Rockfish Surveys
Technical Report

Sara Smith and Dr. David Shull

Huxley College of the Environment, Western
Washington University

For
Whatcom County Public Works – Natural Resources
And
Whatcom County Marine Resources Committee

June 15, 2009

This report was funded in part through a cooperative agreement with the National Oceanic and Atmospheric Administration.

The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies.

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NORTHWEST STRAITS
marine conservation initiative

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by

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Introduction

Rockfish in the Puget Sound region have been observed to be declining from historical levels (Puget Sound Water Quality Action Team 2000, McConnell and Dinnel 2002, Palsson 1998). Their long life spans and low migration rates make rockfish sensitive to over-harvesting. Some species of rockfish have life spans of 50-140 years, with individuals found over 200 years old (Love et al. 2002). Rockfish take 6-12 years to reach sexual maturity (Baskett et al. 2005). Little migration is observed in adults and juveniles. Many migrate as few as a few kilometers during their lifespan (Buonaccorsi et al. 2002). This allows rockfish to be easily over-harvested by recreational and commercial fisheries once a rockfish "hot spot" has been located.

Management of bottomfish stock was minimal until the mid-1970s. In 1974 Judge Boldt affirmed Native American's rights to 50 percent of salmon stocks as defined in original treaty agreements from the 1850s. In response to the increased pressure on salmon populations, the Washington Department of Fish and Wildlife suggested fishermen "go bottom fishing." Bottom fishing peaked in the mid-1980s with fishermen harvesting 400,000 pounds of lingcod in 1983. By 1993 harvest dropped to a few thousand pounds. Similarly, rockfish catch per unit effort had decreased 50 percent by this time (McConnell and Dinnel 2002). In 2000, catch limits were lowered from 10 rockfish per day to one rockfish per day. However, these lowered catch limits have failed to produce sustainable populations (McConnell et al. 2001). Average rockfish size has also decreased by several inches since the 1970s due to preferential harvest of larger individuals (Palsson 1997). In addition to long life spans and slow reproductive rates that cause typical fisheries management techniques such as size limits and catch limits to be insufficient for rockfish management, rockfish are also susceptible to barotrauma. Rockfish have physoclistous swim bladders that hyper-inflate due to decreased pressure when brought up from depth (Meyer 2006). Few rockfish captured from depths greater than 20 m survive release (Starr et al. 2001).

By lowering the rockfish catch limit to one rockfish per day in 2000, the Washington Department of Fish and Wildlife hoped to discourage any directed rockfish harvest but still allow a small number of accidently-caught rockfish to be kept. But, these lowered catch limits have in turn promoted catch-and-release fishing. Number of fish caught and released by recreational fishermen has doubled in the last 20 years, concurrent with decreased bag limits (Bartholomew and Bohnsack 2005). Although catch-and-release does not result in a necessary extraction of fish stock and may be an appropriate conservation method for some species, rockfish's susceptibility to barotrauma causes an usually high mortality rate. With such a low catch limit it is also likely fishermen will hold out for a larger rockfish and release smaller fish.

Conservation interests have shifted in favor of marine protected areas over traditional catch limits. Marine protected areas have been successful in producing larger and higher densities of rockfish (Palsson 1998, Fujita et al. 1998). In the Puget Sound, two marine protected areas have been implemented long enough to provide reliable population data. The Edmonds Underwater Park, established in 1970, showed increased fish abundance and size during assessments in the 1990s. Shady Cove, a marine protected area in the San Juan Islands was surveyed seven years after its establishment and found to contain twice as many and larger copper rockfish than adjacent non-protected habitat (McConnell et al. 2001).

Increased rockfish population size and body size increase overall reproductive potential. Rockfish are viviparous and larvae must survive an initial pelagic phase of two to six months (Buonaccorsi et al. 2002). Survival during this phase is low, in part, due to starvation (Fujita et al. 1998). Although rockfish larvae have consumed most of their yolk at birth, an oil globule acts as an energy store for the larvae during the initial starvation period. For example, as black rockfish mature they provide their larvae with larger oil globules, birthing more fit individuals. Older black rockfish produce larvae that grow three times faster and survive starvation twice as long as younger mothers (Berkeley et al. 2004). Thus, removing the largest mothers has disproportionate effects on the population growth rates that go beyond the simple reduction in number of offspring.

Although rockfish populations in Puget Sound have been documented to be declining, little research on rockfish densities in other areas of the Salish Sea exist. The Strait of Georgia and Rosario Strait in Whatcom County, Washington are host to several species of bottomfish, including lingcod (*Ophiodon elongatus),* kelp greenling (*Hexagrammos decagrammus*), and several rockfish species, most abundant including copper rockfish (*Sebastes caurinus*), quillback rockfish (*Sebastes maliger*), and Puget Sound rockfish (*Sebastes emphaeus*). Population surveys to determine rockfish abundance, distribution, and habitat preference have been conducted through the Whatcom County Marine Resources Committee (MRC) annually for the past two years to provide information for better management decisions. To better understand rockfish distribution in Whatcom County and to provide additional information for future marine protected area location decisions, video ROV surveys were conducted at southern tip of Lummi Island (Carter Point), Lummi Rocks, Viti Rocks, and Chuckanut Bay (Appendix A-1,2,3).

Methods

Data were collected on March 19, 2009 and March 25, 2009 using a VideoRay Pro 3 XE GTO remotely operated vehicle (ROV). The ROV was equipped with parallel lasers distanced 10 cm apart for determination of transect width and fish size during subsequent video analysis. The R/V Zoea (operated by the WWU Shannon Point Marine Center) was used as a research platform and connected to the ROV through a 100-m neutrally-buoyant cable. Times of long slack tide were chosen to minimize tidal current interference. Transect locations were selected based on previous Whatcom County rockfish assessment transect locations (Grove and Shull 2008) and on habitat complexity. Sites were chosen for potentially high habitat complexity of large boulders and rocks or other areas where rockfish were expected from anecdotal evidence.

At each station where rockfish were observed we determined bottom topography and bottom slope. Bottom depth, latitude, and longitude were measured at several points along a transect perpendicular to shore. Bottom depth was measured using a depth finder and the vessel's horizontal position was determined by GPS at points separated by approximately 10 m. Once bottom topography was determined, the R/V Zoea was maneuvered as close as possible to the deepest point along the bottom-topography transect. Cable was fed out as necessary after ROV deployment and the ROV was maneuvered as closely as possible along the same transect up slope from deep to shallow water. ROV camera images were viewed on a console displaying ROV depth and heading for location reference. Video was recorded using a Sony VRD-MC3 DVD recorder for later analysis. Location of the start and end of the ROV transects were recorded to check for differences between the bottom-topography transect and the ROV transect.

Video transect recordings were analyzed for transect area and slope, rockfish abundance and species identification, and habitat complexity. Average transect width was determined by measuring the distance between laser points every five seconds. Actual laser distance (10 cm) was multiplied by a ratio of laser distance to screen width used for viewing. These values were averaged for each transect to determine an average transect width. Transect length was determined by converting the latitude and longitude points from the research vessel's depth profile to nautical miles (nm). The horizontal distances between two points in a profile were calculated using the following formula.

$$\text{Distance(nm)} = \sqrt{(\text{Long}_2 - \text{Long}_1)^2 \cos(\text{Avg. Lat})^2 + (\text{Lat}_2 - \text{Lat}_1)^2}\ .$$

Distance onshore was determined by adding the distance for each location with the distance from the previous one cumulatively. Bottom slopes for each transect were determined from the arctangent of the slope of the linear regression between depth and distance onshore. The length of the subsequent ROV transect was determined from the change in water depth (measured by a pressure sensor within the ROV) divided by sin(bottom slope). Multiplying transect length and average transect width gave transect area. Rockfish, lingcod, and kelp greenling were identified using slow motion video playback. Dividing the number of rockfish observed by transect area gave rockfish m^{-2}. Habitat complexity, as specified by Dinnel et al. (2003) was calculated for transects with video footage every one minute. Overall transect habitat complexity was calculated as the average complexity over the entire transect.

Results

Rockfish population studies were conducted at Carter Point, Lummi Rocks, Viti Rocks, and Chuckanut Bay. Twelve ROV transects were conducted and a total of 58 rockfish were observed. Observed rockfish included: quillback, copper, Puget Sound, and black rockfish. Lingcod, kelp greenling, a painted greenling, and a wolf eel were also sighted. Rockfish density ranged from 0 to 0.19 rockfish m^{-2}. We observed most rockfish over rocky bottoms with high habitat complexity (Fig. 1). Bottom slope was also related to increased rockfish abundance (Fig. 2). Rockfish were sighted at all depth ranges surveyed, from 60 m to 10 m. We observed considerable variation in bottom slope (Fig. 3) and complexity (Fig. 4) among the stations we surveyed. The spatial distribution of rockfish clearly reflected this variation (Fig. 5).

Viti Rocks

VR2 displayed one of the highest densities of rockfish (0.15 rockfish m^{-2}) and the greatest species diversity (Table 1). Unlike other transects VR2 was taken horizontally along the shoreline, not vertically up the shore. The initial section of this transect has bottom coverage of large rocks with some small areas with visible sand. The middle section consists mostly of sandy bottom sediments. The final section is moderately rocky with some sandy sediment visible. All rockfish were sighted in the beginning and final portions of this transect; no rockfish were sighted in the sandy middle region. VR1 has extensive large rocky coverage with a large boulder seen at 20 m and a moderate gradient. A much smaller number of rockfish were seen at VR1 than VR2 (Table 1).

Carter Point

Both slope and habitat complexity decrease from Carter Point northward up the western shore of Lummi Island (Fig.3, 4). We observed high rockfish densities in transects at the southern tip of Carter Point (Table 1). High densities of rockfish were found in LI1 and LI2 (Fig. 5), consistent with previous rockfish population data (Grove and Shull 2008). LI1 has large rocky coverage with interspersed boulders and a steep gradient. Quillback and copper rockfish were sighted here, but not in large groups (Table 1). LI2 had an extensive number of grouped juvenile Puget Sound rockfish (Table 1). LI2 has a steep gradient, large rocky coverage but no boulders. Also in accordance with Grove and Shull (2008), the transect sites in between Lummi Rocks and Carter Point, LI3 and LI4, had low rockfish density and low habitat complexity (Fig. 4, 5). No rockfish were seen at LI3. LI3 has a relatively flat bottom with many large boulders. LI4 also has a flat bottom and coverage consists mainly of medium-small (less than 1-m diameter) rocks with sand. Only one quillback rockfish was sighted in LI4. LI5 is located on the eastern side of Carter Point. This area has a sandy bottom habitat with few rocks and a relatively level bottom. No rockfish were sighted here.

Lummi Rocks

Like VR2, LR1 had a relatively high density of rockfish. The bottom of LR1, located on the westward side of Lummi Rocks, is covered extensively by large, piled rocks and a moderate slope. LR1 had a high number of copper rockfish (Table 1), many of which appeared in groups. A large derelict fishing net was seen at the beginning of LR1. The LR2 bottom is covered by medium-small (less than 1-m diameter) rocks. Although there is an area of LR2 with large rocky habitat similar to LR1, this area has a gentle bottom slope and displayed little change in depth.

Chuckanut Bay

No rockfish were observed in the three Chuckanut Bay transects. Bottom slopes were not determined due to the lack of rockfish.

Discussion

Despite the decreased catch limit from 10 to one rockfish per day in 2000, rockfish populations have continued to decline in the Puget Sound region (Puget Sound Water Quality Action Team 2000, McConnell and Dinnel 2002, Palsson 1998). The failure of traditional fisheries management techniques such as catch limits is largely due to the long life span, low fecundity, low migration of rockfish and high mortality rates of rockfish bycatch (Love et al. 2002, Buonaccorsi et al. 2002). Marine protected areas have the potential of boosting Whatcom County rockfish populations by increasing rockfish density, size, and reproductive potential (Palsson 1998, Fujita et al. 1998). We conducted this study to provide additional information on Whatcom County rockfish distribution and to aid in future decisions of marine protected areas locations. In particular, our study extended the spatial coverage of previous work in Whatcom County to include Chuckanut Bay.

As concluded by other studies (Grove and Shull 2008, Pacunski 2001) rockfish habitat preference is for areas with large boulders and steep bottom slopes. Transects at Lummi Rocks and Viti Rocks with high habitat complexity and steep bottom slopes correspondingly have higher rockfish densities. Habitat characteristics and rockfish abundances were similar to the previous Whatcom County rockfish population assessments of Grove and Shull (2008). (See appendix B-2.) The western side of Carter Point and Lummi Rocks were both found to have high densities of rockfish as well. Grove and Shull (2008) also noted the drop of slope and increasingly sandy sediments in areas off Lummi Island between Carter Point and Lummi Rocks. Both our LI5 transect and the Grove and Shull (2008) transect off the eastern side of Carter Point contained no rockfish.

Although marine protected areas have been documented to produce a larger individuals and a greater density of rockfish (Palsson 1998), there is no established criteria for choosing marine protected area locations. The Skagit County, Washington MRC went through several years of study to determine ideal spots for marine protected areas. Whereas the marine protected areas were not implemented, the assessment of Skagit County rockfish habitat and criteria established is relevant to Whatcom County efforts to establish marine protected areas. Of the Skagit County MRC criteria for marine protected area locations outlined in McConnell et al. (2002), our study covered the criteria of habitat complexity and location, rockfish density, and absence of derelict nets.

Habitat Complexity and Location

Whereas our study supported that rockfish habitat preference is for areas of high habitat complexity and high relief, our data were not sufficient to distinguish species-specific habitat preferences. The NOAA Marine Harvest Refugia workshop (Starr 1998) suggested rockfish be divided into groups based on habitat preference (deep benthic, hard bottom; deep benthic, soft or mixed bottom; shallow benthic; deep semipelagic; shallow semipelagic). A specific group should be targeted to allow sufficient protection of the preferred habitat. The marine protected area location criteria specified by Palsson (2002) are adapted from the NOAA Marine Harvest Refugia workshop to more specifically address Washington rockfish populations. Palsson defined the targeted species for Washington marine protected areas as copper and quillback rockfish. Copper rockfish are typically found at shallower depths than quillback. Copper rockfish habitat preference is for areas of high relief and high habitat complexity. Quillback rockfish are found in lower relief boulder fields, but this is possibly a result of a lack of high relief areas at depth (Pacunski and Palsson 2001). The areas with highest habitat complexity in our study were LI1, VR1, VR2, and LR1 (Fig. 4). The areas with the steepest bottom slopes were LI1 and LI2 (Fig. 5).

Rockfish Density

Both the Skagit County MRC (McConnell and Dinnel 2002) and the NOAA Marine Refugia workshop (Starr 1998) suggest establishing marine protected areas both in locations of currently high rockfish densities and areas of historically high rockfish densities. Historically high density areas that are currently over-harvested have a good potential to repopulate if protected. Areas of currently high rockfish densities will become source populations, providing larvae to depleted areas (Starr 1998). The areas of highest rockfish density in our study were VR2 and LR1 (Figure 6). It is unknown whether areas of low rockfish density found in our study are due to poor habitat or past over-fishing.

Currents for larval dispersal was originally a biological criterion for choosing marine protected area locations for the Skagit County MRC but was dropped due to lack of data and difficulty of assessment. Using the General NOAA Oil Modeling Environment Model, a simulated oil spill near Lummi Island was observed to remain between north Whidbey Island and Lummi Island (McConnell and Dinnel 2002). This suggests that larvae might be preferentially retained within this area and if a marine protected area were to increase reproductive potential here, larval recruitment might facilitate recovery of currently depleted rockfish stocks. However, Chuckanut Bay would have different mean circulation patterns, and thus different patterns of larval dispersal and recruitment.

Absence of Derelict Nets

Although LR1 also has high habitat complexity and high rockfish density, a large derelict fishing net was sighted during this transect.

During this study, we observed several areas dominated by one species of rockfish. LI2 contained a very high number of Puget Sound rockfish at depths below 34.5 m. Because of their small size and tendency to hide the crevices of large rocks, an exact measurement of their numbers is not possible. VR2 also had a high abundance of Puget Sound rockfish, although this transect differs from the others because it was taken horizontally along shore. LR1 had a large number of copper rockfish often observed in groups of up to four. LR1 had the most rock coverage of any transect, with many crevices created from piled large rocks. The complex bottom habitat of LR1 appeared similar to habitats where we observed other rockfish species and it is unclear why copper rockfish would dominate over other species.

In a majority of fish sightings during video analysis bottom fish were observed to swim away in response to ROV presence. It appeared that these escape responses followed fish observation and we were able to identify almost all rockfish recorded on video before they escaped view. Nevertheless, it is unclear how much of an effect this behavior has on ROV-surveyed population estimates. Some species, such as copper and quillback, displayed a short-distance escape response and the fish could easily be followed to avoid recounting the same individual. Puget Sound rockfish tend to react more quickly and swim into rock crevices in response to ROV approach. This, coupled with their small size and tendency to aggregate, made it difficult to account for all Puget Sound rockfish present. Whether ROV surveys give an over estimate of Puget Sound rockfish due to re-counting the same individual, or if it gives an under estimate due to their small size is unclear. Pacunski and Palsson (2001) cited a similar concern when surveying rockfish using a ROV. They estimated 30 percent of rockfish were hidden from camera view, possibly more in areas of high habitat complexity. While ROV surveys are quicker and easier to coordinate than SCUBA studies, it is likely the population estimates of these two survey techniques do not match. Whereas Whatcom County uses ROV surveys for bottom fish population studies, adjacent counties use SCUBA surveys, making comparison not possible. We recommend that SCUBA surveys be conducted in Whatcom County to provide additional information on the relationship between SCUBA and ROV population estimates. These future studies should account for differences in ROV responses among species.

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Figures and Tables

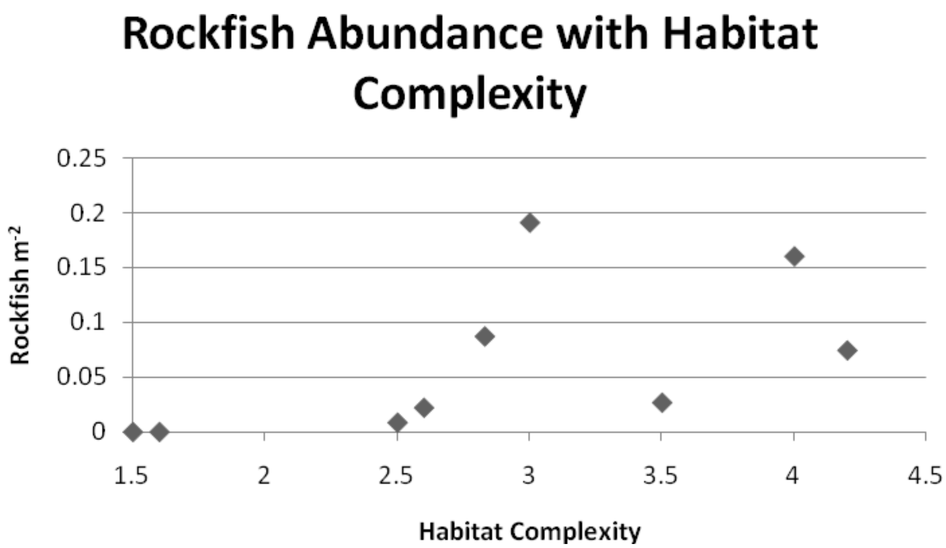


Figure 1. Rockfish density (individuals m^{-2}) and habitat complexity for all transects excluding CB1, CB2, CB3. Habitat complexity index from Dinnel et al. (2003).

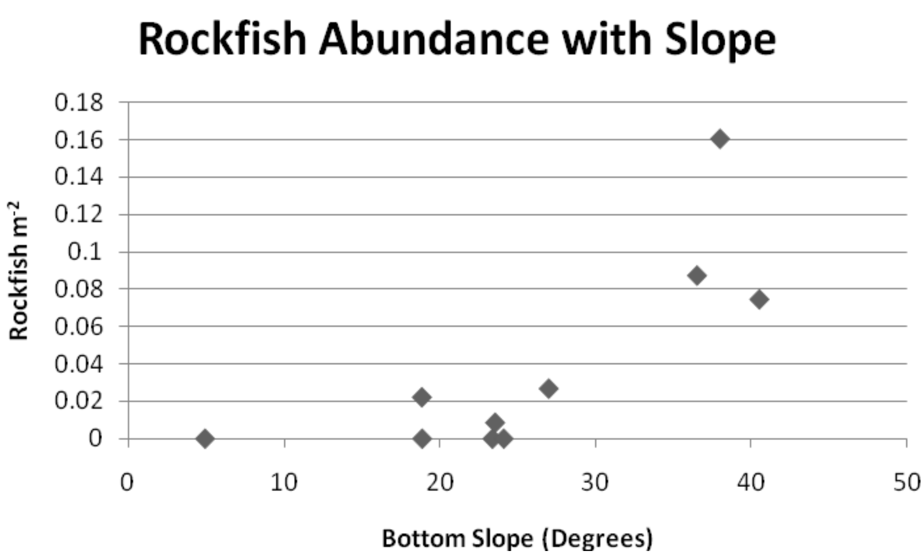


Figure 2. Rockfish density (individuals m^{-2}) plotted versus bottom slope for all transects exluding CB3 and VR2.

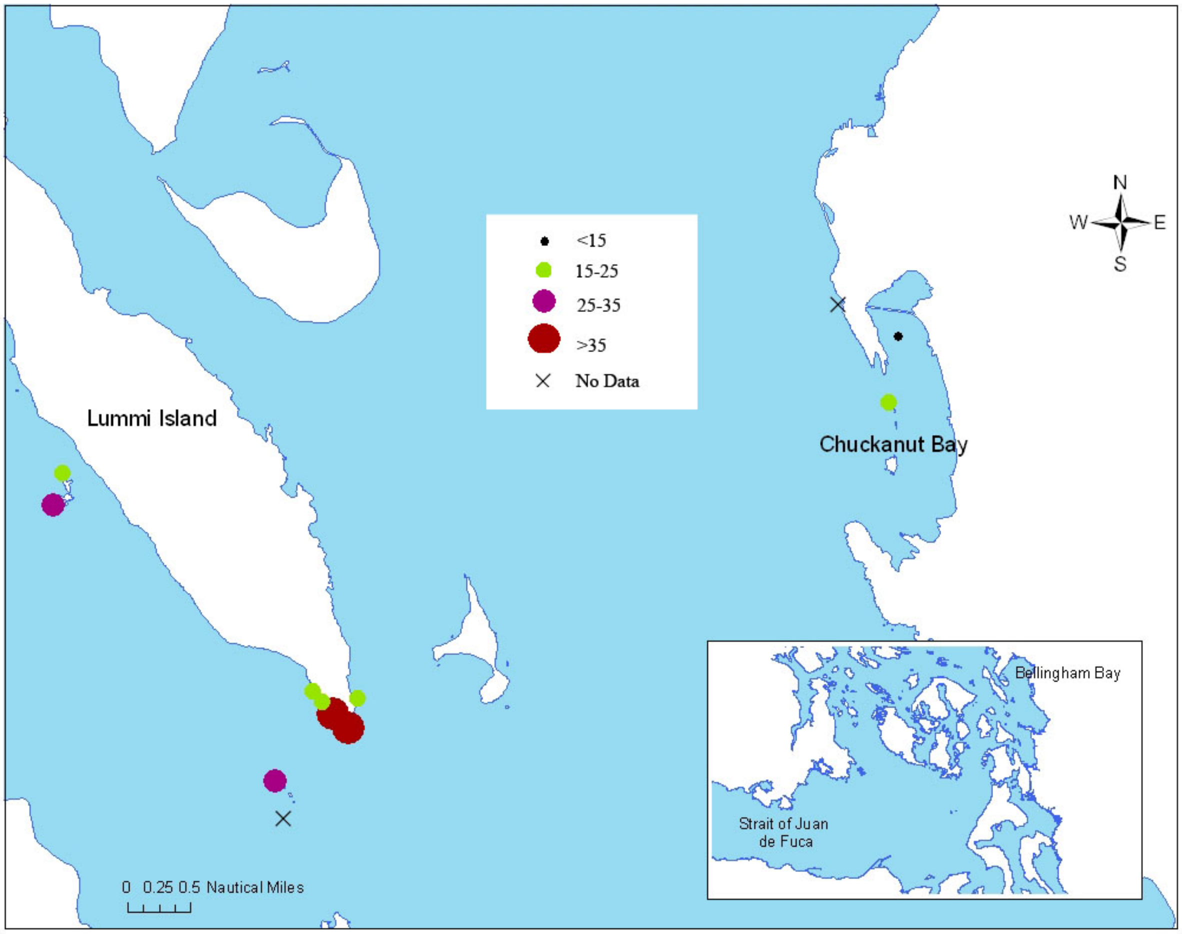


Figure 3. Map of ROV transect locations and average bottom slope (in degrees).

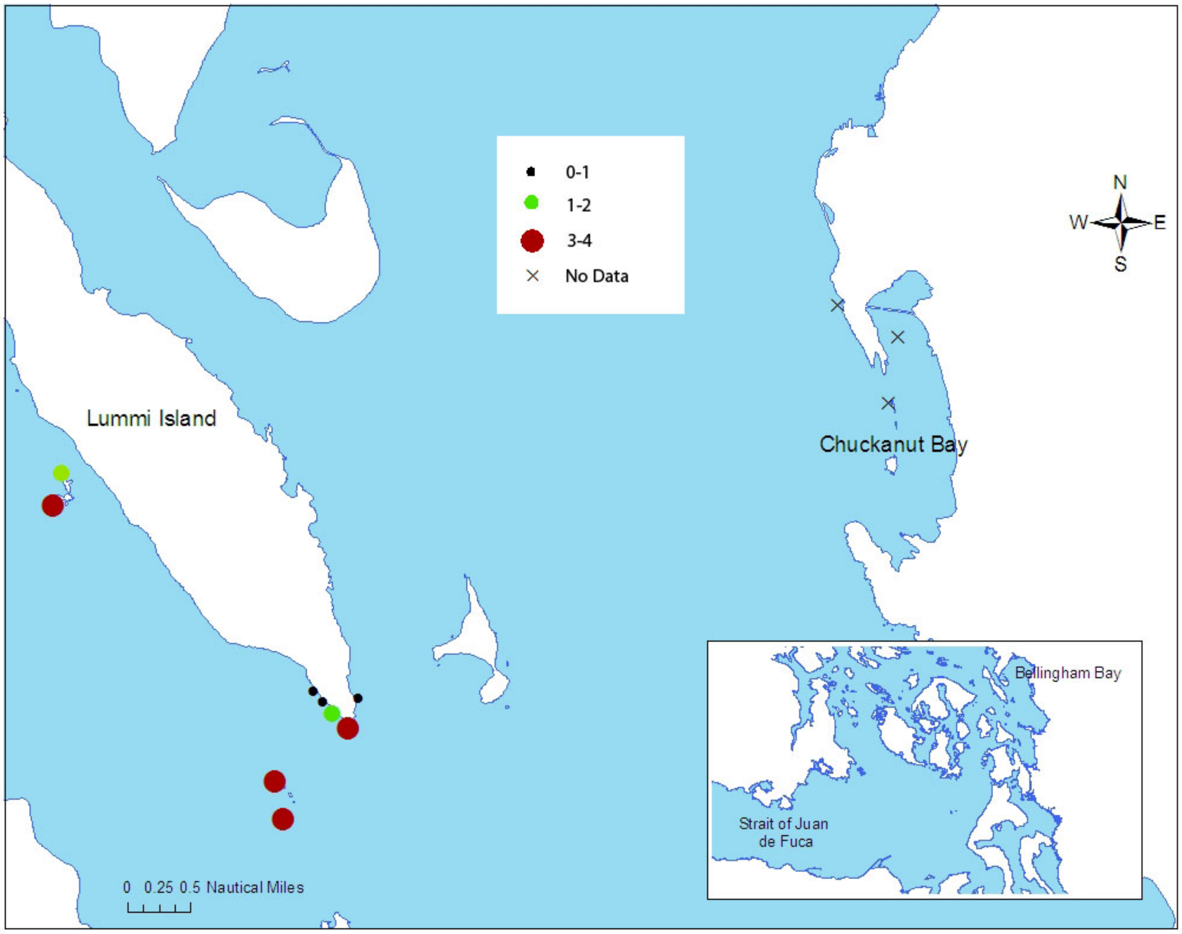


Figure 4. Map of ROV transect locations and habitat complexity (Dinnel et al. 2003).

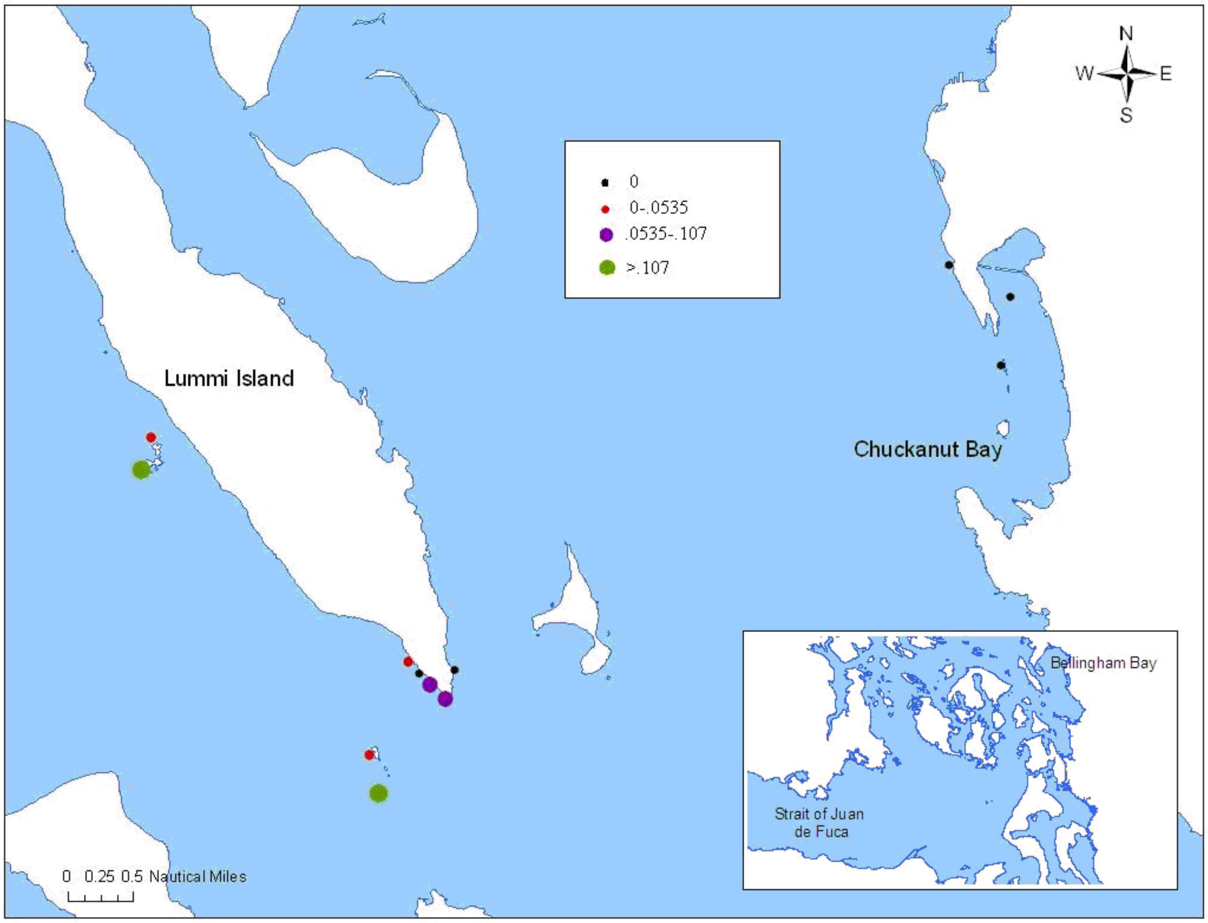


Figure 5. Location map displaying rockfish m^{-2} (all species are of rockfish are included).

Lummi Island 1 (LI1)	
Species	**Number**
Copper	4
Black	1
Kelp Greenling	1 (m)
Lingcod	1

Lummi Island 2 (LI2)	
Species	**Number**
Copper	1
Puget Sound	7

Lummi Island 3 (LI3)	
Species	**Number**
Kelp Greenling	1 (f)

Lummi Island 4 (LI4)	
Species	**Number**
Quillback	1
Kelp Greenling	1 (f), 1 (m)

Lummi Island 5 (LI5)	
Species	**Number**
None	

Lummi Rocks 1 (LR1)	
Species	**Number**
Copper	11
Quillback	1
Kelp Greenling	1 (f), 1 (m)

Lummi Rocks 2 (LR2)	
Species	**Number**
Copper	1
Unidentified	1

Viti Rocks 1 (VR1)	
Species	**Number**
Copper	3
Kelp Greenling	2 (f), 1 (m)

Viti Rocks 2 (VR2)	
Species	**Number**
Copper	4
Puget Sound	19
Painted Greenlin	1
Lingcod	0

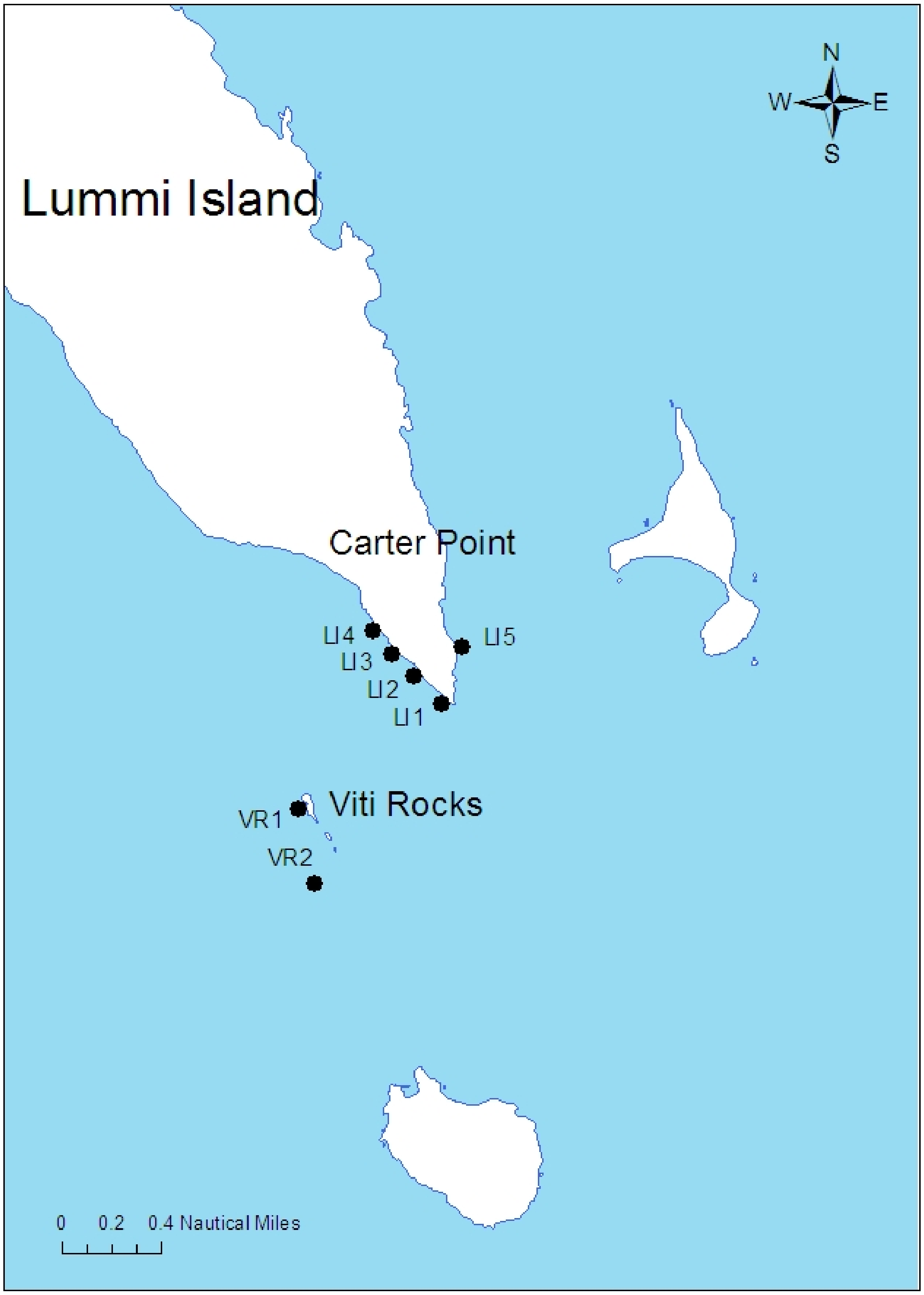
Chuckanut Bay 1 (CB1)	
Species	**Number**
None	0

Chuckanut Bay 2 (CB2)	
Species	**Number**
None	0

Chuckanut Bay 3 (CB3)	
Species	**Number**
None	0

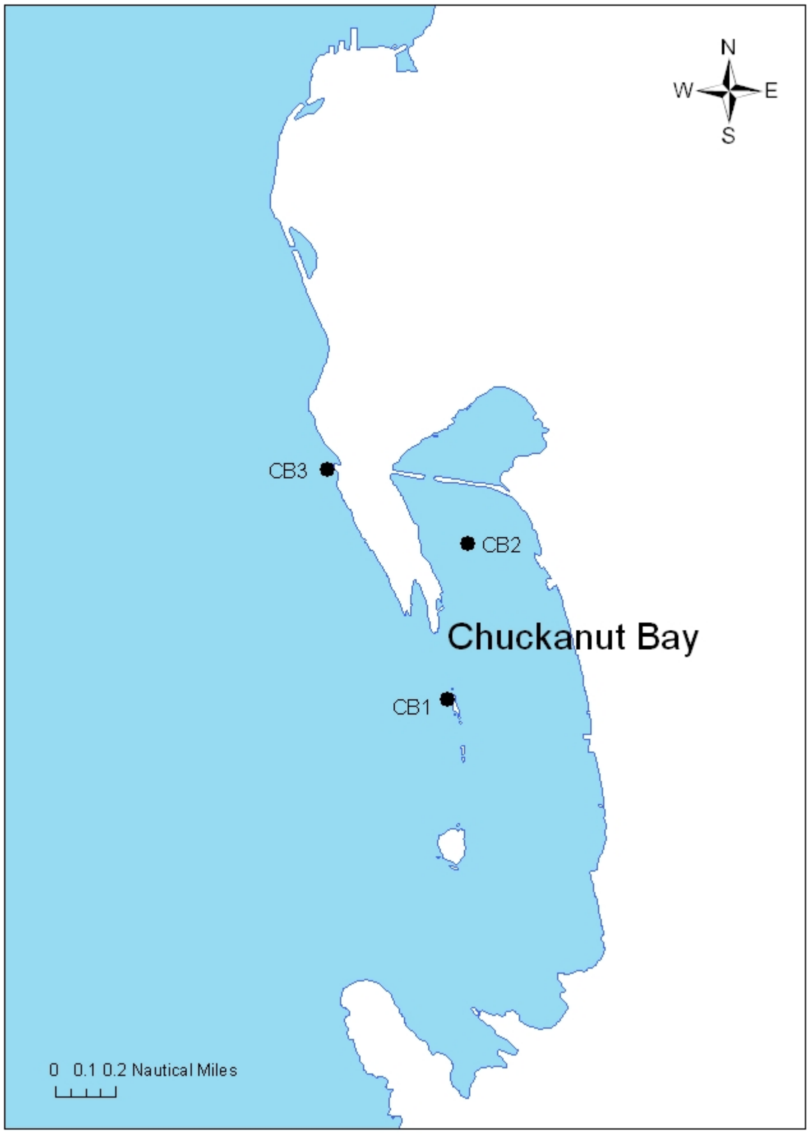
Table 1. Summary of bottomfish sightings at all transect locations.

Appendix A. Transect locations


N
W
E
S
Lummi Island
Carter Point
LI4
LI3
LI2
LI1
LI5
VR1
Viti Rocks
VR2
0 0.2 0.4 Nautical Miles

Appendix A-1. Map of transect locations off Carter Point (LI1, LI2, LI3, LI4, LI5) and Viti Rocks (VR1, VR2).

Appendix A-2. Map of transect locations off Lummi Rocks (LR1, LR2).



Appendix A-3. Map of transect locations in Chuckanut Bay (CB1, CB2, CB3).

Appendix B. Transect bottom profiles, fish identification, and habitat assessments

Lummi Island 1 (LI1)

Date: 3/19/2009

Location: 48° 38.418 N 122° 36.581 W

Habitat: Mostly large rocks and boulders. Some areas with smaller-sized rocks. Rocks cover entire transect, no sand or mud.

Habitat Complexity: 4.2

Slope: 40.536

Rockfish m^{-2}: 0.074390

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Copper	Boulders	1		49.5
Kelp Greenling (m)	Boulders	1		37.4
Black	Boulders	1		24.7
Copper	Boulders	1		22.6
Copper	Medium rocks	1		19.1
Copper	Large rocks	1		18.1
Lingcod	Medium rocks	1		17.9

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48° 38.427	122° 36.567	0.00	58.2
48° 38.425	122° 36.572	7.15	51.3
48° 38.420	122° 36.579	19.77	44.5
48° 38.416	122° 36.583	28.65	34.2
48° 38.411	122° 36.590	41.26	23.1
48° 38.406	122° 36.592	50.84	14.6

Lummi Island 2 (LI2)

Date: 3/19/2009

Location: 48^o 38.530 N 122^o 36.757 W

Habitat: Mostly large rocks. No boulders. Rock cover extensive with no sand or mud sections.

Habitat Complexity: 2.83

Slope: 36.534

Rockfish m^{-2}: 0.087135

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Puget Sound	Large rocks	1		52.5
Copper	Large rocks	1		52.4
Puget Sound	Medium rocks	5		46.5
Puget Sound	Medium rocks	1		35.8

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^o 38.527	122^o 36.775	0.00	54.9
48^o 38.523	122^o 36.768	11.33	46.9
48^o 38.525	122^o 36.761	20.66	40.3
48^o 38.528	122^o 36.757	28.06	38.3
48^o 38.531	122^o 36.752	36.33	27.9
48^o 38.534	122^o 36.749	42.99	23.0
48^o 38.535	122^o 36.747	46.06	19.8
48^o 38.538	122^o 36.744	52.71	17.2

Lummi Island 3 (LI3)

Date: 3/19/2009

Location: 48^o 38.614 N 122^o 36.893 W

Habitat: Lower depths (until about 28 m) have medium-sized rocks. Upper depths have large rocks, but also many very large boulders with little vegetative cover.

Habitat Complexity: 1.6

Slope: 23.400

Rockfish m^{-2}: 0

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Kelp Greenling (f)	Medium rocks	1		35.5

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^o 38.593	122^o 36.914	0.00	67.9
48^o 38.596	122^o 36.912	6.07	66.4
48^o 38.599	122^o 36.906	15.28	64.2
48^o 38.603	122^o 36.903	23.55	62.6
48^o 38.609	122^o 36.899	35.69	59.8
48^o 38.614	122^o 36.895	46.16	57.3
48^o 38.617	122^o 36.892	52.82	51.9
48^o 38.621	122^o 36.887	62.43	46.4
48^o 38.624	122^o 36.882	70.69	41.8
48^o 38.628	122^o 36.877	80.30	37.0
48^o 38.630	122^o 36.875	84.74	29.8
48^o 38.632	122^o 36.873	89.18	14.0

Lummi Island 4 (LI4)

Date: 3/19/2009

Location: 48^{o} 38.703 N 122^{o} 37.015 W

Habitat: Few large rocks interspersed with small rocks. Smaller rocked sections have visible sand in between rocks. Upper areas have larger rocks, but they are spaced with sand.

Habitat Complexity: 2.5

Slope: 23.573

Rockfish m^{-2}: 0.008558

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Quillback	Small rocks with boulders	1		44.4
Kelp Greenling (f)	Small rocks with boulders	1		32.7
Kelp Greenling (m)	Boulders with vegetation	1		5.2

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^{o} 38.691	122^{o} 37.045	0.00	59.1
48^{o} 38.693	122^{o} 37.040	7.15	54.8
48^{o} 38.696	122^{o} 37.032	18.41	50.0
48^{o} 38.700	122^{o} 37.022	32.71	46.1
48^{o} 38.704	122^{o} 37.012	37.02	42.0
48^{o} 38.707	122^{o} 37.007	55.28	38.4
48^{o} 38.709	122^{o} 37.000	64.61	33.8
48^{o} 38.710	122^{o} 36.990	76.99	23.1
48^{o} 38.714	122^{o} 37.986	85.87	19.5

Lummi Island 5 (LI5)

Date: 3/25/2009

Location: 48^{o} 38.650 N 122^{o} 36.472 W

Habitat: Sandy with a few very large boulders.

Habitat Complexity: 1.5

Slope: 24.131

Rockfish m^{-2}: 0

Rockfish Identification

None

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^{o} 38.650	122^{o} 36.450	0.00	42.8
48^{o} 38.649	122^{o} 36.458	9.96	40.2
48^{o} 38.648	122^{o} 36.464	17.54	36.8
48^{o} 38.647	122^{o} 36.470	25.11	32.9
48^{o} 38.647	122^{o} 36.476	32.45	25.2
48^{o} 38.656	122^{o} 36.481	50.20	20.0
48^{o} 38.656	122^{o} 36.486	56.32	15.2
48^{o} 38.644	122^{o} 36.490	79.08	10.6

x

Lummi Rocks 1 (LR1)

Date: 3/19/2009

Location: 48^o 40.123 N 122^o 40.174 W

Habitat: Entire transect covered extensively with piled large rocks. No boulders.

Habitat Complexity: 4

Slope: 28.007

Rockfish m^{-2}: 0.160148

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Kelp greenling (m)	Large rocks	1		30.1
Copper	Large rocks	1		27.5
Quillback	Large rocks	1		25.5
Copper	Large rocks	2		25.2
Copper	Large rocks	4		23.5
Copper	Medium rocks	1		21.3
Copper	Medium rocks	1		19.4
Copper	Medium rocks	1		17.7
Kelp Greenling (f)	Medium rocks with vegetation	1	0.3	15.8
Copper	Medium rocks with vegetation	1		15.0

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^o 40.100	122^o 40.199	0.00	64.4
48^o 40.103	122^o 40.193	9.20	62.3
48^o 40.110	122^o 40.187	24.10	55.8
48^o 40.118	122^o 40.180	41.21	46.7
48^o 40.127	122^o 40.171	61.19	36.6
48^o 40.130	122^o 40.166	69.45	28.0
48^o 40.135	122^o 40.161	80.55	22.0
48^o 40.140	122^o 40.155	92.36	16.9
48^o 40.145	122^o 40.152	102.32	13.6

Lummi Rocks 2 (LR2)

Date: 3/19/2009

Location: 48^{o} 40.377 N 122^{o} 40.079 W

Habitat: Lower depths covered with mostly medium-small rocks with no visible sand. At upper depths rock size increases, but this area is also has little slope. Last part of transect dominated with small-medium rocks

Habitat Complexity: 2.6

Slope: 18.77

Rockfish m^{-2}: 0.023123

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Unidentified rockfish	Small rocks	1		31.0
Copper	Small rocks	1		30.3

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^{o} 40.405	122^{o} 40.087	0.00	44.3
48^{o} 40.398	122^{o} 40.085	13.19	42.3
48^{o} 40.393	122^{o} 40.083	22.77	38.8
48^{o} 40.388	122^{o} 40.081	32.35	36.4
48^{o} 40.383	122^{o} 40.079	41.93	33.6
48^{o} 40.379	122^{o} 40.079	49.33	23.5
48^{o} 40.375	122^{o} 40.078	56.84	26.1
48^{o} 40.370	122^{o} 40.077	66.18	23.0
48^{o} 40.364	122^{o} 40.076	77.36	20.5
48^{o} 40.361	122^{o} 40.075	83.05	17.3
48^{o} 40.356	122^{o} 40.075	92.21	14.5
48^{o} 40.351	122^{o} 40.074	101.65	11.3

Viti Rocks 1 (VR1)

Date: 3/19/2009

Location: 48^{o} 37.978 N 122^{o} 37.463 W

Habitat: Mostly large rocks. Big boulder at 20 m

Habitat Complexity: 3.5

Slope: 27.021

Rockfish m^{-2}: 0.026717

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Copper	Boulders	1	0.31	32.3
Copper	Boulders	1	0.35	32.2
Kelp Greenling (m)	Boulders	1		28.5
Kelp Greenling (f)	Large rocks	1		16.7
Copper	Moderate rocks	1		12.1
Kelp Greenling (f)	Moderate rocks	1		6.5

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^{o} 37.968	122^{o} 37.459	0.00	52.2
48^{o} 37.970	122^{o} 37.458	3.90	48.1
48^{o} 37.971	122^{o} 37.452	11.47	41.2
48^{o} 37.974	122^{o} 37.442	24.92	34.6
48^{o} 37.977	122^{o} 37.433	37.25	29.5
48^{o} 37.980	122^{o} 37.426	47.46	24.6
48^{o} 37.982	122^{o} 37.420	55.69	21.5
48^{o} 37.983	122^{o} 37.415	62.08	18.4
48^{o} 37.985	122^{o} 37.411	68.22	15.2
48^{o} 37.986	122^{o} 37.407	73.46	12.0

Viti Rocks 2 (VR2)

Date: 3/25/2009

Location: 48^{o} 37.683 N 122^{o} 37.322 W

Habitat: Initial and final areas covered with large rocks interspersed with sandy sediment. Middle of transect sandy.

Habitat Complexity: 3

Rockfish m^{-2}: .1488

Rockfish Identification

Species	Habitat	Number	Size (m)	Depth (m)
Unidentified	Boulders	1		61.2
Puget sound	Boulders	1		60.6
Copper	Large rocks	1	0.325	58.4
Puget Sound	Large rocks	2		56.3
Puget Sound	Large rocks	3		52.9
Puget Sound	Boulders	3		51.5
Puget sound	Boulders	1		48.3
Puget sound	Boulders	4		47.4
Painted Greenling	Boulders	1		35.0
Puget sound	Large rocks	1		30.0
Puget sound	Boulders	2		28.6
Puget sound	Boulders	2		27.2
Copper	Boulders	1		26.6
Copper	Boulders	1		24.6
Copper	Boulders	1		24.5
Puget Sound	Boulders	1		24.5

Depth Profile

None

Chuckanut Bay 1 (CB1)

Date: 3/25/2009

Location: 48° 41.112 N 122° 30.204 W

Slope: 18.897

Rockfish m^{-2}: 0

Rockfish Identification

None

Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48° 41.114	122° 30.226	0.00	19.5
48° 41.113	122° 30.217	11.16	19.3
48° 41.113	122° 30.210	19.72	17.1
48° 41.112	122° 30.204	27.28	13.4
48° 41.112	122° 30.200	32.17	11.0
48° 41.112	122° 30.195	38.29	8.8
48° 41.111	122° 30.192	42.40	7.0
48° 41.110	122° 30.187	48.78	4.0

Chuckanut Bay 2 (CB2)

Date: 3/25/2009
Location: 48^{o} 41.636 N 122^{o} 30.121 W

Slope: 4.964

Rockfish m^{-2}: 0

Rockfish Identification

None

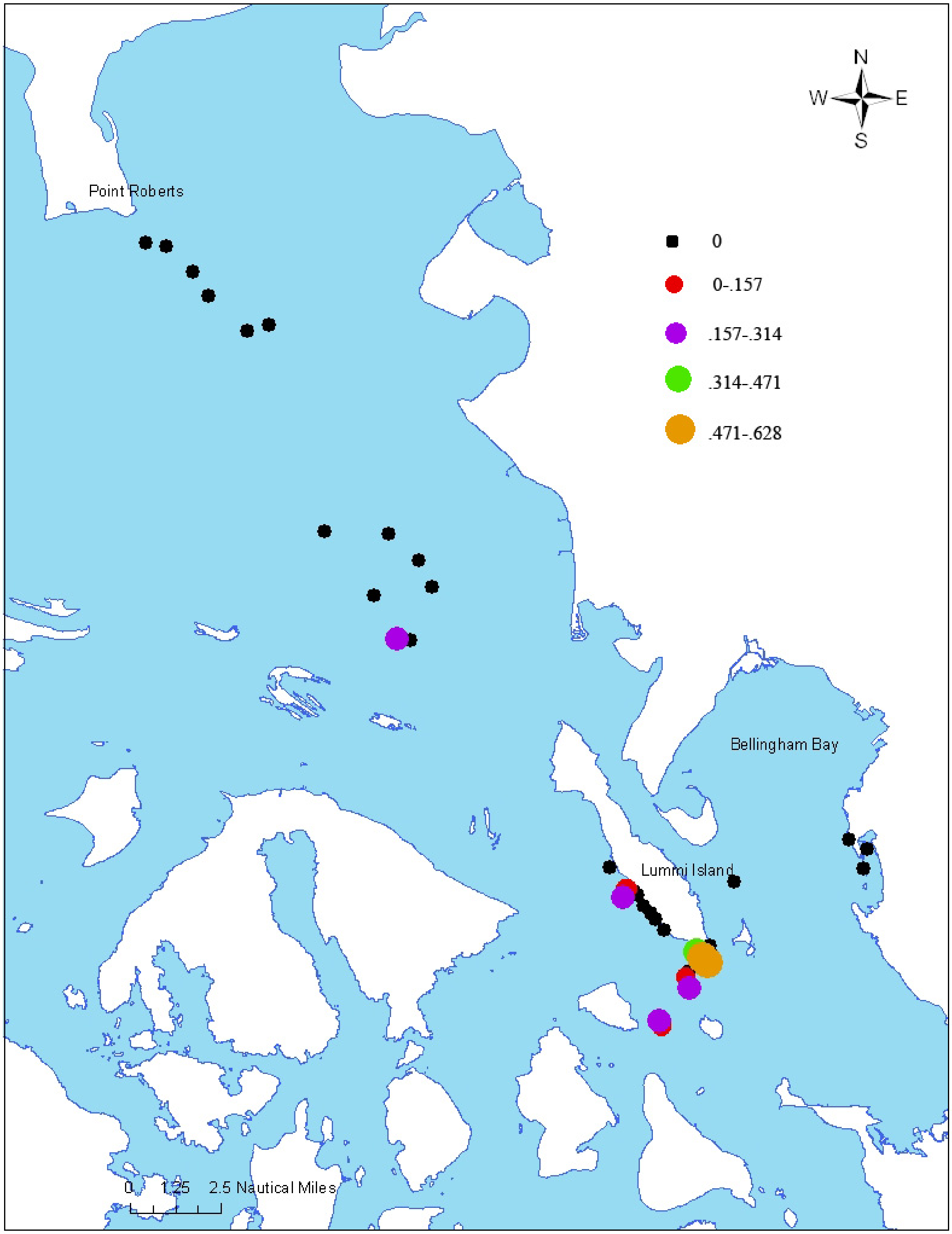
Depth Profile

Latitude	Longitude	Distance onshore (m)	Depth (m)
48^{o} 41.650	122^{o} 30.102	0.00	13.9
48^{o} 41.640	122^{o} 30.108	19.92	13.9
48^{o} 41.640	122^{o} 30.116	29.70	13.6
48^{o} 41.630	122^{o} 30.123	50.10	13.1
48^{o} 41.630	122^{o} 30.128	56.21	11.0
48^{o} 41.630	122^{o} 30.134	63.55	9.2
48^{o} 41.630	122^{o} 30.139	69.66	7.3

Chuckanut Bay 3 (CB3)

Date: 3/25/2009
Location: 48^{o} 41.874 N 122^{o} 30.845 W

Rockfish m^{-2}: 0



Appendix B-2. Rockfish m^{-2} data collected from this study and Grove and Shull (2008). High density, highly surveyed areas appear overlapped.