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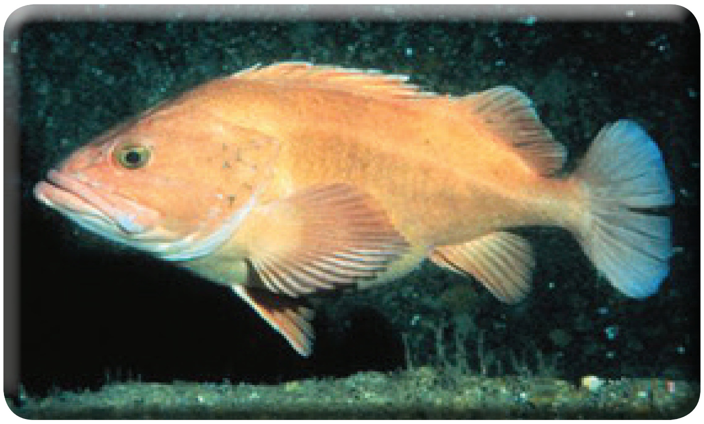
Report on the 2008 Rockfish Survey off Cape Flattery, Washington



by Farron Wallace, Yuk Wing Cheng, and Tien-Shui Tsou

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Table of Contents

List of Tables

List of Figures

Executive Summary

In recent years, Rockfish (*Sebastes spp.*) conservation has become the primary driving force behind management measures for numerous commercial and recreational groundfish fisheries. In coastal waters off California, Oregon and Washington, Canary, Yelloweye and Boccaccio Rockfish were determined to be overfished by the Pacific Fisheries Management Council (PFMC) and within Puget Sound these species have been listed as threatened or endangered by the National Marine Fisheries Service (NMFS).[1] In an effort to promote research to aid in Rockfish conservation, the Washington State legislature passed House Bill 1476 in 2007. This bill, supported by the fishing Industry, created a Rockfish research account for the Washington Department of Fish and Wildlife (WDFW) with funding provided through surcharges on selected commercial and recreational fishing licenses. This funding provided an important opportunity to develop Rockfish research projects to support stock assessments that are intended to inform management and promote conservation of groundfish resources in the Puget Sound basin and off the Washington coast.

In the coastal waters, Yelloweye Rockfish was declared overfished by the NMFS in 2002 and has been one of the main species that limit fishing opportunities. Information for Yelloweye Rockfish collected from the WDFW/ International Pacific Halibut Commission (IPHC) cooperative survey has been incorporated into the PFMC's Yelloweye Rockfish stock assessment since 2001. Unfortunately, the survey catch rate information has varied substantially among years making the population trend information difficult to interpret. In an effort to better understand the fluctuation observed in IPHC survey, WDFW conducted a video survey of IPHC Rockfish stations located off the Washington coast in 2008. The objectives of the survey were to gather data to establish habitat associations and explore catch rates of Rockfish across time and area using ROV survey technology. This information will allow us to develop a more efficient and cost effective way to survey Rockfish populations in areas not accessible to traditional survey techniques while not inducing additional mortality. A long-term no-take monitoring survey program will significantly contribute to Rockfish population status determination. These data will inform stock assessments that will in turn inform fishery managers as they develop effective management measures that provide meaningful fishing opportunity that are in line with conservation of this valuable living resource.

We observed over 2,300 fish from 36 species or species groups, fifteen of which were Rockfish. Rockfish were encountered most frequently and found in the highest density on most transects relative to other species. Among the invertebrates, such as Sea Urchins and feather stars, were encountered most frequently and had highest densities among all other invertebrates. The primary habitat found among transects was gravel with sand as secondary habitat interspersed with boulders that were found in stacked piles or scattered. Many of the Rockfish species including Yelloweye, Rosethorn, SSharpchin/SStripetail grouping, TTiger, Canary, and YYellowtail Rockfish were found largely associated with or near boulder habitat.

Our study suggested that there may be diurnal effects on the relative survey abundance for a number of Rockfish species. For Canary, unidentified juvenile Rockfish, unidentified adult and rosethorn Rockfish, we found higher survey abundance during day light hours compared with

[1] Canary Rockfish were declared rebuilt in 2015 and Bocaccio in 2017.

nighttime. For Sharpchin/Stripetail Rockfish, we found highest abundance at dawn and dusk. However, due to the low number of observations for many other Rockfish or other groundfish species, it was difficult to draw a conclusion. Yelloweye Rockfish, Tiger Rockfish, Yellowtail Rockfish, Lingcod, sculpin and unidentified flatfish density was variable and without apparent diurnal pattern.

Visual survey methodology has a number of advantages and disadvantages for surveying Rockfish, which have been well chronicled in this study and elsewhere. Some of the disadvantages include: 1) difficulties in fish identification, particularly for small fish or fish with cryptic coloration, 2) the potential for attraction or repulsion from the submersible, 3) variation in detection due to habitat type; for example, due to reduced visibility when the submersible maneuvered off bottom to avoid large boulders, or the failure to detect fish hiding behind boulders, 4) possible bias in collecting length measurements and 5) the limitation of the technique to quantifying the density of benthic species found in close proximity to the bottom. The advantages of the technique include the ability to: 1) sample in habitats that are inaccessible to other survey methods, 2) observe in-situ fish behavior, 3) observe the distribution of fish and fish-habitat associations on a fine scale, and 4) survey where additional mortality is not compatible with conservation for species and/or for species poorly sampled by trawl gear, such as Yelloweye Rockfish.

Given limited funding, expense is a major consideration in developing any groundfish survey. We found that costs associated with this survey were at least five times more expensive than the traditional longline survey methods for surveying the same nine study sites. In the future, however, these costs could be substantially reduced by employing smaller vessels and crew than that used in this survey. This approach has been previously demonstrated to be effective by WDFW which recently completed several small-vessel ROV surveys near the San Juan Islands in Puget Sound. It is unclear how effective this approach would be in coastal waters given more extreme weather conditions and survey depths that are greater than 60 fathoms. If no-take surveys are required, we should consider exploring less expensive ROV survey approaches and/ or other no-take survey methods such as self-releasing pots.

Overall, it is clear that relatively large-scale no-take surveys are needed to assess bottomfish abudance/biomass in habitats that are not accessible to bottom trawl survey gear. This study has demonstrated that visual transect surveys could provide a unique no-take alternative method for estimating Rockfish absolute abundance/biomass in habitats not accessible to conventional survey tools, while setline surveys can only produce relative abundance indices. The absolute abundance/biomass estimates can be used to “ground truth” the biomass estimates in stock assessments; and abundance indices can only “guide” the abundance trends. However, further study among several study sites and habitats will be required to better inform development of survey methods and measure the degree of possible bias associated with diel movement and avoidance behavior. Additionally, research that provides insight into the seasonal and/or social behavior patterns associated with prey or mating will be necessary to fully understand or interpret abundance estimates. Because most groundfish species are habitat-specific in their distribution, careful survey design will be necessary to ensure precise and unbiased estimates of abundance. Specifically, the low density and patchy distribution of Yelloweye and many other Rockfish species must be taken into consideration for developing a meaningful index time series that will be responsive to changes in abundance and useful to population dynamics models. If direct observation surveys such as the present study were conducted on a routine basis, a time-series of Yelloweye Rockfish density data could be used to develop an index of the trend in abundance. Such an index would be indispensable information that could be incorporated into a demographic model of the Yelloweye Rockfish population for stock assessment analysis.

Introduction

In recent years, Rockfish (Sebastes) conservation has become the primary driving force behind management measures for numerous commercial and recreational groundfish fisheries. In coastal waters off California, Oregon and Washington, Canary, Yelloweye and Bocaccio Rockfish were determined to be overfished by the Pacific Fisheries Management Council (PFMC) and within Puget Sound these species have been listed as threatened by the National Marine Fisheries Service (NMFS).[2] It is clear that conservation of these stocks is critical for providing sustainable fisheries and preservation of a complex marine ecosystem. The underlying reason for these species susceptibility and declining population trend is linked to the biology of many of the species that are found in this genus. Rockfish biology is adapted for long survival, slow growth, relatively low productivity, and sporadic recruitment success making Rockfish susceptible to over-fishing (Love et al., 2002, Parker et al., 2001). Some species, such as Yelloweye Rockfish, can live to more than 140 years old. Many Rockfish species are associated with physically complex rocky habitats (e.g., ledges, crevices, boulder fields, and pinnacles), which are difficult or impossible to accurately survey using conventional methods such as bottom trawl gear (Krieger et al., 1993, O'Connell and Carlile 1993, Jagielo et al., 2002). Additionally, due to low abundance, survey methods that result in mortality are not desirable or even possible for some species and could result in further constraints on recreational and commercial fisheries. Use and development of novel no-take survey methodology will be essential to assess future recovery and stock status of these species (Wallace et al., 2006).

In an effort to promote research to support Rockfish conservation and management, the Washington State legislature passed House Bill 1476 in 2007. This bill supported by the fishing Industry, created a Rockfish research account for the Washington Department of Fish and Wildlife (WDFW) with funding provided through surcharges on selected commercial and recreational fishing licenses. The Bill directed WDFW to conduct Puget Sound basin and coastal surveys with new and existing technology to estimate the current abundance for future recovery of Rockfish populations and other groundfish species. This funding provided an important opportunity to develop Rockfish research projects to support stock assessment and management needs to promote the conservation of groundfish resources in the Puget Sound basin and off the Washington coast.

This report describes one survey that was made possible by the Rockfish research account conducted by WDFW in 2008. This survey involved using a ROV and was aimed at gathering data to establish habitat associations and explore how catch rates of Rockfish vary in key times and areas visited by an annual set-line survey conducted by the International Halibut Commission (IPHC, https://iphc.int/management/science-and-research/fishery-independent-setline-survey-fiss). The information gained was intended to support WDFW in developing a more efficient and cost effective way to survey Rockfish populations in areas not accessible to traditional survey techniques without mortality.

Surveys provide vital information for understanding stock status (i.e. current abundance relative to a benchmark such as the unfished stock size) and population size. If direct observation surveys such as the present study were conducted on a routine basis, a time-series of Yelloweye Rockfish

[2] Canary Rockfish was declared rebuilt in 2015 and Bocaccio Rockfish in 2017.

density data could be used to develop an index of the trend in abundance. Of note, such index surveys are intended to track the “relative” abundance of the population and not overall or “absolute” abundance. Estimates of absolute abundance would be preferable but are difficult and beyond what is possible with the resources available for conducting surveys. As long as a survey of relative abundance measures a signal that is consistently proportional to the overall size of the population each year, scientists can use the survey to estimate stock size and status in combination with other information in a stock assessment. However, it is typically unknown how well a particular survey actually does at consistently sampling the population. Changes in the index may reflect a true signal in the population or may instead simply be “noise” caused by other factors.

The WDFW/IPHC cooperative survey has been used as an index of abundance in the PFMC’s Yelloweye Rockfish stock assessment since 2001 (Wallace et al., 2006 and Stewart et. al., 2009). Yelloweye catches in the survey have varied substantially among year. A species like Yelloweye is not expected to experience large swings in abundance from year to year, especially when catches have been reduced as low as they have, and so it may be that the changes in the index are noise being caused by other factors. The IPHC survey uses hook and line gear and visits the same stations each year. The 2008 ROV survey was designed to explore the survey stations and search for factors possibly influencing the variability. Fish movement and other behaviors can be critical to properly understanding how well a survey monitors a particular species. There have been several studies showing that many species of Rockfish exhibit strong diel vertical movement behaviors (Wilkins, 1986, Richards et al., 1991, Parker et al., 2007, Parker et al., 2008, Tolimieri et al., 2009). This behavior, especially if occurring nonrandomly, can strongly influence species availability to the bottom tending survey gear such as setline or video survey biasing biomass and/or density estimates.

Others have previously expressed concern that diel behavior may significantly impact precision and/or bias survey biomass estimates (Olsen, 1990; Appenzeller and Leggett, 1992; Simmonds et al., 1992, Stanely et al., 1999 and Stanely et al., 2000). Results from this study support the argument that many Rockfish species exhibit diel vertical movement patterns that could directly affect their availability to bottom-tending survey methods.

Many Rockfish are habitat-specific in their distribution, including Yelloweye. In our survey, Yelloweye Rockfish were found to be most abundant (65%) in boulder-dominated bottom habitat. Previous surveys throughout the West Coast have noted similar associations of Yelloweye Rockfish with complex rocky habitats (Richards, 1986; Pearcy et al., 1989; Stein et al., 1992; O’Connell and Carlile, 1993; Murie et al., 1994; Yoklavich et al., 2000; Johnson et al., 2003).

Observations made by ROVs and other submersibles in British Columbia and southeastern Alaska found greatest Yelloweye densities over boulder fields and broken rock (O’Connell and Carlile, 1993; Murie et al., 1994; Johnson et al., 2003) as well as in wall habitats (Richards, 1986). The density of Yelloweye Rockfish among different habitat types may be influenced by the occurrence of refuge spaces (O’Connell and Carlile, 1993; Johnson et al., 2003), which provide protection from predators and high prey density (Murie et al., 1994). Differential fishing pressure across habitat types may also contribute to the distribution of Yelloweye and other Rockfish species (Yoklavich et al., 2000; Johnson et al., 2003). Our observations of higher Yelloweye densities over complex rocky bottoms may be due to the greater number of microhabitat refugia and increased protection from fishing pressure provided by these habitats.

Methods

In collaboration with the Stanford Research Institute (SRI) and the University of Washington, the WDFW conducted a sub-sea ROV video survey of Rockfish in waters, known to local fishermen as “The Prairie”, located 30 nm WSW of Cape Flattery, Washington. In advent of stormy weather conditions, often found in off-shore coastal areas, alternative survey sites were also selected within Puget Sound near the San Juan Islands (Figure 1). The survey was carried out aboard the University of Washington’s research vessel, *Centennial* between September 11 through September 17, 2008. The vessel served as the survey platform for ROV deployment, navigation, data processing, and crew quarters. The ROV, designed and operated by SRI personnel, was well equipped with a wide array of sonar, lasers, cameras and navigation sensors, a ring laser gyro, Echoscope MKII, DIDSON, split head Doppler Velocity Logger (DVL) and Ultra Short Base Line tracking system (USBL; Figures 2-5).

The coastal survey stations were selected from the IPHC survey sites that have been used in a collaborative IPHC/WDFW longline Rockfish survey that began in 2006. The nine IPHC survey stations selected for study are located in an area of known high Rockfish abundance surrounding IPHC station 1082 (Figure 6). This station has historically produced more than 90% of the total Yelloweye Rockfish caught in the IPHC annual longline survey off Washington. This survey followed the IPHC survey by two months and ROV transect start and stop positions matched 2008 IPHC station start and end points. In addition to the nine survey stations, a series of transects were planned over a 24-hour period on station 1582 to evaluate the possible diurnal effect on fish densities. Each transect was further subdivided into two sub-transects and used as predictor variables for an analysis of variance (ANOVA).
Alternative survey sites within Puget Sound were chosen from a set of survey locations previously selected for a focused survey of groundfish near the San Juan Islands that took place during fall and winter months of 2008 and 2009.

Digital video files collected during the survey were post processed into digital images that could be viewed using Microsoft Windows Media Player. This software provided for on-the-fly control of image color, contrast and brightness and allowed for easy review and enhancement through and within any video segment. Observers recorded measurements of laser width and screen width, bottom type, and number of fish and invertebrate species encountered.

A strip transect was conducted at each site and area swept (m^2) was estimated as the product of average width swept (w), and the total transect length (l). Width swept for each transect was estimated from multiple measurements of two parallel lasers (spaced 24 inches apart) and the width of the viewable video screen. Width swept for each transect was the average of the product of 24 (inches between parallel lasers) and the ratio of the distance between lasers/total screen widths and was calculated as:

$$TW = Average\left(24\frac{s}{l}\right)$$

Where $\overline{TW}$ is the mean transect width, the measured video screen width is s and l is the measured distance between the parallel lasers on the video screen. The distance between the lasers is 24 inches.

A DVL navigation module was used to collected information on distance traveled in any given time interval to determine distance traveled for any given transect. The DVL is highly repeatable and its' relative accuracy is ~ 0.2-1% (i.e. 1 km transect, 0.5% dist travel error = 5 m error over a 1000 m run). Transect length was simply the sum of the distance traveled in each one second interval over the length of transect. Because there is drift in DVL heading sensor, the travel path of the ROV was corrected to estimate the approximate geodetic position of transects. Geodetic positioning of transect lines was completed by shifting the DVL data to fit the mean Ultra-Short-base (USBL) track line, which is geodetically correct but imprecise. This allowed for corrected GIS plotting of transect paths in relation to the presumed path of the IPHC set line. The geodetic repositioning of the DVL data had no bearing on the calculation of transect length only relative position.

Bottom habitat type was visually characterized throughout each video transect and whenever habitat type changed it was noted within the dataset. Habitat typing following the method of Stein et al. (1992) and using the classification criteria developed by Greene et al. (1999), combinations of microhabitat type including mud, sand, pebble, cobble, boulders, and rock ridge were categorized according to primary (at least 50% of the area viewed) and secondary (> 20% of the area viewed). If primary habitat was determined to be "bolder", additional specification of either continuous or stack was also recorded.

Fish and invertebrates were identified and included in the survey counts only if they crossed an imaginary midline that ran between the parallel laser sport. Lighting and visibility was greatest in this zone, and we assumed that the probability of observing and counting fish/invertebrates (q) in this portion of the video image was 100% (i.e., q = 1). To assure that all counted fishes/invertebrates were within the boundaries of the video strip transect, only those swept by the midline were included in our count. Observations were included if any portion of the fish/invertebrate was swept by the midline. Animals were identified to their lowest possible taxonomic classification. We made no attempt to count ronquils, poachers, eelpouts, small sculpins, and other miscellaneous small fishes; however, we attempted to enumerate all Rockfish regardless of size. The grouping "Little Bitty Guy" was used to distinguish small juvenile Rockfishes of unknown species and "Adult Rockfish" was used for unidentifiable adult Rockfish. Submersible survey estimates of fish density (number/hectare) were computed by dividing the number of fish counted by the area-swept estimated at each sample site (one transect per sample site). Diurnal changes in fish and invertebrate density was examined using an ANOVA. The ANOVA included the number of fish or invertebrates observed as a response variable and two predictor variables, transect (8, 9, 10, 11, 12, 13, 14, 15) and sub- transect (A and B).

Results

Due to marginal weather conditions in coastal waters during the first three days of the survey, six alternative stations in Puget Sound near the San Juan Islands area were surveyed (Figure 7). Data were successfully gathered for five of the six transects with video recording devices failing during one transect (transect 4) that resulted in the loss of data. Weather conditions improved and a total of 12 transects (Figure 8) were completed in coastal waters on IPHC stations 1082 (transect 7), 1528 (transect segments 8C+8A+8B+8D), 1529 (transect 16), 1534 (transect 17), and 1533 (transect 17). Length of the coastal transects ranged between 0.4 and 2.2 kilometers in length and area swept estimates ranged from 0.04 Ha to 2.32 Ha for our longest transect (1082). The average over-ground speed of the ROV was 1.9-2.2 km per hour (Table 1). A total of eight repeat transects (transects 8-15) were completed on IPHC Rockfish station 1528. These transects were divided into northern “A” and southern “B” segments for analysis and are a sub-set of IPHC station 1528.

We made over 2,300 fish observations of 36 species or species groups, fifteen of which were Rockfish (Table 2). Rockfish were encountered most frequently and found in highest density on most transects relative to other fish species (Table 3 and 4). Sea Urchins and feather stars were encountered most frequently and highest densities among all other invertebrates (Tables 5-7). The primary habitat found among transects was gravel with sand as secondary habitat (Table 8).

In total, we were able to conduct five transects on IPHC station 1528 between 2:00 pm to 10 pm and three transects between 7 am to 11 am. In this time period, we observed eight different species of Rockfish, ten identifiable groundfish species, ten unidentified flat fish, 337 unidentified Rockfish (mostly small juveniles) and numerous invertebrate species. The variable "sub-transect" was significant ($P=0.02$) for Canary Rockfish, which may imply Canary Rockfish tend to be more localized such that density varies with habitat changes. Sub-transect was also significant for unidentified flatfish but sample size was very low. Sub-transects was not significant ($P > 0.17$) for all other observed fish and invertebrates (Table 9).

Transect was a significant ($P <0.05$) variable for many species including Canary Rockfish, unidentified juvenile Rockfish, Rosethorn Rockfish, SSharpchin/SStripetail Rockfish, unidentified adult Rockfish, Dogfish shark, Rat fish, and Sea Urchins. This suggests that there may be diurnal effects on the relative survey abundance for these species (Table 9). For Canary, unidentified juvenile Rockfish, unidentified adult and rosethorn Rockfish, we found higher survey abundance during day light hours compared with nighttime (Figure 9-12). For SSharpchin/SStripetail Rockfish, we found highest abundance at dawn and dusk (Figure 13). Ratfish abundance was found to be increasing through afternoon hours and lower during daylight hours (Figures 14). Sea Urchin abundance decreased dramatically following sunset (Figure 15). Results for both sea stars and Sea Cucumbers was marginally significant ($0.05<P<0.1$) with both species having higher abundance during day light hours compared with night time (Figure 16-17). Although transect effect was significant for dogfish shark and marginally significant ($0.05<P<0.1$) for eel pout, the low number of observations for these two species was too small to draw any conclusion. Yelloweye Rockfish, Tiger Rockfish, Yellowtail Rockfish, Lingcod, sculpin and unidentified flatfish abundance was variable and without apparent diurnal pattern (Figure 18-22). Diurnal changes in abundance for the remaining fish and invertebrate species were not significant (P>0.20) and showed little pattern (Figure 23-24). Due to poor weather, we were unable to fully complete all the planned survey sites for this experiment and therefore results are somewhat tentative.

A noteworthy fish behavior observation was made during transect 14 on IPHC station 1528. A Lingcod was seen attacking a Yelloweye when two other Yelloweye appeared and were observed defending the smaller individual being attacked. There have been no prior observations of social defensive behavior although many other Rockfish species school to provide defense against predators. This species is thought to be sedentary with small well defined ranges and this observation does not fit this assumption. The great depths inhabited by these species makes it extremely challenging to study the behavior of this and other deeper dwelling species, so little is known about behavior.

Discussion

The ROV and IPHC surveys are designed to target specific species and fish sizes. The IPHC survey is designed to target halibut with large baited circle hooks and also catches any other large, bottom dwelling, piscivorous species. The ROV survey approach is most useful for sampling demersal fish that are not likely to be influenced by the approach of the submersible. These differences are reflected in the data where striking differences in species composition and total numbers of fish between surveys are clear. For example, the IPHC survey caught few if any Canary, Yellowtail, or rosethorn Rockfish because these species are relatively small and are not "selected" by the large baited hooks whereas these species were relatively common in the ROV survey (Table 10). Yelloweye Rockfish, on the other hand, were observed in low numbers in both ROV and IPHC survey. This species is "selected" by both surveys because it is a large, piscivorous, bottom dwelling species that is easily identifiable in video strip transects and captured by the IPHC survey. The IPHC Yelloweye catch was four times that observed during the ROV survey of the same transects taken two months apart suggesting that it may be a more efficient method for sampling Yelloweye Rockfish or that Yelloweye are moving from one favorable habitat to another. Differences could be attributed to a variety of reasons including, bait likely attracts fish from a much larger area than that observed in a narrow strip transect, different survey time period (July for IPHC and September for ROV), different time of day, influence of the submersible, spatial differences covering different habitat types between surveys etc.

Given results from this and previous studies near the current study site, Yelloweye density is very low making it difficult to achieve a large enough sample size to develop an unbiased population index. Yelloweye density estimated from this survey was only 3.00 (CV of 0.4, number/10^3m^2). This compares to a 2002 estimate of Yelloweye density of 2.02 (CV of 0.2, number/10^3m^2) derived from a submersible survey of untrawlable habitats located in a much broader area that covers our current study site (Wallace et al., in review). A 1999 study that compared densities of demersal fish in trawlable and untrawlable habitats, in a small study area near our current study site, observed no Yelloweye in the trawlable area and estimated Yelloweye density to be 10.7 (CV of, number/10^3m^2) in the untrawlable area (Jagielo et al. 2003). Yelloweye catch in the IPHC survey has not only been low compared to catch of other species, but it is also highly variable between years providing little information on population trends off Washington.

Another factor that may affect survey results is movement behavior. There have been several studies showing that several species of Rockfish exhibit strong diel vertical movement behaviors (Wilkins, 1986, Richards et al., 1991, Parker et al., 2007, Parker et al., 2008, Tolimieri et al., 2009). This behavior, especially if occurring nonrandomly, can strongly influence species availability to the bottom tending survey gear such as setline or video survey biasing biomass and/or density estimates. Others have previously expressed concern that diel behavior may significantly impact precision and/or bias survey biomass estimates (Olsen, 1990; Appenzeller and Leggett, 1992; Simmonds et al., 1992, Stanely et al., 1999 and Stanely et al., 2000). Results from this study support the argument that many Rockfish species exhibit diel vertical movement patterns that could directly affect their availability to bottom-tending survey methods.

Many Rockfish are habitat-specific in their distribution, including Yelloweye. In our survey, Yelloweye Rockfish were found to be most abundant (65%) in boulder-dominated bottom habitat.

Previous surveys throughout the West Coast have noted similar associations of Yelloweye Rockfish with complex rocky habitats (Richards, 1986; Pearcy et al., 1989; Stein et al., 1992; O'Connell and Carlile, 1993; Murie et al., 1994; Yoklavich et al., 2000; Johnson et al., 2003). Observations made by ROVs and other submersibles in British Columbia and southeastern Alaska found greatest Yelloweye densities over boulder fields and broken rock (O'Connell and Carlile, 1993; Murie et al., 1994; Johnson et al., 2003) as well as in wall habitats (Richards, 1986). The density of Yelloweye Rockfish among different habitat types may be influenced by the occurrence of refuge spaces (O'Connell and Carlile, 1993; Johnson et al., 2003), which provide protection from predators and high prey density (Murie et al., 1994). Differential fishing pressure across habitat types may also contribute to the distribution of Yelloweye and other Rockfish species (Yoklavich et al., 2000; Johnson et al., 2003). Our observations of higher Yelloweye densities over complex rocky bottoms may be due to the greater number of microhabitat refugia and increased protection from fishing pressure provided by these habitats.

Visual survey methodology has a number of advantages and disadvantages for surveying Rockfish, which have been well chronicled elsewhere (Uzmann et al., 1977; Ralston et al., 1986; Butler et al., 1991; Adams et al.,1995; Starr et al., 1996; Cailliet et al., 1999, Jagielo et al., 2003). Some of the disadvantages include: 1) difficulties in fish identification, particularly for small fish or fish with cryptic coloration, 2) the potential for attraction or repulsion from the submersible, 3) variation in detection due to habitat type; for example, due to reduced visibility when the submersible maneuvered off bottom to avoid large boulders, or the failure to detect fish hiding behind boulders, and 4) the limitation of the technique to quantifying the density of benthic species found in close proximity to the bottom. The advantages of the technique include the ability to: 1) sample in habitats that are inaccessible to other survey methods, 2) observe in-situ fish behavior, and 3) observe the distribution of fish and fish-habitat associations on a fine scale, and 4) survey where additional mortality is not compatible with conservation for species and/or for species poorly sampled by trawl gear, such as Yelloweye Rockfish (Weinberg et al 2002).

Another downside of videotape sampling is the problem of obtaining unbiased measurements of fish from the image, particularly when the image of a fish to be measured is not oriented with the anterior-posterior axis perpendicular to the camera. Fish perpendicular to the camera reflect accurate values but, since the perspective of the optics distorts the images of non-perpendicular fish these estimates will be biased dependent upon axis to the camera. This problem is largely technical and development of 3D video survey methods will greatly improve our ability to correctly measure fish and obtain unbiased estimates of fish size.

This study has demonstrated that visual transect surveys could provide a unique no-take alternative method for estimating Rockfish biomass in habitats not accessible to conventional survey tools. However, setline surveys are currently a much more cost effective method for surveying several adult piscivorous Rockfish species such as Yelloweye Rockfish. Costs associated with this survey were at least five times more expensive than traditional setline survey methods. In the future, these costs could be substantially reduced by employing smaller vessels and crew than used in this survey. This approach has been demonstrated to be effective by WDFW which recently completed several small-vessel ROV surveys near the San Juan Islands in Puget Sound (Palsson et at., report in progress). It is unclear how effective this approach would be in coastal waters where weather is more extreme and survey depths are greater than 60 fathoms. If no take surveys are required, we should consider exploring less expensive ROV survey approaches and other no-take survey methods such as self-releasing pots.

In conclusion, it is clear that relatively large-scale no-take surveys are needed to assess bottomfish densities in habitats that are not accessible to trawl survey gear. The low density and patchy distribution of Yelloweye and many other Rockfish species must be taken into consideration for developing a meaningful abundance time series that will be responsive to changes in abundance and useful to population dynamics models. Further study among several study sites and habitats will be required to better inform development of survey methods and measure the degree of possible bias associated with diel movement behavior. Standardization is needed for any bottom tending survey gear such as video, setlines, pots or trawl. Because most groundfish species are habitat-specific in their distribution, careful survey design will be necessary to ensure precise and unbiased estimates of abundance. If direct observation surveys such as the present study were conducted on a routine basis, a time-series of Yelloweye Rockfish density data could be used to develop an index of the trend in abundance. Such an index would be valuable information to incorporate into a demographic model of the Yelloweye Rockfish population for stock assessment analysis.

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Tables and Figures

Table 1. Descriptive statistics for each transect.

ROV Transect	Sub-Transect	IPHC Station	Date	Start Time	End Time	Mean Transect Width (m)	StDev Transect Width (m)	CV Transect Width (m)	Distance (m)	Elapsed Time	Speed (km/hr)	Area Swept (Ha)
1			11-Sep-08	4:23:31 PM	4:54:25 PM	3.80	1.39	0.37	593.7	0:30:54	1.15	0.226
2			11-Sep-08	7:27:10 PM	7:40:32 PM	4.15	1.38	0.33	180.0	0:13:22	0.81	0.075
3			12-Sep-08	7:50:06 AM	8:09:09 AM	3.73	1.77	0.48	288.7	0:19:03	0.91	0.108
5			12-Sep-08	5:27:48 PM	5:32:54 PM	4.15	1.36	0.33	96.8	0:05:06	1.14	0.040
6			12-Sep-08	5:42:15 PM	5:58:10 PM	3.99	1.40	0.35	608.7	0:15:55	2.29	0.243
7		1082	14-Sep-08	8:47:00 AM	12:45:51 PM	6.13	2.16	0.35	3784.9	3:58:51	0.95	2.320
8	A	1528	14-Sep-08	2:00:28 PM	2:18:26 PM	5.40	2.66	0.49	490.2	0:17:58	1.64	0.265
8	B	1528	14-Sep-08	2:18:27 PM	2:35:09 PM	4.83	2.14	0.44	486.5	0:16:42	1.75	0.235
8	C	1528	14-Sep-08	1:43:28 PM	2:00:25 PM	2.91	0.96	0.33	394.8	0:16:57	1.40	0.115
8	D	1528	14-Sep-08	2:35:21 PM	2:58:55 PM	4.12	1.19	0.29	793.9	0:23:34	2.02	0.327
9	A	1528	14-Sep-08	5:22:50 PM	5:37:40 PM	4.43	1.76	0.4	433.3	0:14:50	1.75	0.192
9	B	1528	14-Sep-08	5:37:49 PM	5:52:38 PM	4.57	1.79	0.39	433.9	0:14:49	1.76	0.198
10	A	1528	14-Sep-08	7:36:06 PM	7:44:55 PM	3.98	1.62	0.41	284.5	0:08:49	1.94	0.113
10	B	1528	14-Sep-08	7:44:56 PM	7:57:25 PM	5.17	1.85	0.36	345.9	0:12:29	1.66	0.179
11	A	1528	14-Sep-08	8:37:29 PM	8:49:56 PM	4.87	1.96	0.4	418.7	0:12:27	2.02	0.204
11	B	1528	14-Sep-08	8:50:02 PM	9:03:27 PM	5.01	1.45	0.29	404.5	0:13:25	1.81	0.202
12	A	1528	14-Sep-08	9:34:46 PM	9:52:06 PM	6.30	1.70	0.27	451.1	0:17:20	1.56	0.284
12	B	1528	14-Sep-08	9:52:22 PM	10:04:37 PM	4.57	1.35	0.29	377.8	0:12:15	1.85	0.173
13	A	1528	15-Sep-08	7:24:20 AM	7:44:38 AM	2.95	0.89	0.3	407.6	0:20:18	1.20	0.120
13	B	1528	15-Sep-08	7:44:51 AM	8:04:56 AM	2.95	1.07	0.36	462.7	0:20:05	1.38	0.137
14	A	1528	15-Sep-08	8:40:20 AM	9:01:24 AM	2.96	0.60	0.2	458.6	0:21:04	1.31	0.136
14	B	1528	15-Sep-08	9:01:45 AM	9:25:45 AM	3.11	1.23	0.4	643.4	0:24:00	1.61	0.200
15	A	1528	15-Sep-08	10:11:28 AM	10:33:02 AM	3.42	1.56	0.45	560.9	0:21:34	1.56	0.192
15	B	1528	15-Sep-08	10:33:24 AM	10:48:19 AM	3.59	1.43	0.4	374.4	0:14:55	1.51	0.134
16		1529	15-Sep-08	6:31:54 PM	7:31:44 PM	3.02	0.74	0.25	2300.1	0:59:50	2.31	0.696
17		1534	16-Sep-08	9:22:32 AM	10:32:29 AM	2.98	1.49	0.5	2192.7	1:09:57	1.88	0.653
18		1533	16-Sep-08	1:24:41 PM	2:29:27 PM	2.61	0.39	0.15	2209.9	1:04:46	2.05	0.577
Total												8.342

Table 2. Numbers of fish observed by species or species group in each transect.

	Transect																											
Species	1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18	Total
Flatfish																												
Arrowthooth Flounder																										35		35
Dover Sole													1						1						37			39
Pacific Halibut						8											1							1			1	11
Petrale Sole																									1			1
Rock Sole									1																			1
Unidentified Flatfish						14	2		3		2		1			1	2		1				1		17	2		46
Sub-total						22	2		4		2		2			1	3		2				1	1	55	37	1	133
Rockfish																												
Yelloweye						9					1			2		4	1				2	1	1	1	1			23
Black																										1		1
Canary						235	27	10		31	16	7	5	3	1	1	7	1	1	1	4		8	5	47		1	411
Green Stripped													1		1													2
Greenspotted						1																						1
Unidentified Juvenile		2				489	10	12	11	19	31	19	3	3	38	18		1	57	18	4	11	47	6	41	9	19	868
Quillback	1																											1
Redstripe							1																					1
Rosethorn						5	14	6	2	2	18	21	8	13	12	9	1		22	14	17	16	10	5	13	1	7	216
Sharpchin																			2	3						4		9
Silvergrey														1							2							3
Striptail or Sharpchin						8											5	8	7	1						1		30
Tiger								3				1	1	1	2	6	2		2		2	1		2	2		1	26
Unidentified Adult	1				1	41	14	20		4	43	33	8	8	3	4			20	14	59	116	126	72	26	4	1	618
Widow Rockfish																												0
Yellowtail Rockfish						2		1				18	18	4			3					4			1	3		54
Sub-total	2	2			1	790	66	52	13	56	109	99	44	35	57	42	19	10	111	51	90	149	192	91	131	23	29	2264
Sharks and Skates																												
Big Skate						1																						1
Dogfish Shark															1	1					1				5	15		23
Long Nose Skate						1										1					1							3
Rat Fish	9	4	10			1		1		1	2		8	10	16	20	21	11	1				1	3	2		1	122
Sandpaper Skate																									1			1
Sub-total	9	4	10			3		1		1	2		8	10	17	22	21	11	1		2		1	3	8	15	1	150
Misc species																												
eel pout or gunnel						1				2	1	2			2	1				1				1				11
Greenling										1												2						3
Lingcod						36	1	7		1	1	2	1	1	1	1	3	3		2			2	1	1	1	5	70
poacher						2					1								2									5
Pollock						1						1																2
Sculpin						2	6	2	1	1			2						2	1	1	5	3	1	12	1		40
Unidentified Sculpin						3	3		2																	1		9
Sub-total						45	10	9	3	5	3	5	3	1	3	2	3	3	4	4	1	7	5	3	13	3	5	140
Grand Total	**11**	**6**	**10**	**0**	**1**	**860**	**78**	**62**	**20**	**62**	**116**	**104**	**57**	**46**	**77**	**67**	**46**	**24**	**118**	**55**	**93**	**156**	**199**	**98**	**207**	**78**	**36**	**2687**

Table 3. Percent of total number of observations by groundfish species or species group observed in each transect.

	Transect																										
Species	1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18
Flatfish																											
Arrowtooth Flounder																										45%	
Dover Sole													2%						1%						18%		
Pacific Halibut						1%											2%							1%			3%
Petrale Sole																									0%		
Rock Sole									5%																		
Unidentified Flatfish						2%	3%		15%		2%		2%			1%	4%		1%				1%		8%	3%	
Sub-total						3%	3%		20%		2%		4%			1%	7%		2%				1%	1%	27%	47%	3%
Rockfish																											
Yelloweye						1%					1%			4%		6%	2%				2%	1%	1%	1%	0%		
Black																										1%	
Canary						27%	35%	16%		50%	14%	7%	9%	7%	1%	1%	15%	4%	1%	2%	4%		4%	5%	23%		3%
Green Stripped													2%		1%												
Greenspotted						0%																					
Unidentified Juvenile		33%				57%	13%	19%	55%	31%	27%	18%	5%	7%	49%	27%		4%	48%	33%	4%	7%	24%	6%	20%	12%	53%
Quillback	9%																										
Redstripe							1%																				
Rosethorn						1%	18%	10%	10%	3%	16%	20%	14%	28%	16%	13%	2%		19%	25%	18%	10%	5%	5%	6%	1%	19%
Sharpchin																			2%	5%						5%	
Silvergrey														2%							2%						
Striptail or Sharpch						1%											11%	33%	6%	2%						1%	
Tiger								5%				1%	2%	2%	3%	9%	4%		2%		2%	1%		2%	1%		3%
Unidentified Adult	9%				100%	5%	18%	32%		6%	37%	32%	14%	17%	4%	6%			17%	25%	63%	74%	63%	73%	13%	5%	3%
Widow Rockfish																											
Yellowtail Rockfish						0%		2%				17%	32%	9%			7%					3%			0%	4%	
Sub-total	18%	33%			100%	92%	85%	84%	65%	90%	94%	95%	77%	76%	74%	63%	41%	42%	94%	93%	97%	96%	96%	93%	63%	29%	81%
Sharks and Skates																											
Big Skate						0%																					
Dogfish Shark															1%	1%					1%				2%	19%	
Long Nose Skate						0%										1%					1%						
Rat Fish	82%	67%	100%			0%		2%		2%	2%		14%	22%	21%	30%	46%	46%	1%				1%	3%	1%		3%
Sandpaper Skate																									0%		
Sub-total	82%	67%	100%			0%		2%		2%	2%		14%	22%	22%	33%	46%	46%	1%		2%		1%	3%	4%	19%	3%
Misc species																											
Eel pout or gunnel						0%				3%	1%	2%			3%	1%				2%				1%			
Greenling										2%												1%					
Lingcod						4%	1%	11%		2%	1%	2%	2%	2%	1%	1%	7%	13%		4%			1%	1%	0%	1%	14%
poacher						0%					1%								2%								
Pollock						0%						1%															
Sculpin						0%	8%	3%	5%	2%			4%						2%	2%	1%	3%	2%	1%	6%	1%	
Unidentified Sculpin						0%	4%		10%																	1%	
Sub-total						5%	13%	15%	15%	8%	3%	5%	5%	2%	4%	3%	7%	13%	3%	7%	1%	4%	3%	3%	6%	4%	14%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 4. Density of fish (#'s/Ha) by species or species group observed in each transect.

	Transect																										
Species	1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18
Flatfish																											
Arrowtooth Flounder																										54	
Dover Sole													9						8						53		
Pacific Halibut						3											4							7			2
Petrale Sole																									1		
Rock Sole									9																		
Unidentified Flatfish						6	8		26		10		9			5	7		8				5		24	3	
Flatfish per Ha						9	8		35		10		18			5	11		17				5	7	79	57	2
Rockfish																											
Yelloweye						4					5			11		20	4				15	5	5	7	1		
Black																										2	
Canary						101	102	43		95	83	35	44	17	5	5	25	6	8	7	30		42	37	68		2
Green Stripped													9		5												
Greenspotted						0																					
Unidentified Juvenile		27				211	38	51	96	58	161	96	27	17	186	89		6	474	132	30	55	245	45	59	14	33
Quillback	4																										
Redstripe							4																				
Rosethorn						2	53	26	17	6	94	106	71	73	59	44	4		183	103	125	80	52	37	19	2	12
Sharpchin																			17	22						6	
Silvergrey														6							15						
Striptail or Sharpchin						3											18	46	58	7						2	
Tiger								13				5	9	6	10	30	7		17		15	5		15	3		2
Unidentified Adult	4				4	18	53	85		12	224	166	71	45	15	20			166	103	435	581	656	536	37	6	2
Widow Rockfish																											
Yellowtail Rockfish						1		4				91	159	22			11					20			1	5	
Rockfish per Ha	9	27			4	341	249	221	113	171	568	499	389	196	279	207	67	58	923	374	664	746	1000	678	188	35	50
Sharks and Skates																											
Big Skate						0																					
Dogfish Shark															5	5					7				7	23	
Long Nose Skate						0										5					7						
Rat Fish	40	53	93			0		4		3	10		71	56	78	99	74	64	8				5	22	3		2
Sandpaper Skate																									1		
Sharks&Skate per Ha	40	53	93			1		4		3	10		71	56	83	109	74	64	8		15	0	5	22	12	23	2
Misc species																											
Eel pout or gunnel						0				6	5	10			10	5				7				7			
Greenling										3												10					
Lingcod						16	4	30		3	5	10	9	6	5	5	11	17		15			10	7	1	2	9
poacher						1					5								17								
Pollock						0						5															
Sculpin						1	23	9	9	3			18						17	7	7	25	16	7	17	2	
Unidentified Sculpin						1	11		17																	2	
Misc spp. Per Ha						19	38	38	26	15	16	25	27	6	15	10	11	17	33	29	7	35	26	22	19	5	9
Total Num. Per Ha	49	27	44	0	4	3809	345	275	89	275	514	461	252	204	341	297	204	106	523	244	412	691	881	434	917	345	159

Table 5. Number of invertebrates observed by species or species group in each transect.

	Transect																											
Species	1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18	Total
Bat Star	1		1																									2
Blood Star						2						1																3
Brittle Star	2		11						2																			15
Cookie star						2												1	1									4
Coral spp	4	1		1	3	1																						10
Crab			10			5																				5		20
Feather Star						191	84	205	4	17	132	259	106	150	163	109	80	183	152	94	156	120	140	105	925			3375
Giant Plumose Anemone						7																						7
Gorgonian	1																										16	17
Gunpowder Star						2																						2
Octopus						1																						1
Sea Anemone	58	2	25	1	14	20			1	1		1		1	1	2	1	6			1				4	51	192	382
Sea Cucumber	12	2	1	16	19	316	101	88	19	112	88	116	102	167	169	189	73	83	46	23	67	60	51	51	104	1	3	2079
Sea Kelp	3		3	2	6	4																				2	1	21
Sea Pen		1																										1
Sea Star	27	7	12	13	54	179	23	38	25	94	35	89	67	142	195	235	14	20	26	23	48	36	10	69	320	933	51	2785
Sea Urchin		1		1	1	2	149	451		166	194	488	248	629	703	745			49		181	152	33	110	2		3	4308
Sea Whip						1																						1
Slime Star												1	1		1	1												4
Sponge														1		1			3		4		2	1	353	35	431	831
Sun Star	3		22	1	1	28	1	2	2	4		2		1	2	1		1	1				1		1	46	90	210
Sunflower Star						1	1									1								1	3			7
Vermilion Star																									20			20
White Branching Hydrocoral						7																						7
Wrinkle Star									1			1											2					4
Unk. Invertebrate	3	1				1																1	1	1		1		9
Derelict fishing gear						1				1											1							3
Total	**114**	**15**	**85**	**35**	**98**	**771**	**359**	**784**	**54**	**395**	**449**	**958**	**524**	**1091**	**1234**	**1284**	**168**	**294**	**278**	**140**	**458**	**369**	**240**	**338**	**1732**	**1074**	**787**	**14128**

Table 6. Percent of total invertebrates observed by species or species group in each transect.

Species	Transect																										
	1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18
BatStar	1%		1%																								
BloodStar						0%						0%															
Brittle Star	2%		13%						4%																		
Cookie star						0%												0%	0%								
Coral spp	4%	7%		3%	3%	0%																					
Crab			12%			1%																				0%	
Feather Star						25%	23%	26%	7%	4%	29%	27%	20%	14%	13%	8%	48%	62%	55%	67%	34%	33%	58%	31%	53%		
Giant Plumose Anemone						1%																					
Gorgonian	1%																										2%
Gunpowder Star						0%																					
Octopus						0%																					
Sea Anemone	51%	13%	29%	3%	14%	3%			2%	0%		0%		0%	0%	0%	1%	2%			0%				0%	5%	24%
Sea Cucumber	11%	13%	1%	46%	19%	41%	28%	11%	35%	28%	20%	12%	19%	15%	14%	15%	43%	28%	17%	16%	15%	16%	21%	15%	6%	0%	0%
Sea Kelp	3%		4%	6%	6%	1%																				0%	0%
Sea Pen		7%																									
Sea Star	24%	47%	14%	37%	55%	23%	6%	5%	46%	24%	8%	9%	13%	13%	16%	18%	8%	7%	9%	16%	10%	10%	4%	20%	18%	87%	6%
Sea Urchin		7%		3%	1%	0%	42%	58%		42%	43%	51%	47%	58%	57%	58%			18%		40%	41%	14%	33%	0%		0%
Sea Whip						0%																					
Slime Star												0%	0%		0%	0%											
Sponge														0%		0%			1%		1%		1%	0%	20%	3%	55%
Sun Star	3%		26%	3%	1%	4%	0%	0%	4%	1%		0%		0%	0%	0%		0%	0%				0%		0%	4%	11%
Sunflower Star						0%	0%									0%								0%	0%		
Vermilion Star																									1%		
White Branching Hydrocoral						1%																					
Wrinkle Star									2%			0%											1%				
Unknown Invertibrate	3%	7%				0%																0%	0%	0%		0%	
Derelict Fishing gear						0%				0%											0%						
Total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Table 7. Density of invertebrates observed by species or species group in each transect.

Species	Transect 1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18
Bat Star	4		9																								
Blood Star						1						5															
Brittle Star	9		102						17																		
Cookie star						1												6	8								
Coral spp	18	13		25	12	0																					
Crab			93			2																				8	
Feather Star						82	317	872	35	52	687	1306	937	840	799	538	282	1061	1264	688	1151	601	729	782	1330		
Giant Plumose Anemone						3																					
Gorgonian	4																										28
Gunpowder Star						1																					
Octopus						0																					
Sea Anemone	257	27	232	25	58	9			9	3		5		6	5	10	4	35			7				6	78	333
Sea Cucumber	53	27	9	398	78	136	381	374	165	343	458	585	902	935	828	934	257	481	383	168	494	300	266	380	150	2	5
Sea Kelp	13		28	50	25	2																				3	2
Sea Pen		13																									
Sea Star	120	94	111	324	222	77	87	162	218	287	182	449	592	795	956	1161	49	116	216	168	354	180	52	514	460	1429	88
Sea Urchin		13		25	4	1	563	1919		508	1010	2461	2193	3521	3446	3680			407		1335	761	172	820	3		5
Sea Whip						0																					
Slime Star												5	9		5	5											
Sponge														6		5			25		30		10	7	508	54	747
Sun Star	13		204	25	4	12	4	9	17	12		10		6	10	5		6	8				5		1	70	156
Sunflower Star						0	4									5								7	4		
Vermilion Star																									29		
White Branching Hydrocoral						3																					
Wrinkle Star									9			5											10				
Unknown Invertibrate	13	13				0																5	5	7		2	
Derelict fishing gear						0				3											7						
Total	**505**	**201**	**789**	**872**	**403**	**332**	**1356**	**3336**	**470**	**1208**	**2338**	**4831**	**4633**	**6107**	**6049**	**6342**	**591**	**1704**	**2312**	**1025**	**3379**	**1847**	**1250**	**2518**	**2490**	**1644**	**1363**

Table 8. Percent habitat type observed in each transect.

Primary	Secondary	Complexity	1	2	3	5	6	7	8A	8B	8C	8D	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	15A	15B	16	17	18
Boulder																													
	Cobble	c																		11%			17%	10%	1%	2%	0%		
	Cobble	s																3%	18%	14%	7%	3%	5%		2%				
	Gravel	c								12%		3%	2%	5%	26%	23%	12%	1%		2%	2%		2%	19%	15%	7%	0%		
	Gravel	s						0%	8%	20%		7%	9%	14%	16%	4%	16%	16%	4%	2%	9%		0%	26%	0%	27%			
	Mud	c																									1%		
	Mud	s																					3%				1%		
	Pebble	c							0%	0%					0%	2%		13%											
	Pebble	s						0%	5%						0%	3%		1%											
	Sand																										5%		
	Sand	c						1%												3%							1%		
	Sand	s						5%	2%											3%	0%		2%		34%		1%		
								5%	15%	33%		10%	11%	19%	42%	33%	28%	34%	21%	35%	18%	3%	28%	56%	51%	35%	9%		
Cobble																													
	Bolder	c						0%											5%										
	Sand	s	59%	0%				1%													11%	29%	7%	7%					
	Gravel																				2%	27%							
	Pebble																	2%	0%			35%							
	Sand							2%																			1%		
			59%	0%				3%										2%	5%		13%	91%	7%	7%			1%		
Gravel																													
	Bolder	c							3%	5%		1%	6%	2%	0%	1%	1%	1%					2%	0%					
	Sand	s	30%	24%			73%	1%	8%	8%	5%	10%	26%	15%	13%	11%	13%	7%	3%	1%	3%	4%	3%	5%	3%	27%		1%	1%
	Cobble		3%		63%	100%	27%													3%			0%	1%				15%	
	Pebble			76%					7%		13%		34%	5%	0%	5%	0%	2%										73%	99%
	Sand							10%	58%	54%	8%	79%	17%	57%	45%	47%	58%	46%	4%	9%	65%	2%	32%	31%	45%	37%			
			32%	100%	63%	100%	100%	11%	77%	67%	27%	90%	83%	80%	58%	64%	72%	56%	8%	13%	68%	6%	37%	37%	49%	65%		90%	100%
Mud																													
	Bolder	c																									4%		
	Sand	s																					1%				1%	0%	
	Cobble				37%																						7%		
	Mud																										10%		
	Sand																										20%	10%	
					37%																		1%				42%	10%	
Pebble																													
	Bolder	s						2%	1%		3%				0%	2%		2%											
	Cobble		8%																										
	gravel							2%			14%		5%	2%				7%											
	Sand							7%			23%																		
			8%					12%	1%		39%		5%	2%		2%		8%											
Sand																													
	Bolder	s						2%	0%										49%	4%			6%				1%		
	Cobble							0%																			5%		
	Gravel							61%	8%		34%								17%	47%	2%						6%		
	Mud							6%															21%				36%		
	Pebble							0%																					
								69%	8%		34%								66%	51%	2%		27%				49%		

Note: c = Continuous and s = Stacked and values are rounded to whole numbers

Table 9. Summary of the analysis of variance results.

Aquatic animal	Common name	Pr(F)	
		Transect (levels=8,9,10,11,12,13,14,15)	Subtransect (levels=A, B)
Fin fish	Yelloweye Rockfish	0.72	0.57
	Canary Rockfish	**0.01**	**0.02**
	dogfish shark	**0.03**	0.35
	dover sole	0.50	0.17
	halibut	0.64	1.00
	Lingcod	0.31	0.23
	unidentified juvenile	**0.01**	0.42
	longnose skate	0.64	1.00
	pollock	0.50	0.35
	rat fish	**0.01**	0.75
	redstripe	0.50	0.35
	rosethorn	**0.01**	0.83
	Sharpchin	**0.04**	0.68
	sculpin	0.32	0.86
	silvergrey Rockfish	0.62	0.68
	Tiger Rockfish	0.54	0.46
	Yellowtail Rockfish	0.34	0.95
	eel pout	*0.06*	0.35
	poacher	0.50	0.20
	unidentified flatfish	0.85	0.03
	unidentified Rockfish	**0.00**	0.67
Echinoidea	feather stars	0.36	0.41
	sea stars	*0.09*	0.21
	Sea Cucumbers	*0.07*	0.89
	Sea Urchins	**0.00**	0.21

Table 10. Comparison of the number of fish observed by species and the 2008 to 2009 IPHC survey catch by station.

2008 ROV Survey	IPHC Station Number					
Species	1082	1528	1529	1533	1534	Total
Boccacio						0
Canary	235	68	47		1	351
Rosethorn	5	24	13	1	7	50
Yelloweye	9		1			10
Yellowtail	2	1	1	3		7
Grand Total	251	93	62	4	8	418

2008 IPHC Survey

Species	1082	1528	1529	1533	1534	Total
Boccacio	1	1	1	1		4
Canary	2					2
Rosethorn						0
Yelloweye	5	22	11	1	4	43
Yellowtail						0
Grand Total	8	23	12	2	4	49

2009 IPHC Survey

Species	1082	1528	1529	1533	1534	Total
Boccacio			1		1	2
Canary	1	1				2
Rosethorn						0
Yelloweye	10	26	10	1	6	53
Yellowtail						0
Grand Total	11	27	11	1	7	57

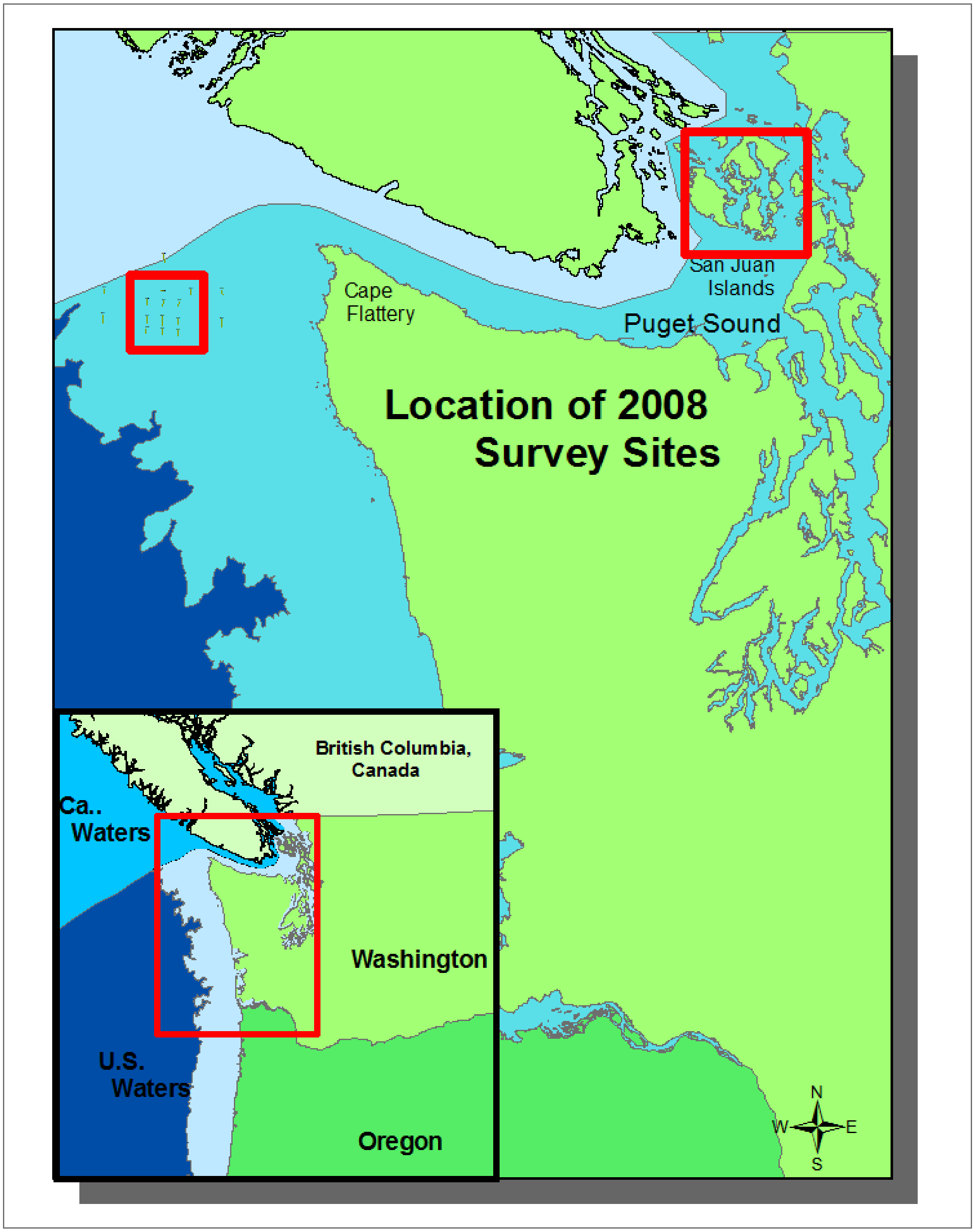

Figure 1. Location of the 2008 groundfish ROV survey sites.

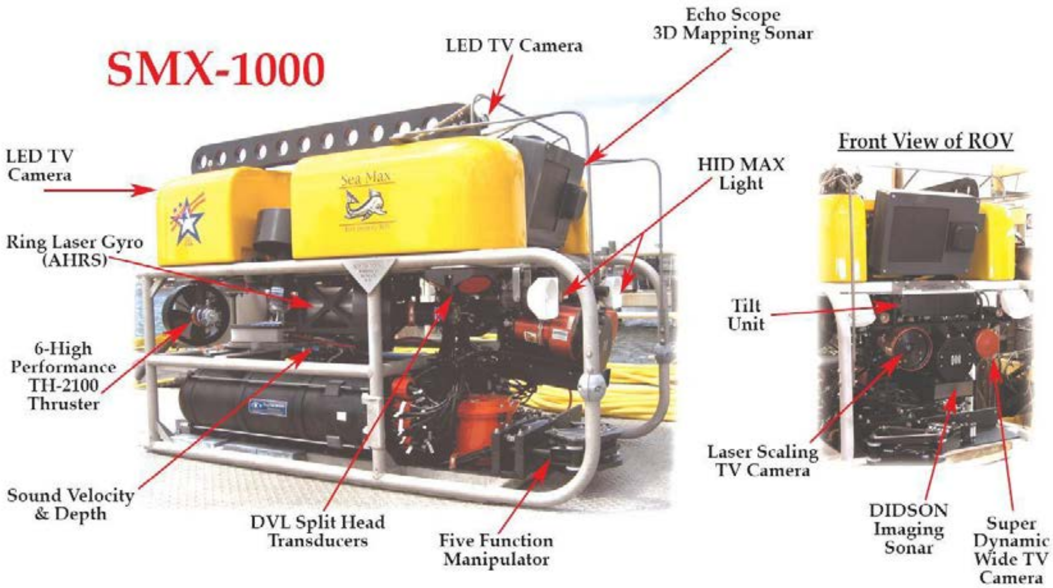

Figure 2. Stanford Research work class ROV and umbilical(far right) on deck of the R/V Centennial. Max SMX-1000 ROV with Mobile Inspection Package

Figure 3. Doppler Velocity Logger (left) and 3-beam menstruation system (right).

Figure 4. Mobile Inspection Package sensor suite


Figure 5. ROV on the deck of the R/V Centennial (left), ROV control center, data accusation and processing.

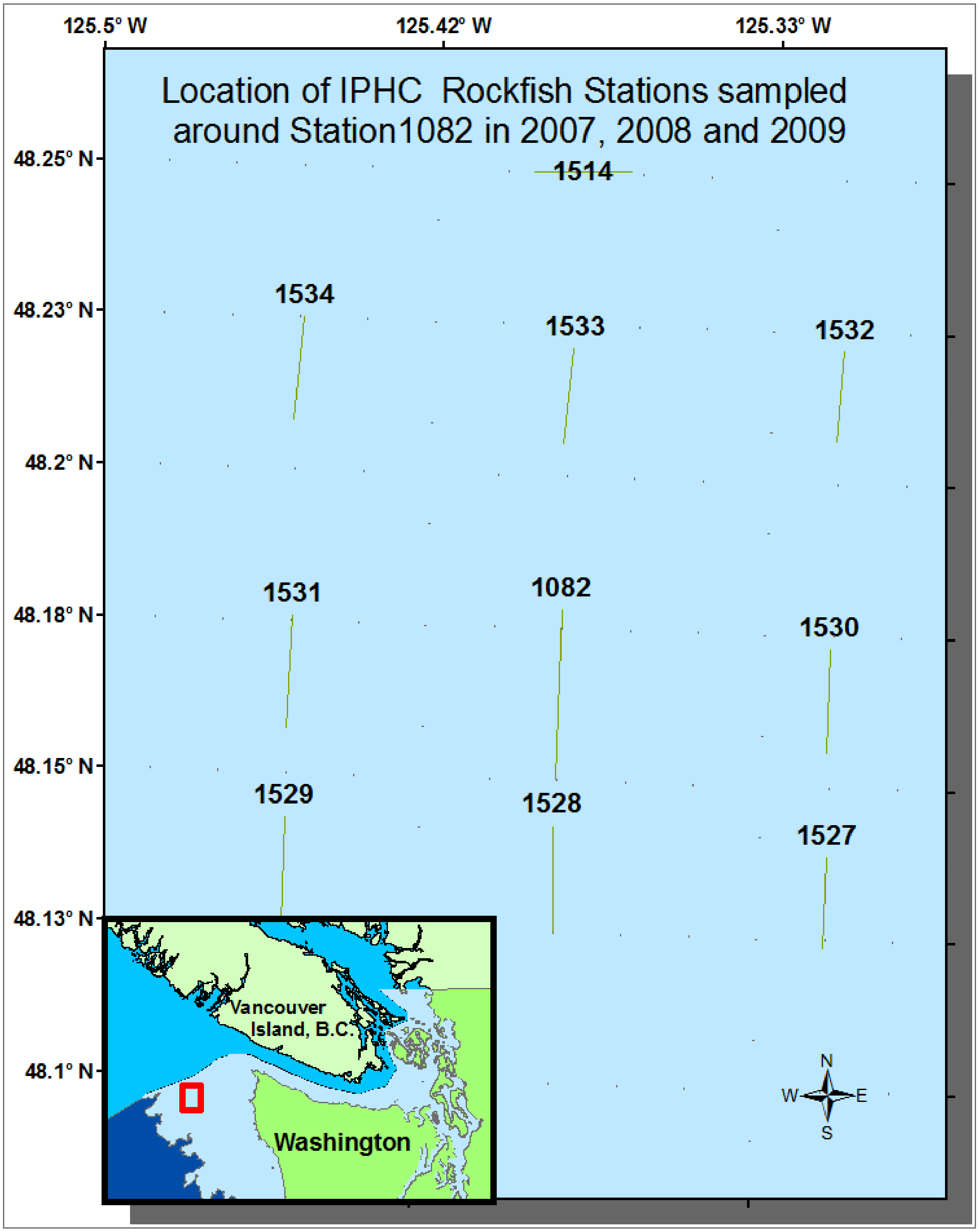

Figure 6. Location of IPHC Rockfish stations sampled between 2007 and 2009 off of Cape Flattery Washington.

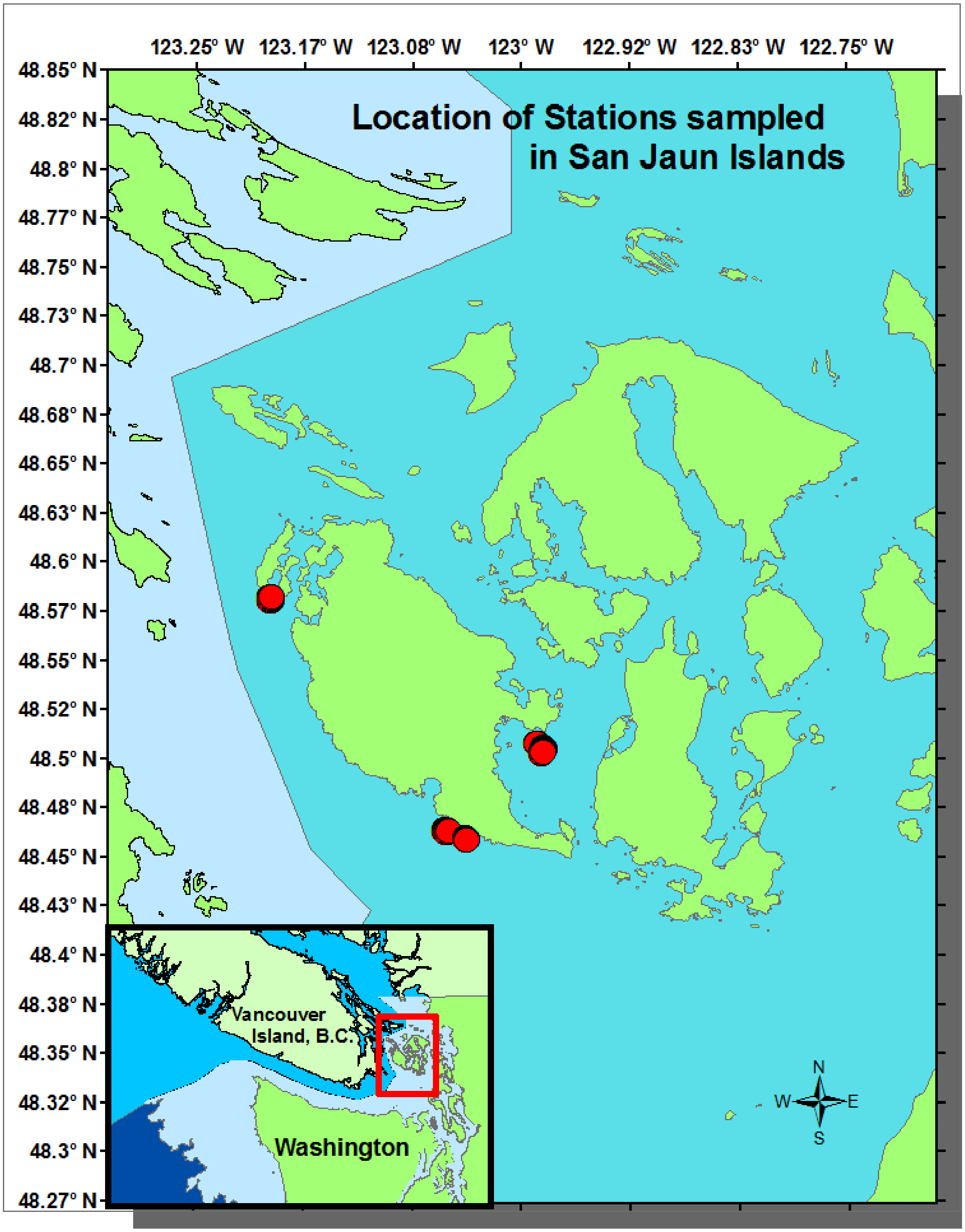

Figure 7. Transect locations near San Juan Islands in Puget Sound.

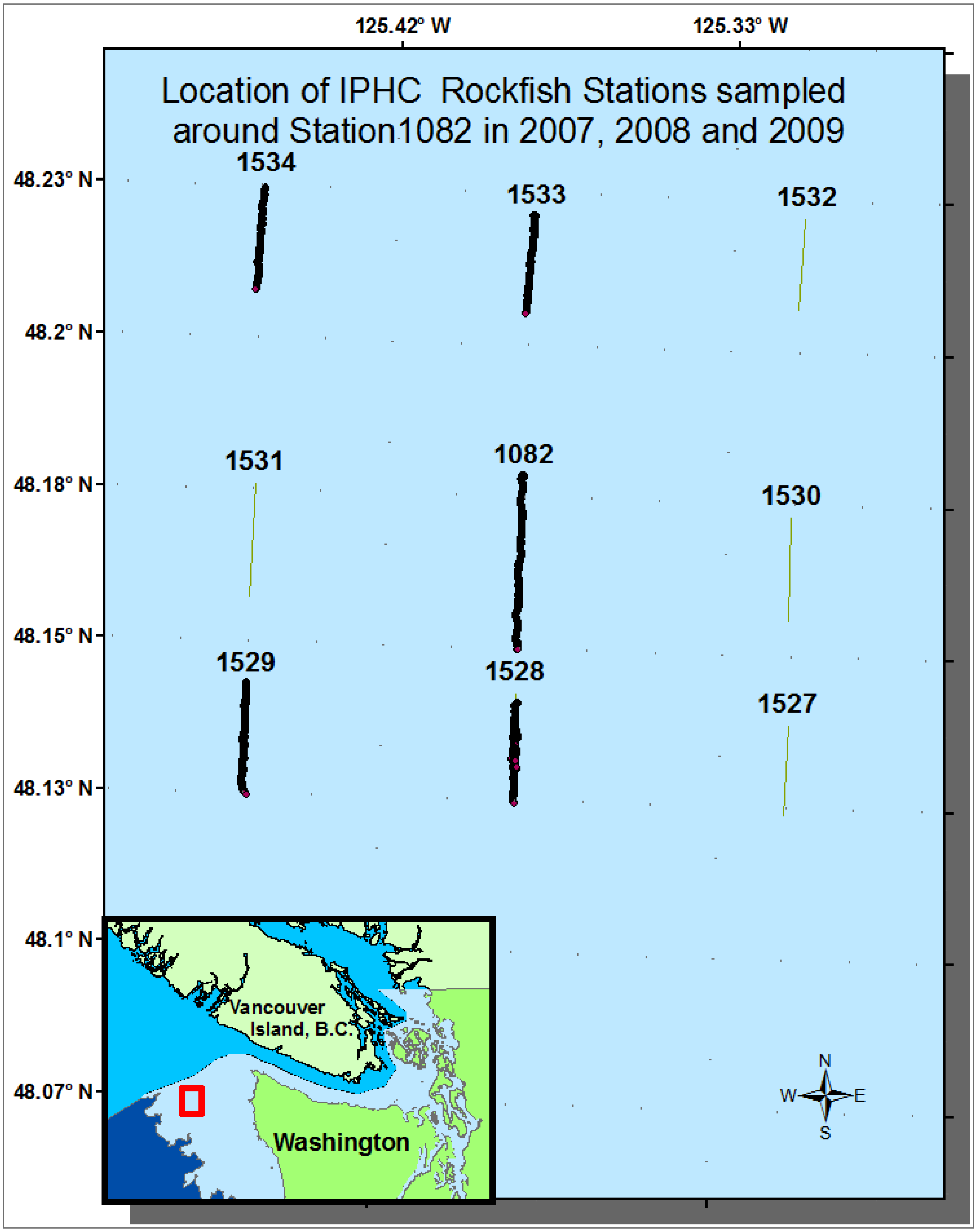

Figure 8. Transect locations (dark lines) on "The Prairie, 40 kilometers " WSW of Cape Flattery Washington.

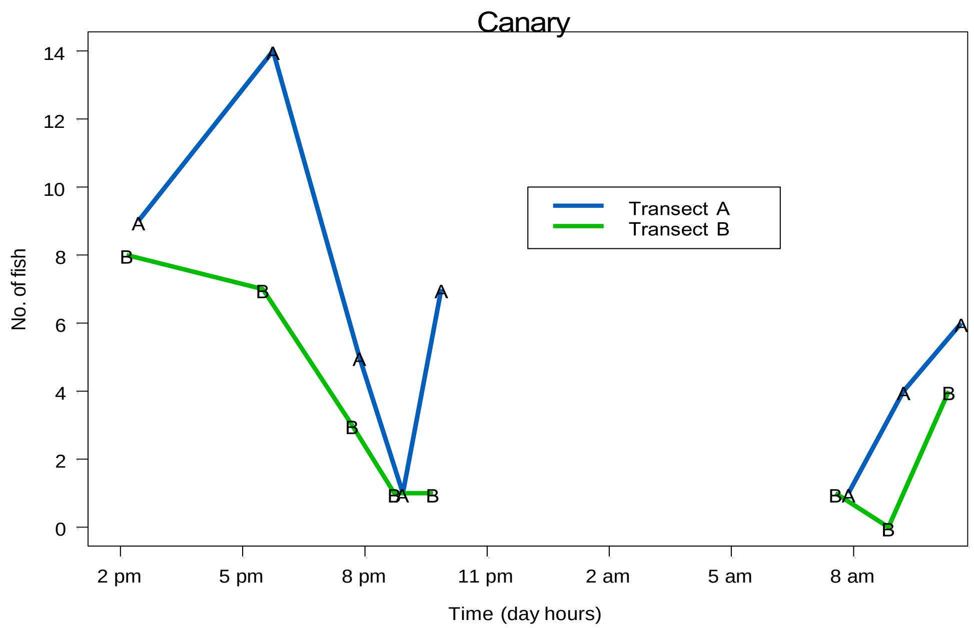

Figure 9. Plot of diurnal changes in Canary Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

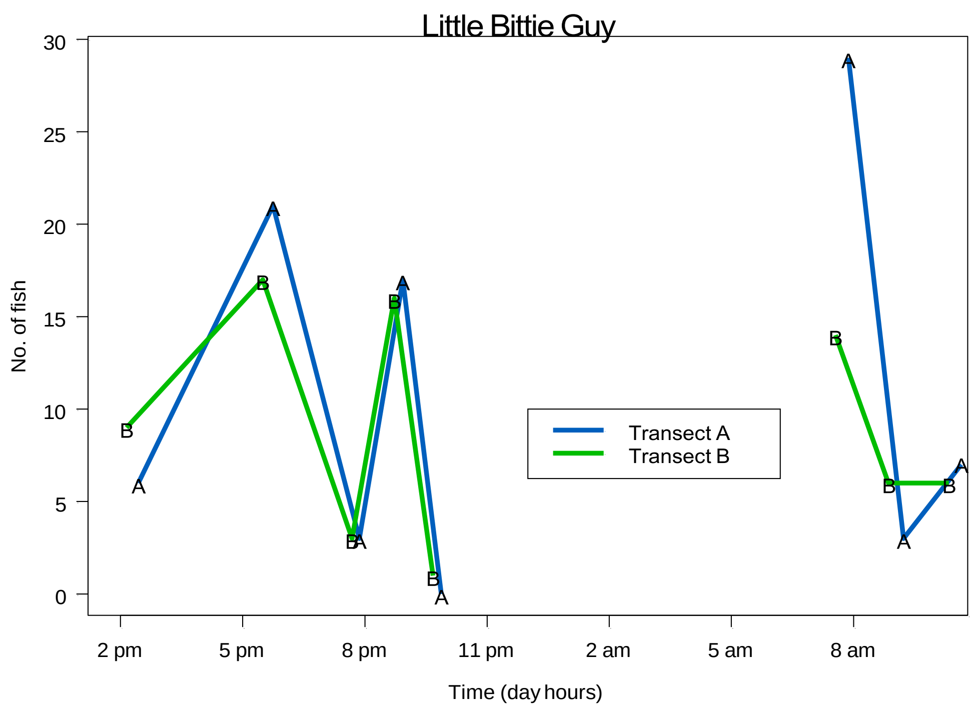

Figure 10. Plot of diurnal changes in juvenile Rockfish (Little bitty guy) densities between two ROV sub- transects (A and B) within the 24 hours

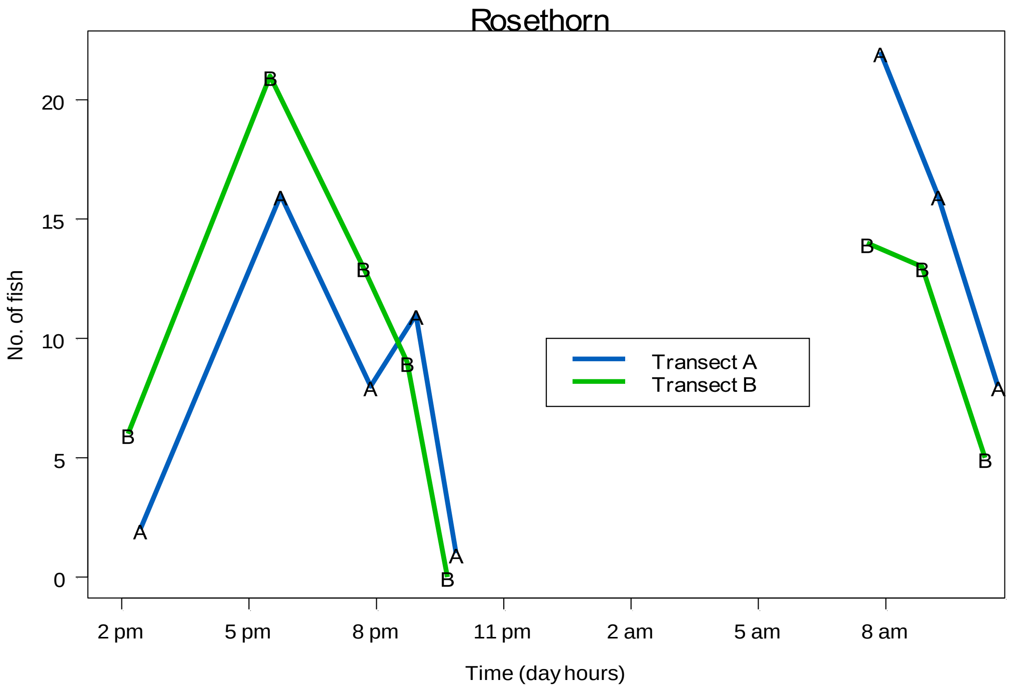

Figure 11. Plot of diurnal changes in rosethorn Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

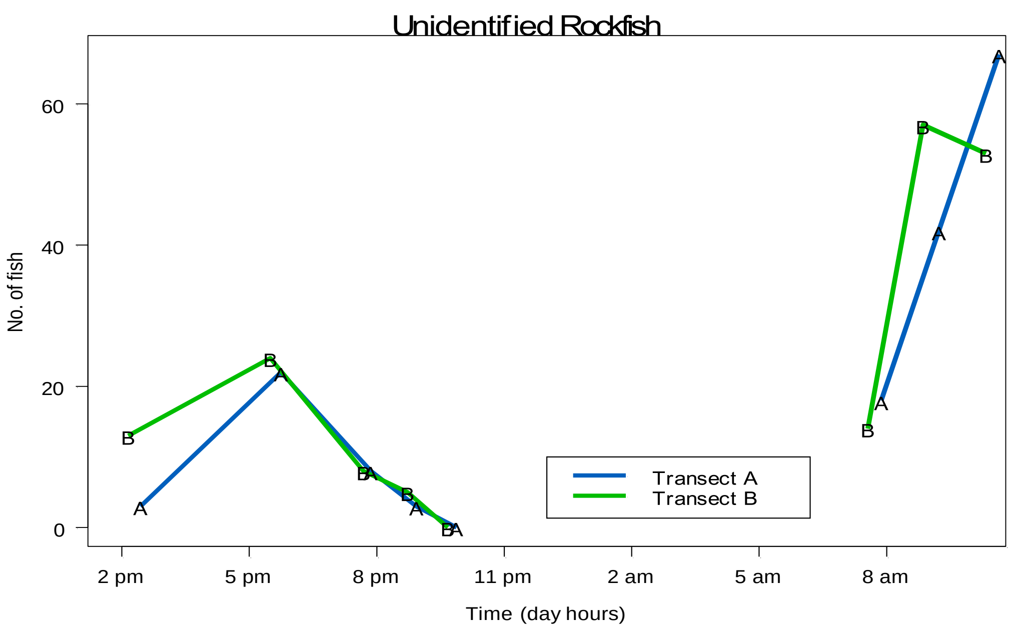

Figure 12. Plot of diurnal changes for unidentified adult Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

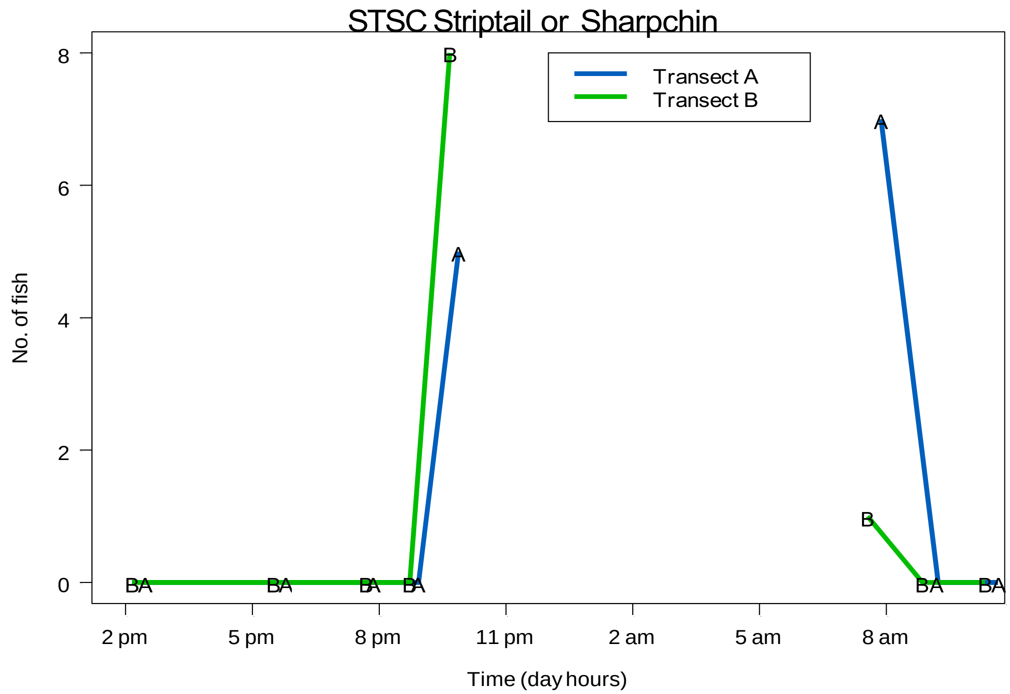

Figure 13. Plot of diurnal changes for Stripetail/Sharpchin Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

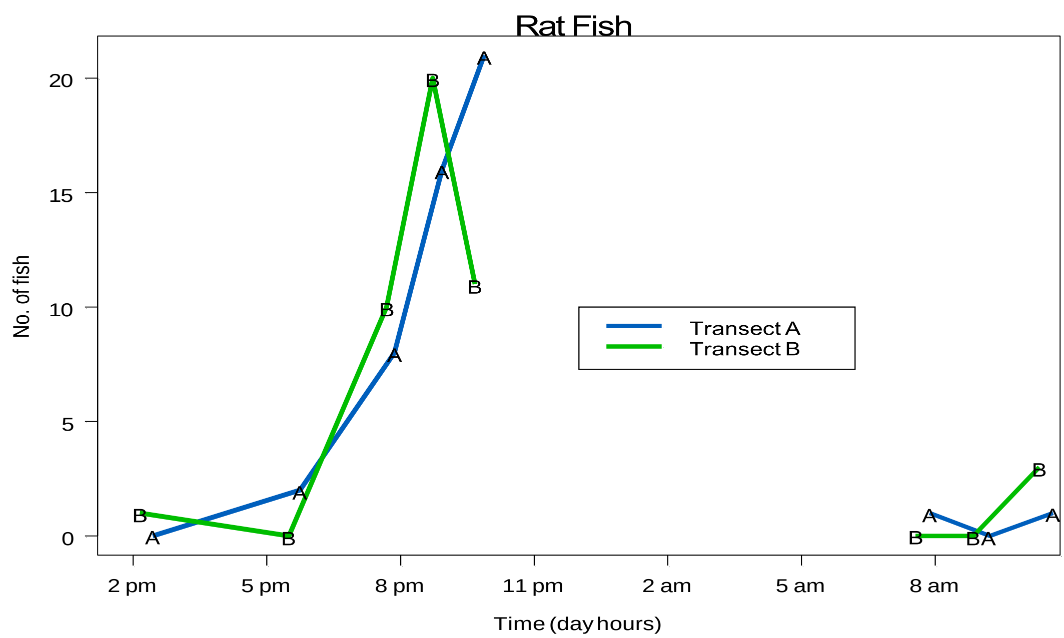

Figure 14. Plot of diurnal changes for dogfish shark densities between two ROV sub- transects (A and B) within the 24 hours.

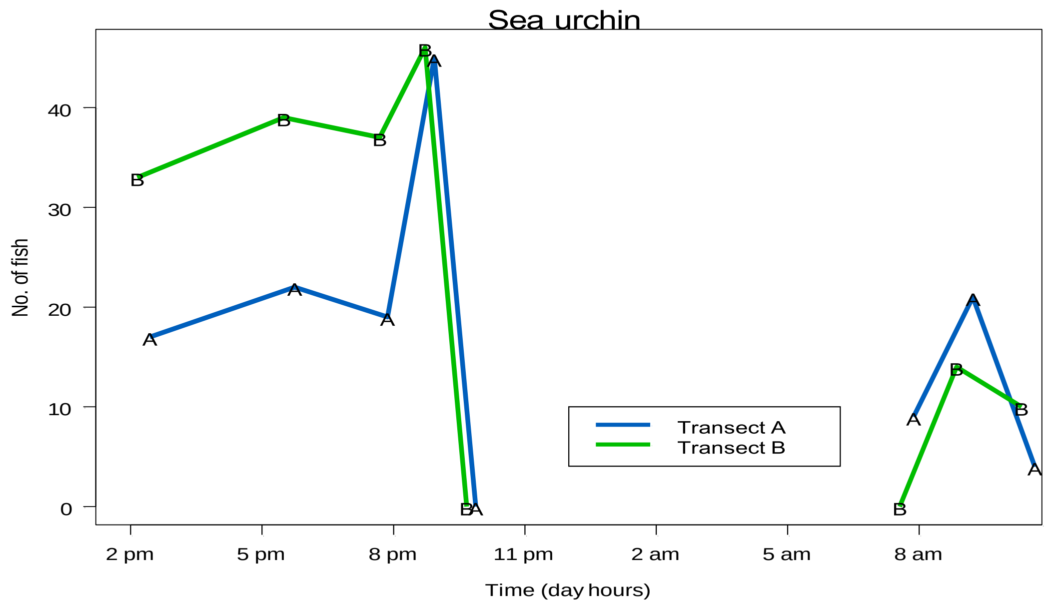

Figure 15. Plot of diurnal changes for Sea Urchin densities between two ROV sub- transects (A and B) within the 24 hours.

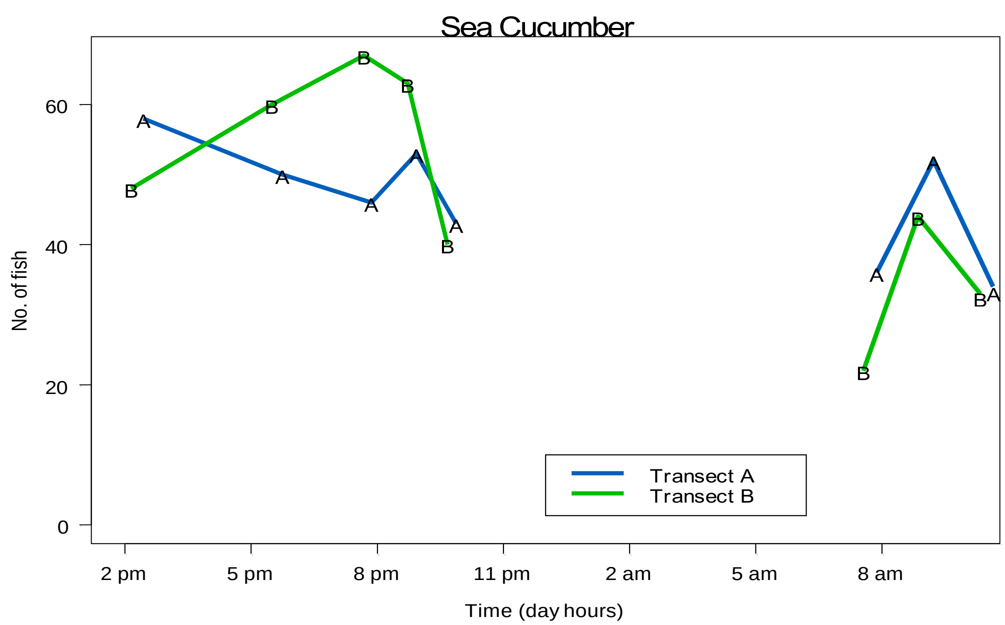

Figure 16. Plot of diurnal changes in Sea Cucumber densities between two ROV sub- transects (A and B) within the 24 hours.

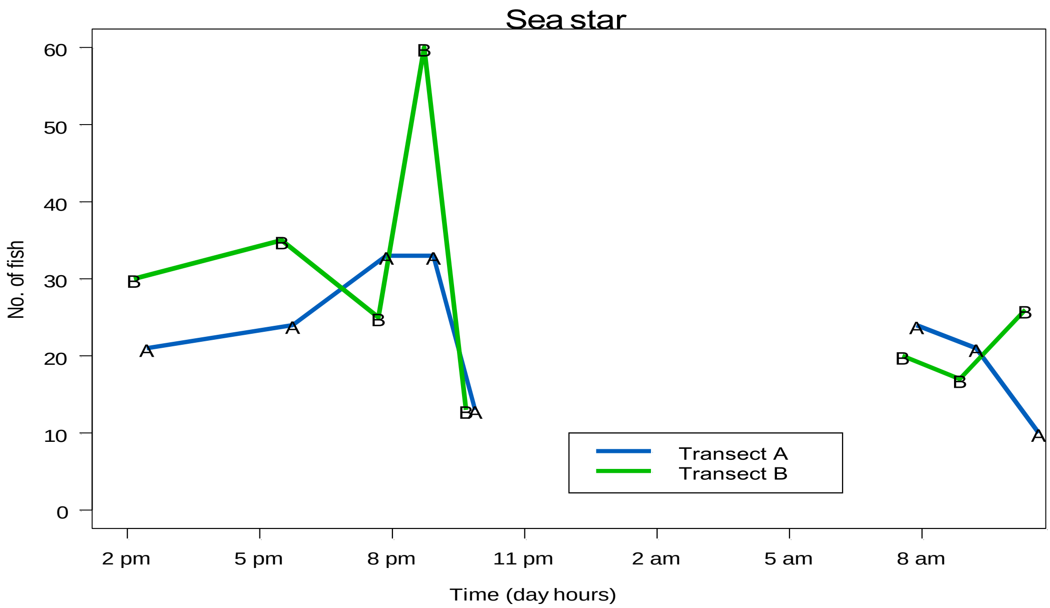

Figure 17. Plot of diurnal changes in sea star densities between two ROV sub- transects (A and B) within the 24 hours.

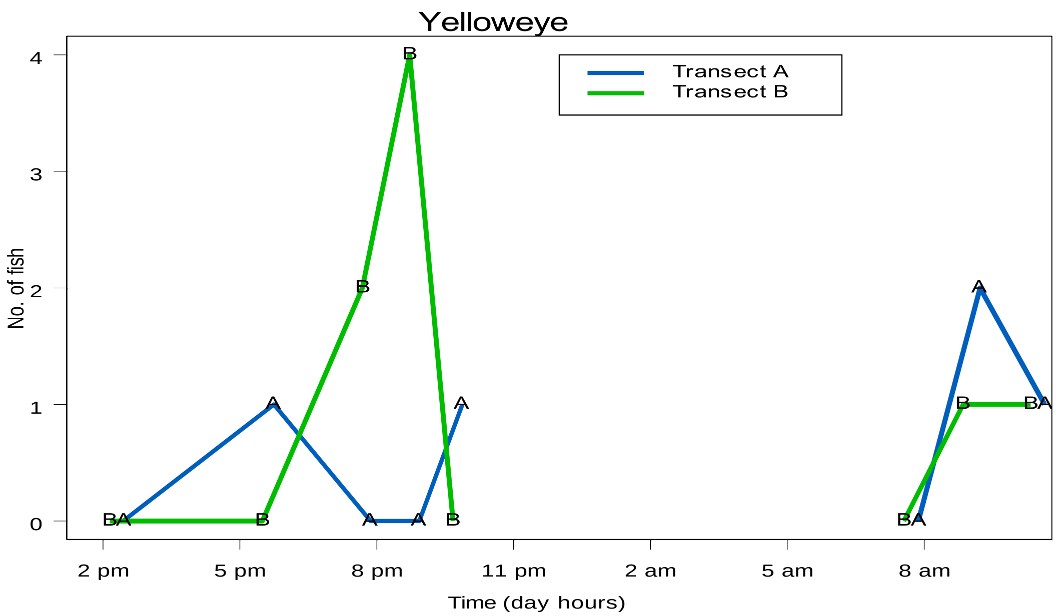

Figure 18. Plot of diurnal changes for Yelloweye Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

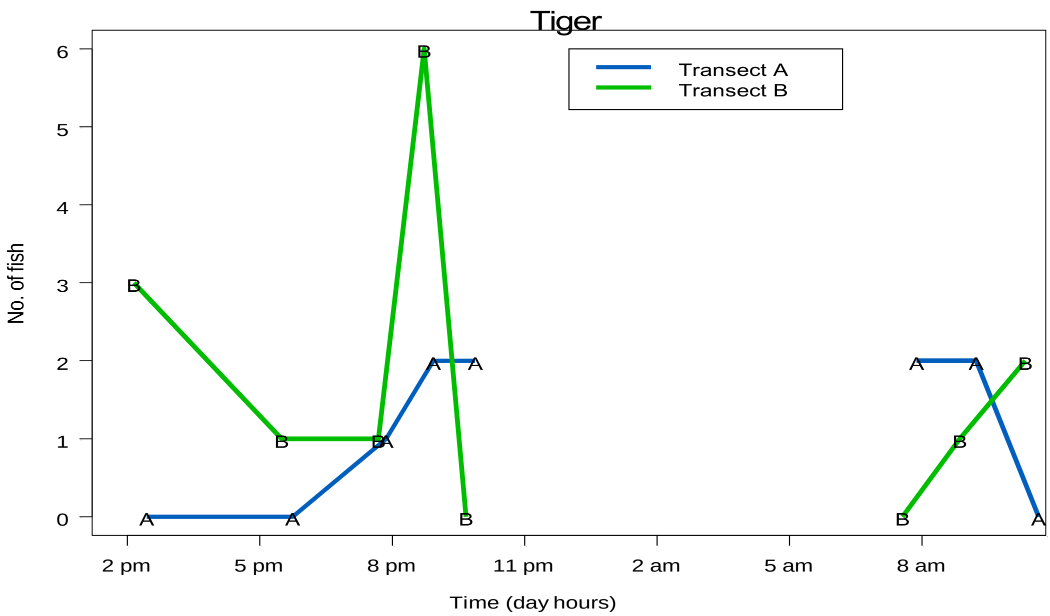

Figure 19. Plot of diurnal changes for Tiger Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

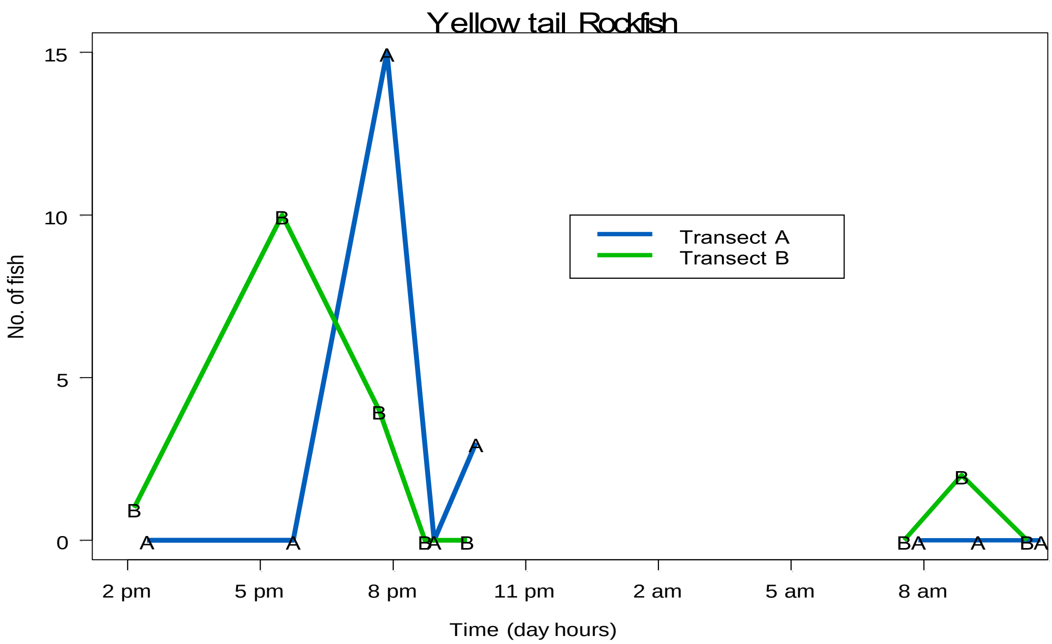

Figure 20. Plot of diurnal changes for Yellowtail Rockfish densities between two ROV sub- transects (A and B) within the 24 hours.

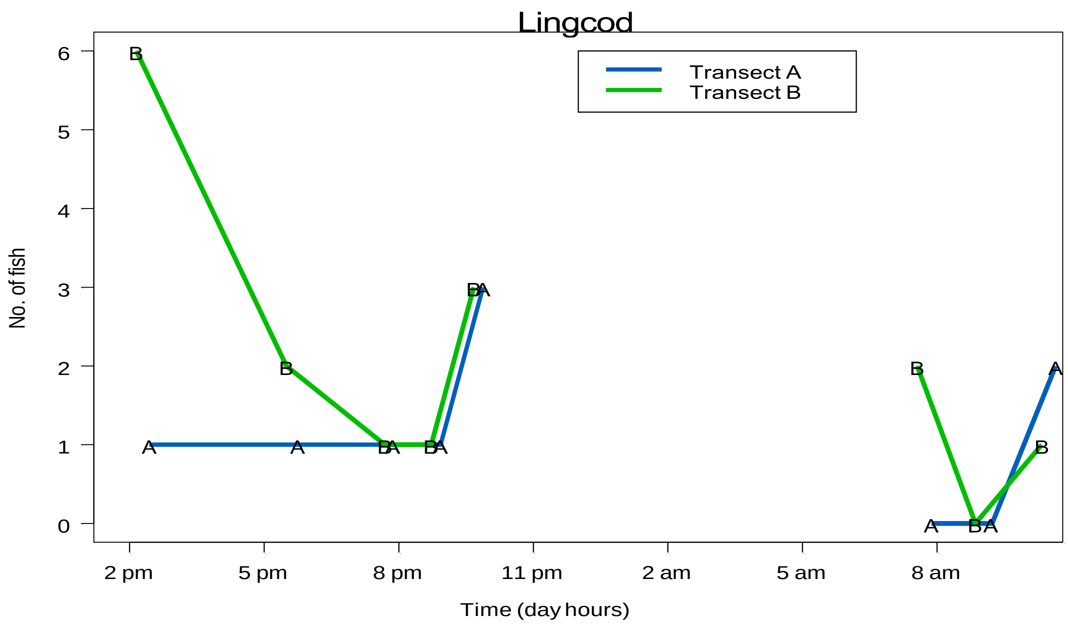

Figure 21. Plot of diurnal changes for Lingcod densities between two ROV sub- transects (A and B) within the 24 hours.

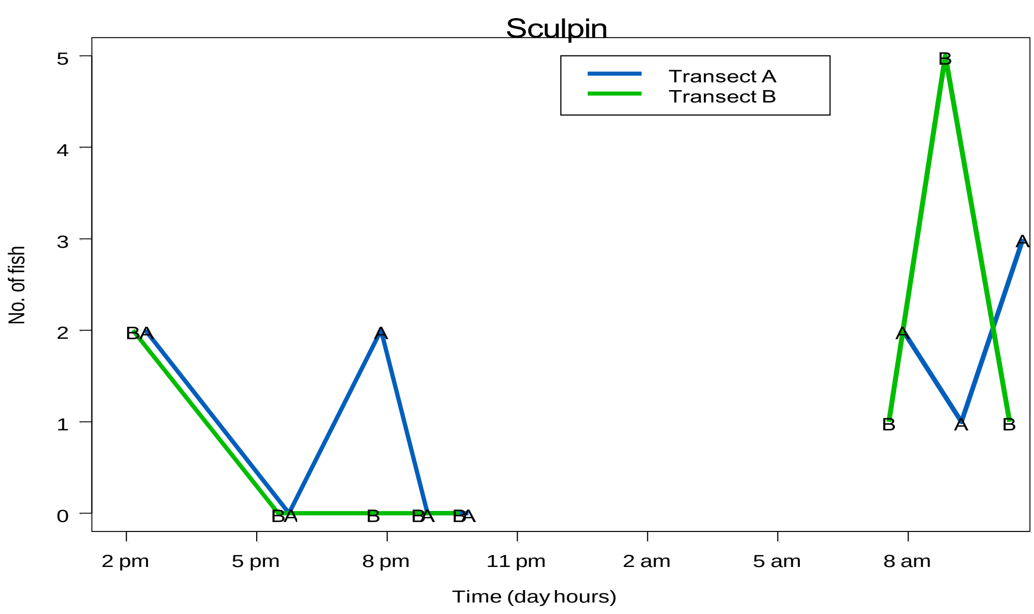

Figure 22. Plot of diurnal changes in sculpin densities between two ROV sub- transects (A and B) within the 24 hours.

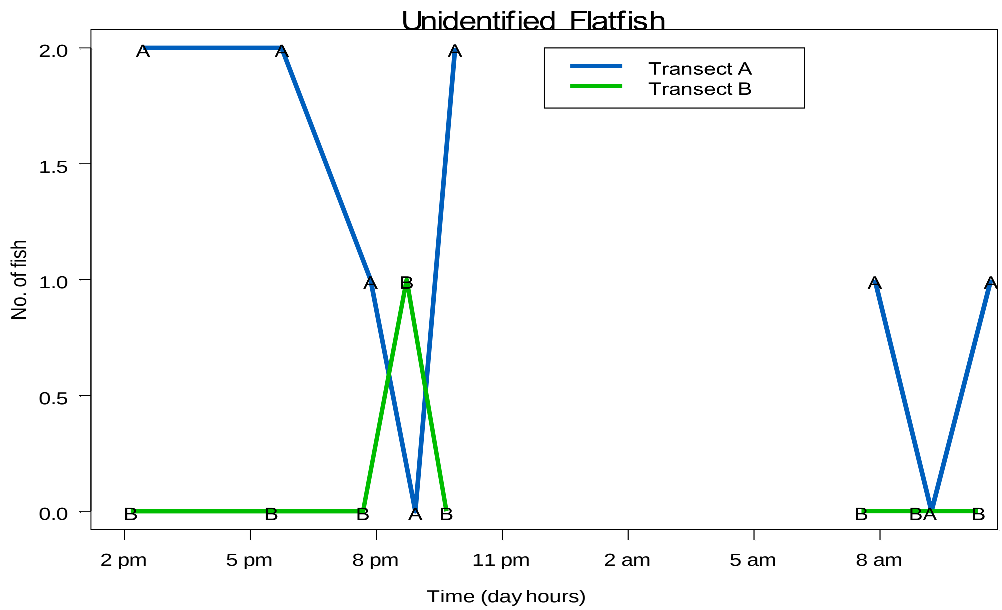

Figure 23. Plot of diurnal changes for unidentified flatfish densities between two ROV sub- transects (A and B) within the 24 hours

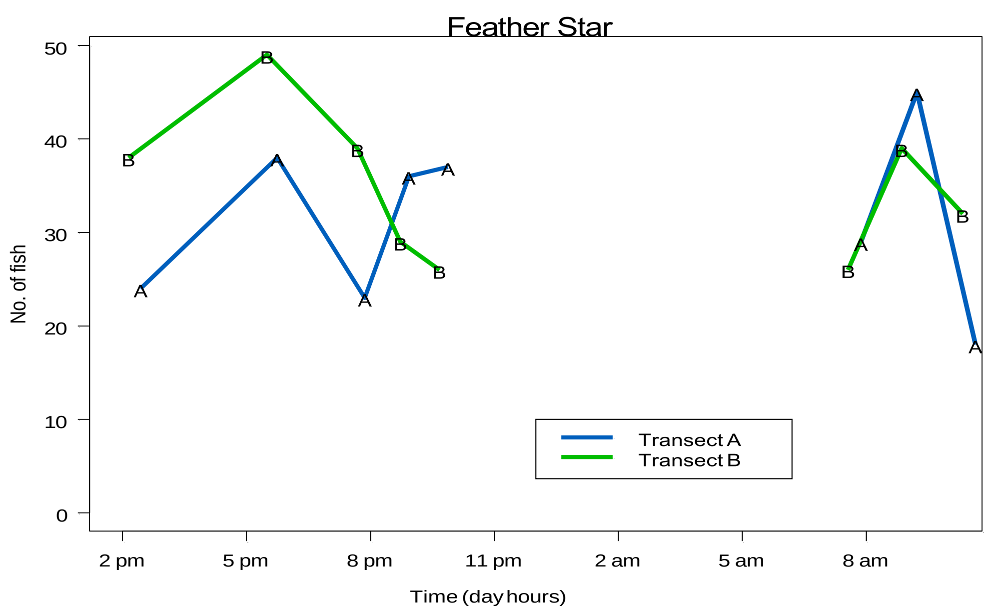

Figure 24. Plot of diurnal changes in feather star densities between two ROV sub- transects (A and B) within the 24 hours.