfish	*Sebastes helvomaculatus*
Redstripe rockfish	*Sebastes proriger*
Silvergray rockfish	*Sebastes brevispinis*
Silvergray / Redstripe rockfish	*Sebastes helvomaculatus* or *S. proriger*
Tiger rockfish	*Sebastes nigrocinctus*
Juvenile yelloweye rockfish	*Sebastes flavidus*
Yelloweye rockfish	*Sebastes ruberrimus*
Other unidentified rockfish	
Large rockfish unspecified	*Sebastes*
Small benthic rockfish unspecified	*Small benthic oriented sebastes* (could be juvenile or adult)
Small benthic red rockfish unspecified	*Small benthic oriented red colored sebastes* (could be juvenile or adult)
Juvenile rockfish unspecified	*Junenile Sebastes*
Other fish	
Bathyraja unspecified	*Bathyraja*
Large gadid unspecified	*Large gadidae*
Juvenile gadid unspecified	*Juvenile Gadidae*
Walleye Pollock	*Theragra chalcogramma* or *Gadus chalcogrammus*
Kelp greenling	*Hexagrammos decagrammus*
Greenling unspecified	*Hexagrammidae*
Prowfish	*Zaprora silenus*
Sculpin unspecified	*Cottidae*
Northern ronquil	*Ronquilus jordani*
Alaska ronquil	*Bathymaster caeruleofasciatus*
Searcher	*Bathymaster signatus*
Ronquil unspecified	*Bathymasteridae*
Prickleback / eelpout unspecified	*Stichaeidae* or *Zoarcidae*
Prickleback unspecified	*Stichaeidae*
Halibut	*Hippoglossus stenolepis*
Flat fish unspecified	*Pleuronectiformes*
Juvenile fish unspecified	*Juvenile Teleostei*
Unidentified fish	*Teleostei*
Invertebrates	
Tanner crab	*Chionoecetes tanneri*
Brown box crab	*Lopholithodes foraminatus*
Red sea cucumber	*Parastichopus californicus*
Red urchin	*Strongylocentrotus franciscanus*
Demspong unspecified	*Demospongiae*
Hydrocoral unspecified	*Stylasteridae*

Appendix A5.–Distribution of 1000 bootstrap replicates of density estimates by species and strata.



Appendix A6.–Species or species group counts by transect for the Chiswell north stratum.

Species or species group	Transect																					
	2005R02001	2005R02002	2005R02003	2005R02004	2005R02005	2005R02019	2005R02020	2005R02021	2005R02024	2005R02025	2005R02026	2005R02029	2005R02030	2005R02031	2005R02032	2005R02033	2005R02034	2005R02043	2005R02044	2005R02045	2005R02047	2005R02048
Lingcod	2	1		2						2	3		6		1		2	3	1	4		
Pelagic rockfish																						
Black rockfish						4	1		4		33		51		2	4	1	7		4	1	2
Black / dark rockfish						1	2										1					
Dark / dusky rockfish						1														1		
Dark rockfish			3								2		3			4						
Dusky rockfish	1				2	1																
Yellowtail rockfish																						
Demersal rockfish																						
Canary rockfish																						
China rockfish										3	5		2			1		1			2	3
Quillback rockfish	2	13	5		2	1	7	3	2		1	1	2			1	3	8	1	2	1	5
Rosethorn rockfish					1							5		1					2			
Redstripe rockfish							9	7			2	12					1	1	15	1		1
Silvergray rockfish			2		3		6										1			2		
Silvergray / Redstripe rockfish		5	3		4																	
Tiger rockfish		1	2				1	1		1	1	1	1		2	2		1	1	1		
Juvenile yelloweye rockfish							2				1				1		1	1	1	2		
Yelloweye rockfish		1		2	1	2	2			2	3		3	1	7	2		1	1	1		
Unidentified rockfish																						
Large rockfish unspecified	1					1	1			1				3			1					
Small benthic rockfish unspecified	1	2	7	2	3			2										1		3		2
Small benthic red rockfish unspecified	15	5	24	4	18	6	61	23		2	1	17			10	1	2	9	41	2		2
Juvenile rockfish unspecified	21	6		4	2	17	10	6	1	1	38			1	3	6	25	88		26		11

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Species or species group	Transect 2005R02001	2005R02002	2005R02003	2005R02004	2005R02005	2005R02019	2005R02020	2005R02021	2005R02024	2005R02025	2005R02026	2005R02029	2005R02030	2005R02031	2005R02032	2005R02033	2005R02034	2005R02043	2005R02044	2005R02045	2005R02047	2005R02048
Other fish																						
Bathyraja unspecified		1																				
Large gadid unspecified							3															
Juvenile gadid unspecified	3							34											5	5		
Walleye Pollock							2	1														
Kelp greenling	1		1	1					2	4	3		3	1			1	5	1	1	1	5
Greenling unspecified																						
Prowfish																		1				
Sculpin unspecified							2	2								15		3	3	4		
Northern ronquil																						
Alaska ronquil										1												
Searcher																						
Ronquil unspecified																						
Prickleback / eelpout unspecified																	2		6	3		
Prickleback unspecified																						
Halibut																	1		1			
Flat fish unspecified	1							2				1					4	4	3	1		
Juvenile fish unspecified																						
Unidentified fish								1				2	1						6	1		
Invertebrates																						
Tanner crab				1				1														
Box crab				6																		
Red sea cucumber	35	16	10	32	39	30	106	17	7	16	76	110	10	78	93	22	115	51	99	132		107
Purple urchin		1	1																			
Demspong unspecified	1		1								1									1	1	2
Hydrocoral unspecified	1				1	2				3	5	17	233		12	10	11	27		5		10

Appendix A7.–Species or species group counts by transect for the Chiswell south stratum.

	Transect																					
Species or species group	2005R02006	2005R02007	2005R02008	2005R02009	2005R02010	2005R02011	2005R02012	2005R02013	2005R02014	2005R02015	2005R02016	2005R02017	2005R02018	2005R02035	2005R02036	2005R02037	2005R02038	2005R02039	2005R02040	2005R02041	2005R02042	2005R02049
Lingcod	8	4					10	9	2		3	2		8		1		9			11	3
Pelagic rockfish																						
Black rockfish	4		1				4	1	2	1	1	7		5				3	1		4	
Black / dark rockfish									2		3	1									1	
Dark / dusky rockfish			1				3		2	1	1	2										
Dark rockfish				1	1		2	1			1	1						1				
Dusky rockfish				1			3		5	1						3				1		
Yellowtail rockfish																						
Demersal rockfish																						
Canary rockfish																						
China rockfish	1										2	1										
Quillback rockfish		2	1	1	2	1	4		2	1	3	2		1	2	4	1	5	1	1	4	1
Rosethorn rockfish			2							3		1		1	1		1	1				
Redstripe rockfish												1		3	17	4	9					
Silvergray rockfish					1								1		1		1			1		4
Silvergray / Redstripe rockfish		2		2					2	1	1		2									
Tiger rockfish	3	1		1	1	1			3			3			1	3	3		1		3	1
Juvenile yelloweye rockfish								2	1			1			2	4	3	3	2	1	2	3
Yelloweye rockfish		3	1				2	1	8	2	3	5		2	2	3	1	4	1		3	2
Unidentified rockfish																						
Large rockfish unspecified									1		1					1	1				5	
Small benthic rockfish unspecified											1	2				2	4	1			5	1
Small benthic red rockfish unspecified			5	2			1	1	8			3	3		26	33	19			5	21	
Juvenile rockfish unspecified		5	27	17	11		38	27	3	38	56			4	3	5	4	1		10	26	8

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Appendix A7.–Page 2 of 2.

Species or species group	2005R02006	2005R02007	2005R02008	2005R02009	2005R02010	2005R02011	2005R02012	2005R02013	2005R02014	2005R02015	2005R02016	2005R02017	2005R02018	2005R02035	2005R02036	2005R02037	2005R02038	2005R02039	2005R02040	2005R02041	2005R02042	2005R02049
Other fish																						
Bathyraja unspecified																						
Large gadid unspecified																						
Juvenile gadid unspecified	3		12	6	17		2	2		4					3	2	2	9		13		
Walleye Pollock																						
Kelp greenling	1	1			1	1	6			2	3	1		1		1	1	4	1		3	1
Greenling unspecified								2			1											
Prowfish																						
Sculpin unspecified									1						1	1		1		2		
Northern ronquil																						
Alaska ronquil																						
Searcher															3							
Ronquil unspecified												1									1	
Prickleback / eelpout unspecified			3	7				1						3		1						
Prickleback unspecified	2	1			2																	
Halibut																						
Flat fish unspecified	1									1					1			1		2		
Juvenile fish unspecified																						
Unidentified fish		1	1	1			4										1					
Invertebrates																						
Tanner crab																						
Box crab	20		1									1										
Red sea cucumber	33	56	47	58	9	28	30	39	85	80	30	132	4	32	78	110	150	72	68	41	70	87
Purple urchin																						
Demspong unspecified							1						1		48	150	122					
Hydrocoral unspecified	78	48		2	51	9	187	99	10	33	132	150		172	51	296	50	71	14	13	21	38

Appendix A8.–Species or species group counts by transect for the Granite I study area.

Species or species group	Granite I													
	2005R02027	2005R02028	2005R02050	2005R02051	2005R02052	2005R02053	2005R02054	2005R02056	2005R02057	2005R02058	2005R02059	2005R02060	2005R02061	2005R02062
Lingcod	1	1	1	1		2	2				1	1		1
Pelagic rockfish														
Black rockfish	14	10		10			17			4				
Black / dark rockfish				1										
Dark / dusky rockfish														
Dark rockfish		3					9			3				
Dusky rockfish		1	1									1	1	
Yellowtail rockfish				2										1
Demersal rockfish														
Canary rockfish							2			4				
China rockfish	1	3		7			6			2				
Quillback rockfish	4	7	9			11	1	1	6	2	1	3	6	3
Rosethorn rockfish														
Redstripe rockfish	22	3	23	3					2	2	2	4	1	
Silvergray rockfish	1	2	1			1					1	1		
Silvergray / Redstripe rockfish														
Tiger rockfish						1			2	1				
Juvenile yelloweye rockfish			2	1							2	1	2	
Yelloweye rockfish	1		2	1		1				1	1		1	1
Unidentified rockfish														
Large rockfish unspecified			1	1							2	2		
Small benthic rockfish unspecified			2					1						
Small benthic red rockfish unspecified	29	6	1	10					4		1	2	2	
Juvenile rockfish unspecified		1	5	3		6		1	31	21	2	43		

-continued-

Species or species group	2005R02027	2005R02028	2005R02050	2005R02051	2005R02052	2005R02053	2005R02054	2005R02056	2005R02057	2005R02058	2005R02059	2005R02060	2005R02061	2005R02062
Other fish														
Bathyraja unspecified														
Large gadid unspecified														
Juvenile gadid unspecified		1	1											
Walleye Pollock														
Kelp greenling	4	1		10	5	2	2		2	4	2	1	1	2
Greenling unspecified														
Prowfish														
Sculpin unspecified			1		3			22	6					
Northern ronquil					1									
Alaska ronquil				3										
Searcher														
Ronquil unspecified														
Prickleback / eelpout unspecified	1					1		2	22	1	1	3	4	
Prickleback unspecified														
Halibut						1		1						
Flat fish unspecified		1	1		2		3	4	4	11	1			1
Juvenile fish unspecified														30
Unidentified fish			1	1		1		2	2	1	1			
Invertebrates														
Tanner crab													1	
Box crab	1													
Red sea cucumber	79	65	129	15	1	20		29	72	7	70	104	73	55
Purple urchin														
Demspong unspecified	1	6	1						1	1	1		13	
Hydrocoral unspecified			27	6								9		5