Whatcom County

Grant No. G1000002

A Comparison of Two Methods, Paired-Diver Surveys and Remotely Operated Vehicle Surveys, for Determining Rockfish Abundance

Rockfish Technical Report
Task 5
February 1, 2011

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

A Comparison of Two Methods, Paired-Diver Surveys and Remotely Operated Vehicle Surveys, for Determining Rockfish Abundance

Brandy M. Carpenter and David H. Shull

Department of Environmental Sciences, Huxley College of the Environment, Western Washington University, Bellingham, WA

Abstract

Rockfish are a commercially and ecologically important resource to the Salish Sea, but populations are declining. This is due, in part, to pressure-related death from catch-and-release fishing. Any solution to the problem of declining rockfish populations will require an efficient and effective monitoring program to assess changes in population size and the effectiveness of conservation policies. Rockfish monitoring programs are conducted by several counties in Washington State and by the Washington Department of Fish and Wildlife, but monitoring methods differ. In Whatcom county, rockfish monitoring is done by remotely operated vehicle (ROV) whereas surrounding counties use diver surveys. Differences in survey methods could complicate understanding of spatial and temporal variation in rockfish abundance and make it difficult to evaluate the effectiveness of management strategies. Our study compared these two rockfish monitoring methods to evaluate their relative effectiveness and to assess potential sources of bias with each. We observed and counted rockfish along multiple transect lines using both methods and compared the estimated rockfish densities from each. We found that divers observed more Puget Sound rockfish than the ROV, but the ROV observed more Copper Rockfish. We attribute this to differences in fish behavior. A higher proportion of Puget Sound rockfish were observed within holes and crevices, which the ROV did not observe. On the other hand, highest rockfish densities were observed in deep water, below the maximum depth surveyed by the divers. Despite differences between the two methods, our results suggest that the ROV is an effective monitoring tool for Copper Rockfish and because it has fewer bottom-time and depth constraints compared to SCUBA it can thus give a more comprehensive picture of rockfish populations in Whatcom County.

Introduction

Populations of rockfish (*Sebastes* spp.) in Puget Sound and surrounding areas have declined in recent decades. In an assessment of the status of rockfish stocks in Puget Sound, only 3 of 17 stocks in Northern Puget Sound were considered healthy, 11 were considered precautionary, one was vulnerable and two were identified as depleted (Palsson et al. 2009). In the South Sound only 4 out of 15 stocks were labeled healthy, 7 stocks precautionary, one vulnerable and 3 depleted (Palsson et al. 2009).

Rockfish populations are especially susceptible to overfishing because of their inability to adjust to rapid pressure changes associated with fishing. Even as by-catch, fishing mortality rate is high due to barotrama (Rogers et al. 2008). The mortality rate decreases the sooner a fish is recompressed after decompression (Jarvis and Lowe 2008), but the long-term effects on the fish are not well understood.

A commonly implemented strategy for protecting fishes is a bag-limit (fishers are only allowed to catch a certain number of fish). But, because rockfish brought up from a depth greater than 18 to 27m are likely to die as a result of barotrama (Starr et al. 2001, Palsson et al. 2009), bag-limit strategies are not successful (McConnell et al. 2001, Mills and Rawson 2004). Marine protected areas (MPAs) are considered a better way to preserve these fish. MPAs are reserves that limit or prohibit the harvest of some fish (Palsson 2002). Those that work best for rockfish are no-take zones, where all fishing is prohibited, to reduce accidental capture of these fish.

There is much debate and research regarding the development of MPAs due to the effects they can have on local, native and commercial fishing. Resistance to MPAs exists despite studies that have shown reserve protection can increase biomass and density and lead to spill-over into areas around the reserve (e.g., Halpern 2003). Additional establishment and effective monitoring of MPAs would enable further assessment of the effectiveness of such methods.

Whatcom County has monitored rockfish using a small remotely operated vehicle (micro ROV) since 2007 (Grove and Shull 2008). Many other counties in the Puget Sound area use diver surveys to monitor rockfish populations. ROVs have been widely used to survey environments that are difficult for divers to access such as deep sea, or Arctic/Antarctic seas (Bachmayer et al. 1998). Results of comparisons between diver surveys and ROV surveys have been mixed (Marliave and Challenger 2009). When target species are closely associated with the bottom, as is the case with megafauna, diver and ROV survey results can be similar (Parry et al. 2002). The effectiveness of fish surveys using a micro ROV nearly identical to ours (VideoRay Pro III ROV) was recently conducted in the Gulf of Mexico. Although

fish density estimates obtained using the ROV were not compared to estimates by divers, comparisons of fish counts and sizes observed by the ROV in a swimming pool and at an artificial reef suggested that the fish population estimates and fish size estimates generated by the ROV were accurate (Patterson et al. 2008). Given the differences in methods used to survey rockfish by counties in Washington State, and lack of consensus from the literature on which methods are more accurate, it is important to compare these methods and to assess differences and potential sources of bias so that data on rockfish abundance from different counties can be compared.

The objective of our study was to compare methods of estimating population densities and species composition of rockfish in Whatcom County by diver and ROV surveys. If rockfish population estimates do not differ between the diver and ROV surveys, then data collected by either should be comparable without a correction factor. If the two methods differ in rockfish density estimates, surveys of sites with different rockfish densities using both methods could enable us to determine a correction factor that will enable comparison of surveys done with the two methods. With these goals in mind, surveys were done by divers and ROV over the same transect lines at several sites to estimate rockfish population densities.

Materials and Methods

Survey Sites

The sites were selected based on past data on rockfish habitat and fish abundance in Whatcom County (Grove and Shull 2008, Figure 1). Two transects were run perpendicular to shore at each site. We surveyed using a VideoRay Pro III XE GTO ROV with a front-mounted color video camera, parallel red laser beams, a DVD recording system and a pressure gauge for determining water depth of the vehicle. The divers used SCUBA with a Nitrox gas mixture in order to maximize dive time and minimize surface

intervals. The surveys were conducted in August and September, 2010, using the WWU R/V Zoea as the dive and ROV-deployment platform.

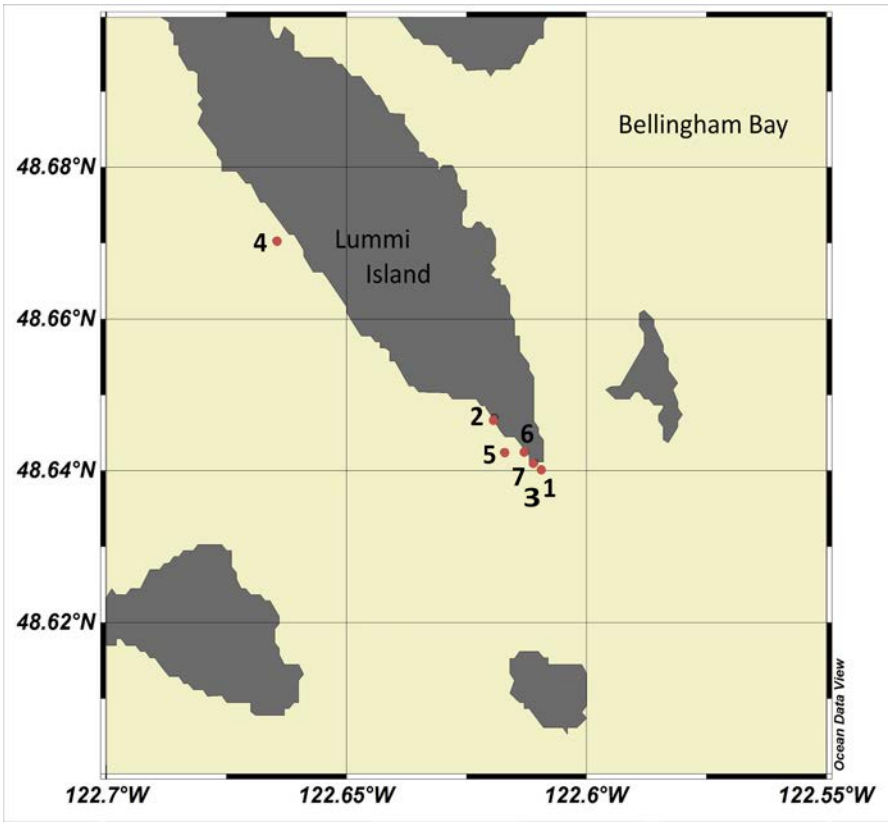

Figure 1. Transect locations. Chart created using Ocean Data View (Schlitzer 2008).

At sites 1,2 and 6, divers and the ROV surveyed the same areas (located by GPS coordinates) on separate days. At site 3, the ROV and divers ran the same transects at the same time. The ROV was carried down to depth by the divers and then flown up-slope. The divers followed the ROV along the same transect. On this transect, the divers were able to look for any avoidance behavior by fish or other reactions to the ROV. None was observed. At sites 4, 5 and 7, a lead line was laid out by the divers prior to the fish surveys. They anchored it at the shallow end and swam it down to depth, releasing a float at the deep end to allow the ROV pilot to find the transect. After deploying the line, the divers moved

approximately 30m away and surveyed fish along another transect. The ROV was deployed while the divers were conducting their first survey and surveyed fish along the lead line. After the ROV survey was completed, the divers surveyed the same line while the ROV surveyed the second transect.

ROV surveys

ROV surveys were run perpendicular to shore starting at the deepest portion of the transect and the ROV was flown up slope toward shallow water. The ROV was flown as far off the bottom as possible to maximize the field of view, but close enough to the bottom so that the pilot could observe the laser dots on the bottom so that transect width could be determined later. During the survey the bottom depth and ROV heading were continuously recorded and stamped on the video recording. The change in water depth was used, along with the measured bottom slope, to determine transect length.

Bottom slope

Before each transect was surveyed, we determined the bottom slope using GPS locations and depth readings from the depth sounder on the R/V Zoea. Horizontal distance onshore was determined from the GPS readings using a spherical earth approximation (1).

$$Distance\ (m) = \left(\sqrt{(Lat_B - Lat_A)^2 + [(Long_B - Long_A)(\cos(average\ Lat))]^2}\right) * 1852 \qquad (1)$$

Bottom slopes for each transect were determined from the arctangent of the slope of a linear regression between depth and distance onshore. The length of the subsequent ROV transect was determined from the change in water depth (measured by the ROV pressure sensor) divided by sin(bottom slope).

Diver surveys

A pair of divers would begin at the deepest part of the transect and then swim up-slope side-by-side toward shore. Divers were equipped with flashlights, an underwater pad and pencil and depth gauges. The divers recorded all fish observed within a 4-m wide strip. They recorded number of fish, depth. and distance from transect line. At sites where a lead line was deployed prior to the survey, the divers would count all fish observed along the lead line. At other sites, the divers would start the

transect at a predetermined depth and location and swim along a compass course upslope toward shore. Because of safety and bottom-time constraints, the maximum depth of the diver surveys was 25m.

Determination of transect area

The transect area was determined using the change in depth of the ROV or diver transect, the slope of the bottom, and the average transect width. The width of the diver transects were 6 m. The average transect width was determined from the ratio of width of the video screen (d_s) to the width of the lasers on the video (d_L= 10 cm) (eq. 2).

$$transect\ \ width = \frac{10\ (cm) d_s}{d_L} \quad (2)$$

The surveyed area is the product of the transect length and width.

Video and data analysis

We analyzed the ROV video transect data by playing the video on an LCD screen. In each video frame, the depth and the distance between the lasers on the screen was measured and recorded. Each time a fish was sited, the species of fish and the water depth (m) were recorded. Average rockfish per square meter were calculated for both ROV surveys and diver surveys for total fish and by individual species. The two transects from each site were averaged. Fish abundance (Rockfish m^{-2}) was also determined for depth increments of 5 m at each site. Linear regression analysis was used to compare the two survey methods. The regression intercepts were set equal to zero, reflecting the fact that neither the divers nor the ROV would observe rockfish at sites containing none. Thus, the slope of the regression line, if different than unity, would represent a correction factor. The product of fish abundance observed by the ROV and the correction factor would give an estimate of fish abundance that would be expected if the survey were conducted by divers.

Results

Three species of rockfish were recorded during our study, Puget Sound rockfish, *Sebastes emphaeus*, Copper rockfish, *Sebastes caurinus*, and Quillback rockfish, *Sebastes maliger*. In addition, Black rockfish, *Sebastes melanops*, and Yellowtail rockfish, *Sebastes flavidus*, were observed by the divers, however, they were outside the transect lines and were not included in the quantitative results (Table 1).

When all the survey sites were analyzed together over the same depth range, high variability between the two methods was apparent (R^2 = 0.44, Figure 2). The slope of the linear regression between total rockfish density determined by diver and ROV, about 1.24, indicates that the divers observed about 24% more rockfish than the ROV. However, correspondence between diver and ROV , surveys depended upon which species was observed. On average, Divers observed 20% more Puget Sound rockfish than the ROV (slope = 1.2), but the ROV observed about 23% more of less cryptic Copper and Quillback Rockfish, than the divers (slope = 0.81). The divers reported that many of the Puget Sound Rockfish they observed were inhabiting caves and crevices within the rocky substrate whereas Copper and Quillback Rockfish were primarily in the open. The divers, which surveyed a larger area than the ROV, tended to observe more species along each transect compared to the ROV (Figure 2).

Table 1. Rockfish densities determined by ROV and diver surveys at the seven study sites.

Station information			Rockfish abundance (fish m^{-2})					
	Latitude	Longitude	Puget Sound Rockfish		Copper Rockfish		Quillback Rockfish	
Site	(°N)	(°W)	Diver	ROV	Diver	ROV	Diver	ROV
1	48.64013	122.6094	0.044	0	0.026	0.023	0	0.008
2	48.64693	122.6191	0	0	0.000	0.009	0	0
3	48.64043	122.6096	0.079	0.010	0.028	0.048	0.009	0
4	48.67025	122.6646	0	0.006	0.016	0.025	0	0
5	48.64242	122.6171	0.008	0	0.018	0.031	0.003	0
6	48.64242	122.6127	0.050	0.052	0.022	0.036	0	0
7	48.64102	122.6108	0.019	0.000	0.041	0.040	0.008	0

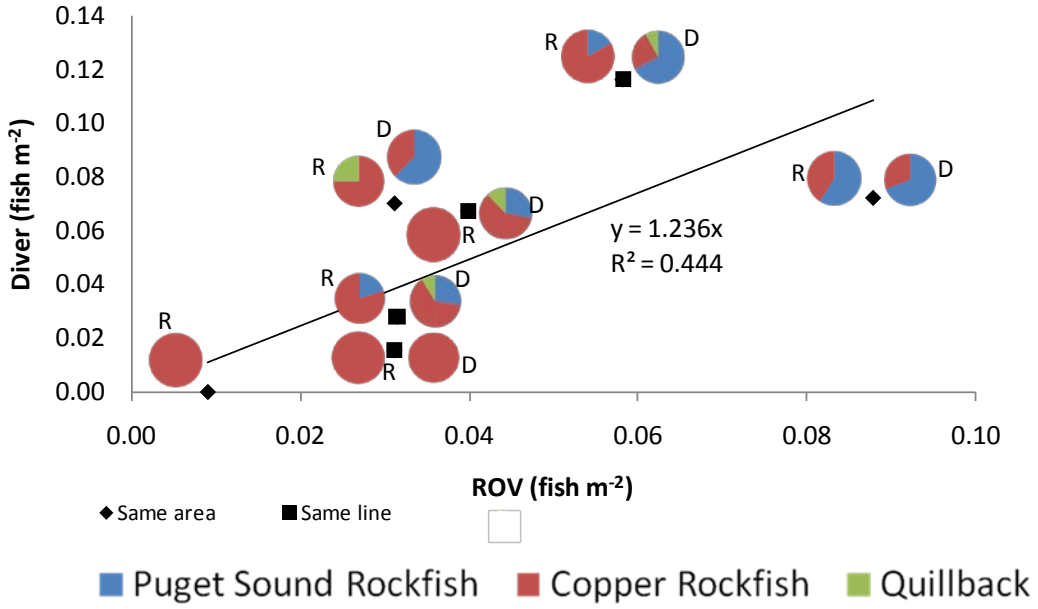

Figure 2. Composition of rockfish observed by both divers (D) and ROV (R) at each site. All sites are included but only fish seen over the depth range that both methods covered are included.

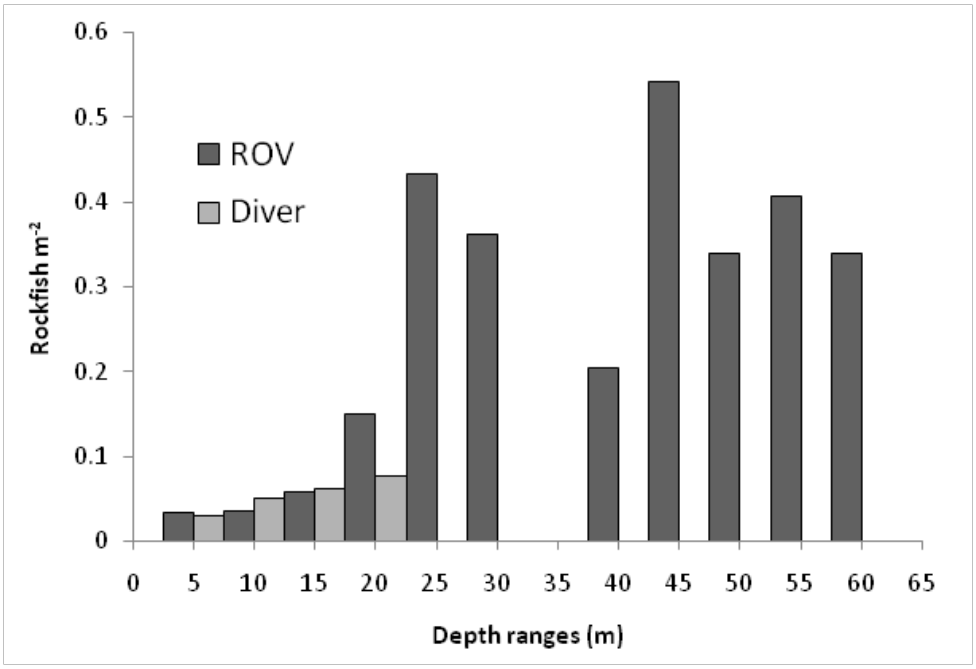

Figure 3. Depth distribution of rockfish in Whatcom County using diver surveys and ROV surveys.

The depth distribution of rockfish observed by divers and ROV between water depths of 0 and 25 m is comparable (Figure 3). However, at some sites, the ROV also surveyed deeper depths; the deepest ROV dive was to 60 m. The depth distribution of rockfish observed by the ROV demonstrate higher densities of rockfish deeper than 25 m, the diver's depth limit.

Discussion

We found high variability when comparing rockfish density estimates between diver and ROV surveys. Some of this variation is due to differences in the areas surveyed by the two methods. The transects surveyed by the divers were 4 m in width compared to the ROV transects which varied in width depending upon the ROV's distance from the bottom, but which averaged about 1.5 m. We would thus expect the divers to observe different fish and more fish overall than the ROV. Indeed, the divers tended to observe more species than the ROV because they surveyed a greater area.

The divers observed higher densities of the more cryptic Puget Sound rockfish than the ROV, whereas the ROV observed higher average densities of Copper Rockfish than the divers. This finding was likely related to differences in behavior and microhabitat use by these species. Puget Sound rockfish were frequently observed by divers within crevices and underneath boulders, largely hidden from the ROV. Copper Rockfish on the other hand were mainly observed in the open where both the ROV and divers could observe them. The higher densities of Puget Sound rockfish observed by the divers is most likely due to their better ability to observe these small rockfish within crevices. There are at least three other possible explanations for this observation as well. Puget Sound rockfish might be attracted to divers, they might avoid the ROV, or the result might be due to differences in the areas surveyed by the two methods. (There were different transect widths and at stations 1, 2, and 6 the divers and ROV did not follow a ground line affixed to the bottom so precise survey locations likely differed.) It is also possible that the fish changed their spatial distributions between surveys.

The higher densities of Copper Rockfish observed by the ROV might be due to differences in the areas surveyed. Copper Rockfish might avoid the divers. Or, they might be attracted to the ROV. It is also possible that we recounted fish observed during the ROV surveys because it was difficult to keep track of fish with the ROV, which cannot follow them once they leave the field of view. While we cannot discount any of these explanations, we did not observe any rockfish swimming toward the ROV, a behavior that would indicate an attraction to the ROV. And, although rockfish sometimes fled from the ROV when it would draw near, we generally detected the fish at a distance and before this avoidance behavior occurred. Also, because there was often a fairly large distance between Copper Rockfish sightings during the ROV surveys, we are reasonably confident that we did not recount Copper Rockfish. Thus, the two most likely explanations for this result is that the fish either avoided the divers, or differences were due to differences in the area surveyed by the divers and the ROV.

A closer examination of the diver's observations suggests that the difference is likely due to diver avoidance. In addition to recording the number of different fish species observed at different depths, the divers noted the locations of the fish they observed (whether they were located near the center of the transect or near the edges) and whether they observed any fish just outside the transect area (which were noted but not counted). When the total number of Copper Rockfish observed by divers at different depths along the bottom-line transects (including fish just outside the transect area) are compared to the fish total number of fish observed by the ROV, both divers and ROV observed the approximately the same number of fish along the transect lines. Thus, it appears that both observation methods detected the same fish. But, during the diver surveys some of these fish had moved just outside of the transect area. Because we did not notice behaviors that indicated the fish were actually attracted to the ROV, we conclude that the divers observed fewer Copper Rockfish due to diver avoidance behavior and that Copper Rockfish densities recorded by the ROV are likely less-biased

estimates. If the divers were to survey an even wider transect, this would likely reduce the extent of diver avoidance.

One important difference between the capabilities of the divers and the ROV is depth range. We compared rockfish densities observed by these two methods over the same depth range. However, at some sites the ROV also surveyed deeper habitats. The depth distribution data demonstrate that the highest rockfish densities at Lummi Island occurred at depths greater than the divers' depth limit. Thus, even though the ROV observed fewer Puget Sound Rockfish than the divers, it still might give a better estimate of population densities because it is capable of surveying these fish over the depth range where they are more abundant.

Our findings for Copper Rockfish contrast with the results of a study that compared rockfish counts by divers with counts from a video census in British Columbia (Marliave and Challenger 2009). In the British Columbia study, divers observed significantly higher numbers of rockfish than were observed in a video recording taken by a diver. These contrasting findings might reflect various differences in methodology, bottom topography or perhaps an ROV is a better platform for video recording than a diver with a camera. Nevertheless, ROVs are becoming a popular tool for underwater surveys as they are often less time consuming and have a greater depth range compared to diver surveys (Bachmayer 1998, Spalding 2001, Stein et al. 2005).

Diver surveys have several advantages. Divers have a larger field of view (visibility pending) compared to a micro ROV. Thus, the chances of recounting fish that swim in and out of the field of view is higher with the ROV. Determining species while analyzing a video is limited by the quality of video taken. Divers in our study observed two species of rockfish that were not recorded by the ROV due to the greater area surveyed along each transect by the divers. It was also easier for the divers to look into cracks and crevasses to observe fish, which likely resulted in higher observed densities of Puget Sound Rockfish. This did not translate into higher observed densities of Copper Rockfish, however.

During our surveys it was a challenge for the divers and the ROV to cover precisely the same region of habitat unless they were both following a transect line secured to the bottom. This suggests that future surveys should use permanent transect lines so that the ROV can consistently cover the same area. David Shull has been conducting annual fall surveys of rockfish at Lummi Island as part of his oceanography courses. Permanent transect lines would likely improve the quality of data for this long-term monitoring program by ensuring that the data were collected from the same area.

The large variability observed between the diver and ROV data limit the conclusions of this study. It is possible that some of the contrasting results of the diver and ROV surveys were due to chance. This variability could be attributed several factors. First, the divers and ROV did not cover exactly the same area of bottom due to differences in transect width. Second, the ROV surveyed the transect line before the divers did. If the presence of either the ROV or the divers disturbed some of the rockfish species, this could have changed the densities of fish along the transect.

We conclude that our micro-ROV surveys detect Copper Rockfish with high efficiency and that the ROV surveys might actually provide a better estimate of Copper Rockfish abundance than diver surveys. Although Copper Rockfish are sometimes observed taking refuge within caves and crevices, our data suggest the ROV can detect them and we expect this is true for other rockfish species that tend to remain in the open such as Quillback, Black, and Yellowtail. On the other hand, Puget Sound Rockfish are likely undercounted by the ROV. Because the extent of this under estimate will depend upon the availability of crevices or current velocities or other environmental factors that affect the proportion of Puget Sound Rockfish taking refuge, it is not possible to determine a correction factor that would allow us to correct for this source of bias and apply it to other habitats.

We conclude that if diver surveys and ROV surveys are conducted over the same depth interval, and if the diver transects are wide enough to reduce fish avoidance, then diver and ROV estimates of Copper Rockfish abundance should be comparable.

Acknowledgments

This research was supported by a grant from the Whatcom Marine Resources Committee. We thank the divers for the study, Karl Mueller and Nathan Schwark, Gene McKeen who served as skipper of the R/V Zoea, and the director and staff of Shannon Point Marine Center. We also thank the Whatcom County Marine Resources Committee for guidance as we planned and carried out this work.

References

Bachmayer, R., S. Humphris, D. Fornari, C. Van Dover, J. Howland, A. Bowen, R. Elder, T. Crook, D. Gleason, W. Sellers and S. Lerner. 1998. Oceanographic Research Using Remotely Operated Underwater Robotic Vehicles: Exploration of Hydrothermal Vent Sites on the Mid-Atlantic Ridge at 37°North 32°West. *Marine Technology Society Journal* 32: 37-47.

Grove, T.L. and D.H. Shull. 2008. ROV Assessment of Rockfish Abundance, Distribution, and Habitat in Whatcom County Marine Waters. Whatcom County Marine Resources Committee pp. 74.

Halpern, B.S. 2003. Marine Reserves: Do Reserves Work and does Reserve Size Matter? *Ecological Applications* 13: S117-S137.

Jarvis, E.T and C.G. Lowe. 2008. The effects of barotrauma on the catch-and-release survival of southern California nearshore and shelf rockfish (Scorpaenidae, *Sebastes* spp.).*Canadian Journal of Fisheries and Aquatic Sciences* 65: 1286-1296.

Marliave, J. and W. Challenger. 2009. Monitoring and evaluating rockfish conservation areas in British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 66: 995-1006.

McConnell, M. L., P. Dinnel, I. Dolph, J. Moorad, J. Robinette, and D. Semrau. 2001. Rocky Reef Bottomfish Recovery Phase 1: Marine Protected Areas—Preliminary Assessment & Public Input. Skagit County Marine Resources Committee, Washington.

Mills, C.E. and K. Rawson. 2004. Outlook grim for North Pacific Rockfish: Rockfish Symposium, Friday Harbor Laboratories, University of WA, USA, Sept. 25-26, 2003. *Fish and Fisheries* 5: 178-180.

Palsson, W.A. 2002. The Development of Criteria for Establishing and Monitoring No-take Refuges for Rockfishes and Other Rocky Habitat Fishes in Puget Sound. Puget Sound Research 2001. Puget Sound Action Team, Olympia, Washington.

Palsson, W.A., T.S. Tsou, G.G. Bargmann, R.M Buckley, J.E. West, M.L Mills, Y.W. Cheng, and R.E. Pacunski. 2009. The Biology and Assessment of Rockfishes in Puget Sound. Fish Management Division, Fish Program, Washington Department of Fish and Wildlife.

Parry, D.M., L.A. Nickell, M.A. Kendall, M.T. Burrows, D.A. Pilgrim, and M.B. Jones. 2002. Comparison of abundance of burrowing megafauna from diver and remotely operated vehicle observations. *Marine Ecology Progress Series* 244: 89-93.

Patterson, W.F. III, M.A. Dance, and D.T. Addis. 2009. Development of a Remotely Operated Vehicle Based Methodology to Estimate Fish Community Structure at Artificial Reef Sites in the Northern Gulf of Mexico. *Gulf and Caribbean Fisheries Institute* 61:263-270.

Rogers, B.L., C.G. Lowe, E. Fernandez-Juricic, and L.R. Frank. 2008. Utilizing magnetic resonance imaging (MRI) to assess the effects of angling-induced barotrama on rockfish (*Sebastes*). *Canadian Journal of Fisheries and Aquatic Sciences* 65: 1245-1249.

Spalding, H.L. 2001. To Dive or not to Dive: Scuba Versus ROV Sampling of Macroalgae at 30M Depth. *Journal of Phycology* 37: 46-46.

Starr, R. M., J. N. Heine, J. M. Felton, and G. M. Cailliet. 2001. Movements of Bocaccio (Sebastes paucispinis) and Greenspotted (S. chlorostictus) Rockfishes in a Monterey Submarine Canyon: Implications for the Design of Marine Reserves. US Fish. Bull. 100: 324-337.

Stein, D.L., J.D. Felley, M. Vecchione. 2005. ROV observations of benthic fishes in the Northwind and Canada Basins, Arctic Ocean. *Polar Biology* 28:232-237.