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Bottomfish Variability in the Proposed Marine Reserves of Skagit County, Washington

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Abstract

Among groundfishes, rockfishes (genus *Sebastes*) are some of the most over-fished species in the United States. Populations in Puget Sound have declined rapidly over the last century; some rockfish species have 10% or less of their historical reproductive output. This population decrease is paralleled by declines in physical size. To address this problem, the Skagit County Marine Resources Committee has proposed establishing one or more no-take marine reserves to protect rockfishes and other groundfishes. The majority of studies of groundfish populations in the northeast Pacific have focused on summer distributions. The goal of this study was to relate intra-annual dynamics of groundfish, especially rockfishes, to physical and biological factors to assess the suitability of individual sites as reserves. Twenty-four dives were performed over one year at six sites under consideration as Skagit County marine reserves. Each dive consisted of eight 25-m transects where fish number and size, plus bottom composition were measured. Initial results show that changes in season were associated with changes in densities of the most abundant groundfishes (copper rockfish, kelp greenling, and lingcod). Depth and site also had a significant effect on densities of copper rockfish, which was the most common rockfish observed. Because of the large seasonal trends and effects of physical factors, more diverse sampling regimes should be used rather than the common summer sampling schedules. Additionally, larger-sized and deeper reserves should be considered to compensate for the seasonal migration of groundfishes.

Introduction

Fishery stocks have declined to the point where 29% of worldwide stocks have collapsed (Worm *et al.*, 2006). Using different measurements, the United Nations' Food and Agricultural Organization suggested that 69% of the world's marine stocks were either fully exploited or depleted (Tuya *et al.*, 2000).

Fish that live on reefs have been especially affected by overfishing and alterations to the reefs (Parrish, 1999). Benthopelagic and benthic fish that have moderate to little movement have been particularly affected by trawl-based fisheries (reviewed in Parris, 1999; Weispfenning, 2006).

Fish of the genus *Sebastes*, commonly called rockfish, are some of the most overfished and depleted species in the United States (Love *et al.*, 2002). Formerly commercially viable species such as boccacio and blue rockfish have had their catches diminished by 99 and 95%, respectively (Love *et al.*, 2002). Over the last four decades the average size of several species of rockfish have fallen significantly (Mason, 1998).

Rockfish populations in Puget Sound have declined to where some rockfish species have less than 10% of their historical reproductive output (Palsson, 1998). Associated with this decrease in reproductive output are declines in size and abundance (Palsson, 2001). In response to these declines, the Washington Department of Fish and Wildlife (WDFW) gradually reduced bag limits from 15 to a bag limit of one rockfish per day (Palsson, 1998). However, because rockfish are often bycatch for the recreational lingcod fishery, and do not recover from barotrauma, they are likely far more affected by fishing than this bag limit represents.

While rockfish populations have suffered over the last 20 years, lingcod (*Ophiodon elongatus*) and kelp greenling (*Hexagrammos decagrammus*) populations in Skagit County have increased (Moulton, 1977; Weispfenning, 2006). These shorter-lived fish are also predators of both larval and adult rockfish. Their recovery may be hampering the recovery of the long-lived and slower reproducing rockfish. While even the shortest-lived rockfish take several years to reach reproduction, male lingcod are reproductive after two years, at the size of 50 cm. Kelp greenlings also grow and mature quickly, reaching reproductive age in two to three years (Eschmeyer *et al.*, 1983). Both of these fish prey on immature rockfish, especially in their pelagic and young-of-the-year (YOY) forms.

Marine Reserves

In order to protect marine species governments around the world have instituted areas where harvest of organisms is prohibited or severely limited. These marine reserves are designed to conserve marine species and habitat for research, posterity, and replenish non-reserve areas for future commercial and recreational fisheries. In some areas the restrictions are limited to a few species, while other governments have expanded them to include all living organisms in the designated area. Theoretically, these reserves will protect fish and invertebrates that live within the boundaries, creating a large broodstock that will reach, or approach, pre-exploitation levels. These broodstocks will then export excess larvae into areas still fished, causing increases in available stocks outside of the marine reserves. This is referred to as the 'reserve effect' (reviewed in Yoklavich 1998, McConnell *et al.,* 2001).

The effects of marine reserves have been tested in tropical ecosystems. Studies have shown both an increase in fish density inside the reserves, as well as increased fisheries catches outside of the reserves (Roberts *et al.*, 2001; Russ and Alcala, 1996)

In the northeast Pacific few studies have been completed to show if marine reserves are producing a reserve effect. Palsson (1998) showed much higher fish densities in five protected areas in Puget Sound. Also observed was a 55-fold increase in reproductive output of the area, compared to unprotected areas with similar bottom composition. Paddack and Estes (2000) compared three reserves and three unprotected areas in kelp forests in coastal California. They found that fish in the reserves were larger and that densities increased 12-35% in the protected areas. Both studies showed that older reserves have larger effects than newer reserves.

Different marine regions and ecosystem types are protected to varying degrees. Spalding and others (2006) estimated that 23% of coral reefs receive some level of protection, while only four percent of the areas of the sea 200 m or shallower receive some protection. However, Mora *et al.* (2006) described only 0.01% of the world's coral reefs as fully protected from poaching, overfishing, coastal development, and pollution.

By comparison less than three percent of north Puget Sound and Strait of Juan de Fuca shorelines are protected. When looking at subtidal area, far less than one percent of that area is protected. Within Skagit County less than a hundredth of the shoreline is protected, with no subtidal areas specifically designated for protecting groundfish.

Recommended sizes for the reserves depend on the goal of each reserve system. For minimal protection, in order to allow the perpetuation of species for heritage and research, Yoklavich (1998) recommended a size up to five percent of the habitat. The recommendations for protecting target species for insurance against overfishing with current management rules ranges from five to 20% (Yoklavich, 1998). Palsson (2001) sets a target of 20 percent for Puget Sound. In order to create an alternative to the current management strategies, marine reserves would have to be 20 to 50% of the available habitat of the fished species (Yoklavich, 1998). However, Parrish (1999) argued that these large reserves may actually have deleterious effects for those species the reserves are supposed to aid. It should be noted that the author used a spawning biomass that is less than the current biomass of Puget Sound groundfish. The species used are also less sedentary, therefore making them less ideal for protection than those in most need of help in Puget Sound.

Marine reserves must also occur in diverse enough habitats and areas to protect the majority of the life stages of the organisms they are trying to protect. Yoklavich (1998) recommended protecting the vast majority of the movement of the organisms that a marine reserve is intended to protect. This means that for several species which migrate either seasonally, or at some point during their life, a large area, which is also diverse, must be included. For example, yellowtail rockfish (*S. flavidus*) in Washington State migrate from the north Puget Sound to the open coast as they reach maturity (Love *et al.*, 2002). If a marine reserve were to only protect the adult phase, the protection would likely be inadequate, due to fishing pressure on the juvenile form in Puget Sound.

Research Objectives

The primary goal of this research is to describe the variability of rockfish in the proposed marine reserves of Skagit County, and how that variability relates to season, bottom composition, and site. Additionally, by comparing the fish densities from previous studies done in Skagit County (Moulton, 1977; Weispfenning, 2006), estimations of inter-annual variability can be refined.

Season has been shown to affect the movement of rockfish as well as other groundfish (Moulton, 1977; Love *et al.*, 2002). It is believed that the fish migrate to avoid changes in water temperature, and to also avoid the large storm surge that affects shallower water. However, it is not well established how great the seasonal migration is in protected areas such as Skagit County, where the storm surge is not as great.

There have been very few studies done throughout an entire year, even though previous publications have mentioned that seasonal studies need to be completed (Jagielo *et al.*, 2003).

This study is significant, especially at the local level, where the sizes and locations of the proposed marine reserves might be reconsidered. If there is found to be a large effect of season, where species move to greater depths during parts of the year, additional areas might need to be considered, in order to protect the intended species. While a small seasonal study has been completed in the area, the study did not include the proposed marine reserves. Additionally, this study was completed before a large population shift occurred. Formerly, long-lived prey dominated, however now the more common species are short-lived predators (Moulton, 1977; Weispfenning, 2006).

Our hypotheses for this research are:

1. Groundfish densities will change throughout the year in the surveyed areas. Groundfish densities will be lowest in winter, when the large surge and colder temperatures of winter storms will drive fish out of the relatively shallow depths of the survey areas.

2. Groundfish will be found in higher densities at the deeper transects. This will confirm previous research locally (Weispfenning, 2006) and in California (Love *et al.*, 2002).

3. The effect of depth on the density of groundfish species will change with the seasons. The lowest densities in shallow water will be recorded during the winter, and the highest densities will be recorded during the summer.

4. Bottom composition, intra-annual (season), YOY habitat, bottom algal composition, and visibility will describe the majority of the variance seen in rockfish populations.

Methods

Seasonal Surveys

Twenty-four underwater visual strip transect surveys following the methods of Weispfenning (2006), adapted from Eisenhardt (2001), were used to determine changes in groundfish densities at six sites in Skagit County, Washington (Figure 1). A pair of divers completed an 800 m^2 survey at each site during each season starting in the fall of 2005 and ending in the summer of 2006. The six sites existed within five of the eight marine reserves proposed by the Skagit County Marine Resources Committee (McConnell *et al.*, 2001; McConnell and Dinnel 2002). The six sites surveyed were Burrows Channel (BC), northwest Allan Island (AI), Dennis Shoal (DS), South Cone Island (CI), east Strawberry Island (SI), and Towhead Island (TI) (Figure 2). Sites were chosen from within the proposed marine reserves on the basis of similar topography (boulder/wall with a moderate slope) and the known presence of bottomfish based on previous research by Weispfenning (2006).

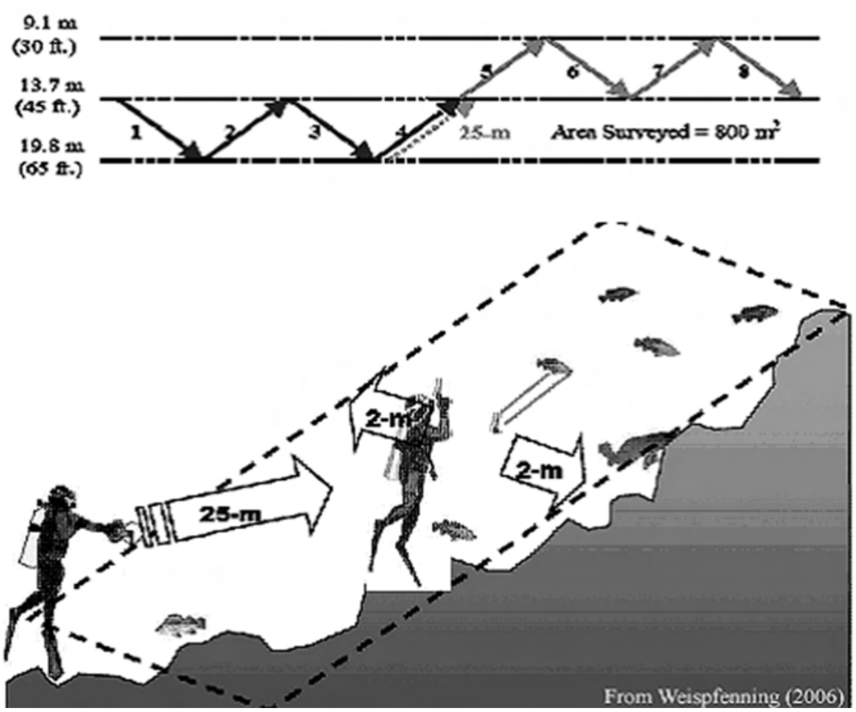

Figure 1. Diagrams of survey technique. Visual strip transects using open-circuit SCUBA were employed to determine groundfish densities along a 25 m wide, 4 m tall, 4 m wide transect. The transects were separated into four shallow (30-45 ft) and four deep (45-65 ft) transects. The first diver recorded groundfish counts as well as total length to 5 cm accuracy using a dual laser system. The second diver recorded bottom composition and coverage data.

The Burrows Channel site surveys started at 48°29.451'N and 122°41.872'W and progressed west along the south-facing slope of Fidalgo Island near Washington Park. This site exists within the proposed Burrows Channel marine reserve. It is heavily fished during the lingcod season from boats and shore, but is closed for salmon fishing from July 1 to September 30, during the peak season.

The northwest Allan Island site surveys started at 48°28.097'N and 122°42.552'W and progressed northwest along the underwater reef at the tip of the island. This site exists within the proposed Allan Island, Williamson Rocks and Dennis Shoal marine reserve. The area is fished during the lingcod season from May 1 to June 15 by anglers and spearfishers, but is closed to salmon fishing from July 1 to September 30, during the peak salmon fishing season. It is also close to a small seal haul-out on the west side of Allan Island (Banks, WWU, pers. comm.).

The Dennis Shoal site surveys started at 48°27.545'N and 122°48.880'W and progressed north along the west-facing slope of the underwater reef, eventually curving towards the east. Like the northwest Allan Island site, this site is also within the proposed Allan Island, Williamson Rocks and Dennis Shoal marine reserve. This site is fished during the lingcod season but is closed to salmon fishing. It is also near Williamson Rocks, which is part of the San Juan National Wildlife Refuge (Site #81), which is part of the San Juan Islands National Wildlife Refuge and is a large haul-out area for seals and stellar sea lions.

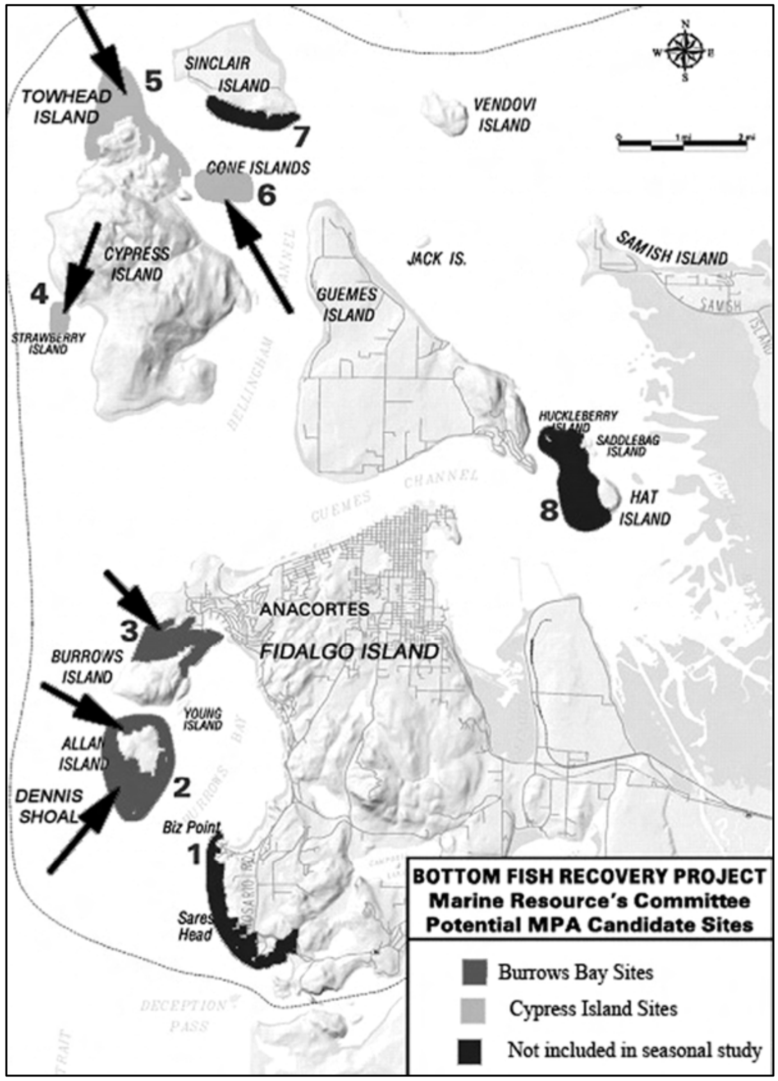

Figure 2. Sites sampled among the eight marine reserves proposed by Skagit Marine Resources Committee. Five of the eight proposed reserves were sampled, three near Cypress Island, and three near Fidalgo Island. Sites were selected for similarity of bottom composition and availability for diving. Map altered by author and original courtesy of the Skagit Marine Resources Committee.

The South Cone Island site surveys started at 48°35.437'N and 122°40.921'W, and progressed south along the west-facing depth contour of the underwater reef south of the island, eventually turning east and then north. This site is within the proposed Cone Islands reserve and also lies within the Washington Department of Natural Resources (DNR) Cypress Island State Aquatic Reserve. The designation as a DNR reserve give it no protection from fishing in subtidal areas. The site is fished during lingcod and salmon seasons.

The east Strawberry Island site surveys started at 48°33.684'N and 122°44.079'W and continued south along the east-facing slope of the island. This site is within the proposed Strawberry Island reserve and also lies within the DNR Cypress Island State Aquatic Reserve. This site is fished during lingcod and salmon seasons.

The Towhead Island site surveys started at 48°36.776'N and 122°42.916'W, and continued east, progressively turning south, along the north-east facing curve of the island. This site exists within the proposed North Cypress Island, Towhead Island, and Cypress Reef reserve. It also exists within the DNR Cypress Island State Aquatic Reserve. This site is heavily fished during lingcod and salmon seasons.

The surveys were completed seasonally at least 22 days after the change of season, and at least 16 days before the start of the next season. This gave at least 38 days between each set of surveys, in order to maximize the differences observed between each season. Fall surveys were conducted from October 24, 2005 to December 2, 2005. Winter surveys were conducted from January 12, 2006 to February 27, 2006. Spring surveys were conducted from May 2, 2006 to June 5, 2006. Summer surveys were conducted from July 18, 2006 to August 17, 2006.

Dive surveys were only performed when current was predicted to be less than 0.2 knots for 45 minutes or longer, as predicted by Tides and Currents Pro 3.0 (Nobeltec). Surveys were completed on high-slack tides, after 1200 Pacific Standard Time and 1300 during Pacific Daylight Savings Time. Surveys usually took between 25 and 35 minutes.

The surveys were 200 m long, 4.0 m wide, and 4.0 m in height (Figure 1). Each survey was divided into eight transects of 25 m. The first four transects completed were between 45 and 65 ft (13.7 and 19.8 m). These were identified as the 'deep' transects. The second four transects completed were between 30 and 45 ft (9.1 and 13.7 m). These were identified as the 'shallow' transects. In each 25 m transect, the first diver would count and measure groundfish, using a 20-cm wide dual-laser (Lasermate, Inc.) measuring device, to the nearest 5.0 cm.

The second diver followed the first diver and estimated bottom composition and biotic bottom coverage. Bottom composition was separated into four categories: Sand and Gravel (under 3 cm in diameter), Rock (3-30 cm), Boulder (30 cm-3 m), and Wall (greater than 3 m in diameter). Bottom coverage of all organisms (algae and fauna) was visually estimated as a percentage of the 4.0 m wide, 25 m long transect. All data were recorded using an underwater slate and pencil.

During the summer of 2006, short young-of-the-year (YOY) rockfish transects were used following the general strategy of Hayden-Spears (2005) in water 3-6 m deep. The first diver swam approximately 30 fin strokes disturbing shallow flat-bladed brown macroalgae while looking for YOY rockfish. The second diver estimated the percent coverage of different types of brown algae during the swim. These data were also recorded underwater on dive slates.

Additional data were also recorded during and after the dive: time in and out of the water, perceived currents by the divers, surface and at depth underwater visibility, weather conditions, swell size and timing, cloud cover, marine life observed near site, estimated wind speed, tidal heights, predicted currents, precipitation, and measured wind speed at a nearby site. These were recorded for future analysis as covariates that may have affected rockfish densities.

Analysis

Analysis of variance with repeated measures (ANOVAR) was completed using SPSS version 12.0 (SPSS, Inc.). Huynh-Feldt corrections were made for all p values, when departures from sphericity occurred. *A posteriori* contrasts were made controlling alpha at the family level using a Scheffé correction.

Results

The average density of all groundfish observed over all sites was 284.4 fish·ha^{-1}. Of this, 47.4 fish·ha^{-1} were lingcod (*Ophiodon elongates*), 83.3 fish·ha^{-1} were kelp greenling (*Hexagrammos decagrammus*), 46.9 fish·ha^{-1} were copper rockfish (*Sebastes caurinus*), 95.3 fish·ha^{-1} were Puget Sound rockfish. The remaining fish were a small number of cabezon, quillback rockfish, wolfeel and red Irish lords.

Seasonal Effects

The effects of season on groundfish species were different for different species. The most common rockfish in this study, the copper rockfish densities was significantly affected by season (Huynh-Feldt corrected ANOVAR, p=0.007). During fall the average density of copper rockfish was 52.1 fish·ha^{-1} (Figure 3). The density then decreased five-fold to 10.4 fish·ha^{-1} in winter. In spring, densities increased to 35.4 fish·ha^{-1}, and in summer the density increased to its highest density of 89.6 fish·ha^{-1}. Season did not interact with either of the two other factors (depth and location).

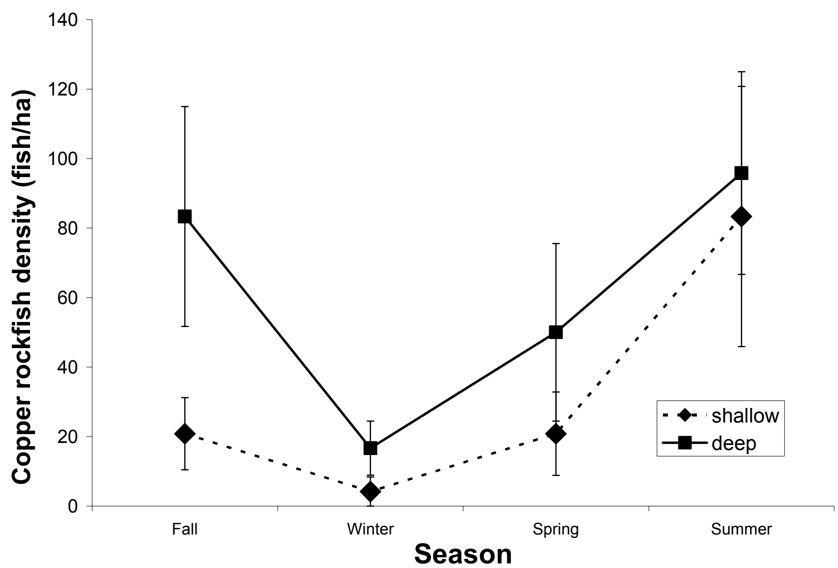

Figure 3. Densities of copper rockfish (*S. caurinus*) separated by season and depth. Both depth and season had a significant effect on copper rockfish density. Densities in deeper water (45-65 ft) averaged 90% higher than those in shallow water (30-45 ft). The greatest density of rockfish was during the summer, when densities reached 96 fish·ha^{-1}. Error bars represent ±1 standard error.

The most common groundfish observed in the study was kelp greenling. The effect of season on density was significant for kelp greenling as well (Huynh-Feldt corrected ANOVAR, p<0.001). Density of kelp greenling started at 122.9 fish·ha^{-1} in fall (Figure 4). Like copper rockfish, the density fell in winter, to 43.5 fish·ha^{-1}. The density then rose in spring to 58.3 fish·ha^{-1}. The density finished at 108.3 fish·ha^{-1} in summer. Season did not interact with either of the other two factors
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Lingcod had a similar trend during the year as kelp greenling. The effect of season was significant for lingcod as well (Huynh-Feldt corrected ANOVAR, p=0.021). Density of lingcod was highest in fall, at 70.8 fish·ha^{-1} (Figure 5), but then decreased in winter to 29.2 fish·ha^{-1}. It then increased to 35.4 fish·ha^{-1} in spring, and then increased further to 54.2 fish·ha^{-1} in summer. There was an interaction between season and depth (p=0.027); however, this was a result of large decreases in densities from fall to winter at northwest Allan Island and Dennis Shoal.

Depth effects

Of the three common groundfish, depth had only a consistent effect on copper rockfish (Figure 3). For this species, deeper sites consistently had higher densities (between-subject ANOVAR, p=0.035) through all seasons. Transects in deeper water had a 90% greater density of copper rockfish than shallower water (32.3 vs. 61.4 fish·ha^{-1}). For kelp greenling and lingcod, depth did not have a significant effect on density (Figure 4). There was no significant interaction for depth with location or season for all species. However, for both kelp greenling and lingcod, there were much higher densities in shallower water compared to deep water in spring (Figures 4 and 5).

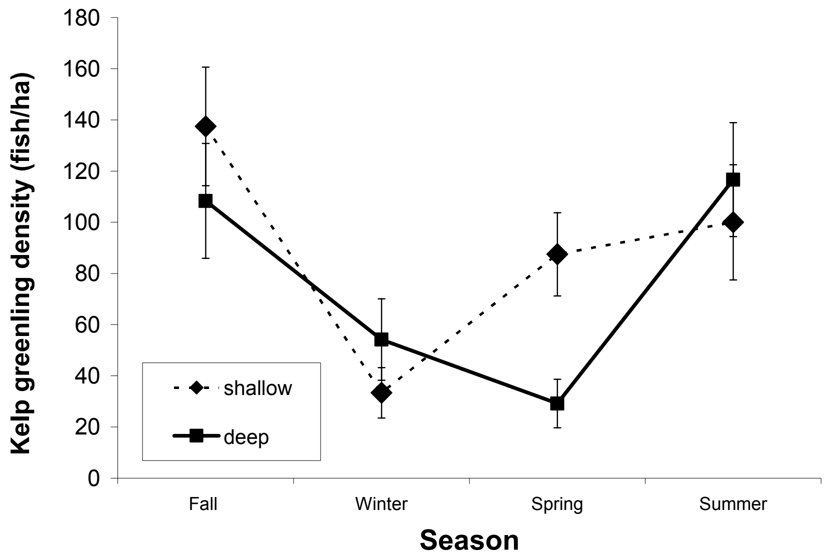

Figure 4. Density of kelp greenling (*H. decagrammus*) separated by season and depth. Season had a significant effect on kelp greenling density (p<0.001), but depth did not (p>0.05). While depth was not significant as a whole, an *A posteriori* pairwise contrast between the deep and shallow sites during spring showed a significant change in density (p=0.0033, Sheffé corrected alpha = 0.0125). Error bars represent ±1 standard error.

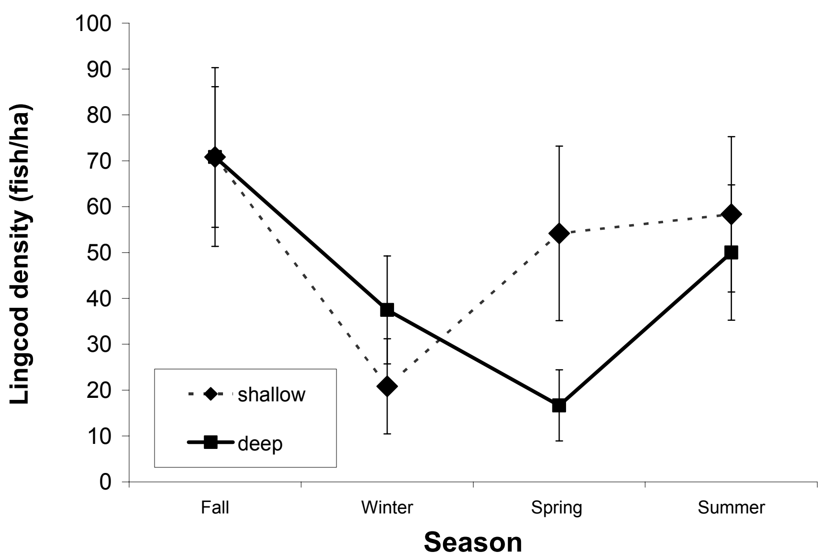

Figure 5. Density of lingcod (*O. elongates*) separated by season and depth. Season had a significant effect on kelp greenling density (p=0.021), but depth did not (p>0.05). An *a posteriori* pairwise contrast between the deep and shallow sites during spring showed non-significant change in density, however there is a strong trend, with the lack of power in this initial analysis (p=0.07441, Sheffé corrected alpha = 0.0125). Error bars represent ±1 standard error.

Location (site) effects

Location was only found to cause a significant difference in density for copper rockfish (Figure 6). The three sites near Burrows Bay and Fidalgo Island were found to have significantly lower densities than the three sites that surrounded Cypress Island (between-subject ANOVAR, p=0.004). Both kelp greenling and lingcod were not significantly affected by location effects (p=0.225 and p=0.058, respectively).

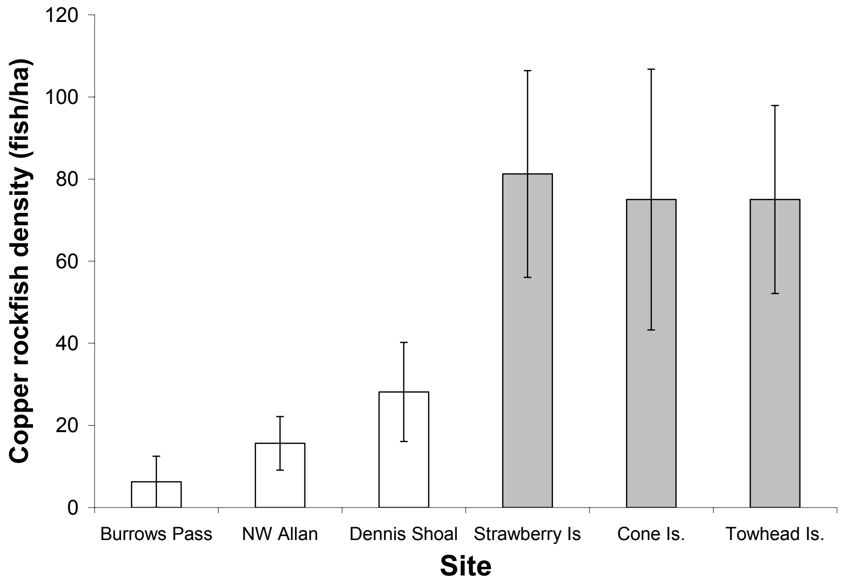

Figure 6. Density of copper rockfish (*S. caurinus*) at six sites in five of the proposed reserves. Sites with unshaded bars were those closest to Fidalgo Island, the location of high human populations. Sites with shaded bars are those closest to Cypress Island, which is further away from heavily inhabited areas. Site had a significant effect of copper rockfish densities (p=0.004), and an *A posteriori* contrast between sites near Fidalgo and Cypress Island showed significantly different densities (p=0.00025, Sheffé corrected alpha=0.0033). Error bars represent ±1 standard error.

Discussion

We observed seasonal migration of the three most common species of groundfish in the proposed marine reserves of Skagit County. Our initial analysis shows that season had a significant effect on densities of kelp greenling, lingcod and copper rockfish (Figures 3, 4 and 5, respectively). This has strong implications for marine reserve design in Skagit County, and throughout Puget Sound. The movement of groundfish during seasons, especially the movement of rockfish to water deeper than the transects we used (Figure 3), shows that reserves should be designed to include large amounts of deep water habitat, which the rockfish are likely to inhabit during the winter and spring months. Most of the proposed reserves in Skagit County are associated with an island (Figure 2), which improves ease of enforcement and avoidance by fishers: however, this tends to include shallower water than a reserve which may be placed in a channel, or include an entire deep water environment.

While seasonal migration has been seen in other rockfish species, especially into deeper water during the summer (Love *et al.*, 2002), this is one of the few studies to show this seasonal migration of copper rockfish in protected waters like Puget Sound.

Copper rockfish were found in greater densities in deeper transects, confirming observations in Skagit County by Moulton (1977) and in nearby San Juan Island County by Eisenhart (2001).

Changes in density with changes in depth were not significant for kelp greenling and lingcod throughout the year (Figures 4 and 5), with the exception of spring. In the spring, densities of kelp greenling and lingcod in shallow water became much higher than those in deep water. For kelp greenling, densities in shallow water were 200% higher, and densities were 225% higher for lingcod in the shallow water transects. While a cause for this movement into shallow waters was not investigated in this study, it may be that these two predators are following newly available food sources into shallow waters, as the prey ascends into the photic zone. Included in these prey are newly hatched larvae from rockfish, as well as lingcod and kelp greenling (Love *et al.*, 2002). Additionally, kelp greenling and lingcod also nest in shallower water during the late winter and early spring, however, the vast majority of these nests would be hatched and abandoned before the spring surveys (Wright *et al.*, 2000; King and Beaith, 2001; King and Withler, 2005).

While changes in densities with changes in season and depth were expected, a large effect of site was not anticipated. The six sites had relatively similar bottom composition (unpublished data): however, there was a large difference in densities between the sites (Figure 6). This difference separates based on the site's region, with sites near Fidalgo Island having far less density of copper rockfish than those sites near Cypress Island (Figure 2 and 6). There are several possible explanations for this large difference. Cypress Island is closer to a better supply of available larvae, with the San Juan Islands to the west and Strait of Georgia to the north. The San Juan Islands have over a dozen established marine reserves, which have shown increased fish densities, as well as increased larval production from the reserves (Eisenhart, 2001; Weis, 2004). Additionally, the San Juan Islands are believed to offer better habitat for rockfish (Palsson, WDFW, pers. comm.). However, the distance from Cypress to the San Juans is not much less than the distance from the Fidalgo Island sites to the San Juans.

Another possible explanation for this difference in rockfish density may be the proximity of the sites to local marinas used by recreational fishers for the lingcod and salmon fisheries. The three sites near Fidalgo Island are all less than four miles from a large marina, and the passage to these sites is in waters protected from high wave action and heavy winds, and is easy to access for anglers. These anglers often have rockfish as part of the bycatch from the recreational fisheries. The Cypress Island sites, by comparison, are much further, through less protected waters.

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References

Berkeley SA, Chapman C, Sogard SM. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology. 2004; 85(5): 1258-1264.

Eisenhardt EP. Effects of the San Juan Islands marine preserves on demographic patterns of nearshore rocky reef fish. M.S. Thesis, University of Washington. Seattle, Washington, 2001.

Eschmeyer WN, Herald ES, Hamann H. A Field Guide to Pacific Coast Fishes of North America. Peterson Field Guide Series. Houghton Mifflin Co., Boston, MA, 1983.

Hayden-Spears J. Minutes of the San Juan Marine Resources Committee, November 16, 2005.

Jagielo TJ, Wallace FR, Cheng YW. Assessment of lingcod (*Ophiodon elongatus*) for the Pacific Fishery Management Council in 2003. Washington Department of Fish and Wildlife, Olympia, WA, 2003.

King JR, Beaith BW. Lingcod (*Ophiodon elongates*) nest density SCUBA survey in the Strait of Georgia, January 16-April 26, 2001. Can Tech Rep Fish Aquat Sci. 2001; 2374; 21pp.

King JR, Withler RE. Male nest fidelity and female serial polyandry in lingcod (*Ophiodon elongates*, Hexagrammidae). Molec Ecol. 2005; 14: 653-660.

Love MS, Yoklavich M, Thorsteinson L. The rockfishes of the northeast Pacific. University of California Press, Berkeley, California, 2002.

Mason JE. Declining rockfish lengths in the Monterey Bay, California, recreational fishery, 1959-94. Mar Fish Rev. 1998; 60: 15-28.

McConnell ML, Dinnel PA, Dolph J, Robinette J, Semrau D. Rocky reef bottomfish recovery in Skagit County: Phase I Final Report: Marine Protected Areas – Preliminary Assessment and public input. Skagit County Marine Resources Committee, Mount Vernon, WA, 2001.

McConnell ML, Dinnel PA. Rocky reef bottomfish recovery in Skagit County: Phase II Final Report: Assessment of eight potential marine reserves sites and final site recommendations. Skagit County Marine Resources Committee, Mount Vernon, WA, 2002.

Mora C, Andrefouet S, Costello MJ, Kranenburg C, Rollo A, Veron J, Gaston KJ, Myers RA. How protected are coral reefs? Letters to Sci. 2006; 314: 758-760.

Moulton LL. An ecological analysis of fishes inhabiting the rocky nearshore regions of northern Puget Sound, Washington. Ph.D. Dissertation, University of Washington, Seattle, Washington, 1977.

Paddack MJ, Estes JA. Kelp forest fish populations in marine reserves and adjacent exploited areas of central California. Ecolog Applic. 2000; 10: 855-870.

Palsson WA. Monitoring the response of rockfishes to protected areas. Pp. 64-73 in Marine harvest refugia for west coast rockfish: A workshop, ed. M. Yoklavich. NOAA Tech. Mem. NMFS-SWFSC 255, 1998.

Palsson WA, Northrup TJ, Barker MW. Puget Sound groundfish management plan (revised). State of Washington Department of Fish and Wildlife, Marine Resources Division, Olympia, WA, 1998.

Palsson WA. The development of criteria for establishing and monitoring no-take refuges for rockfishes and other rocky habitat fishes in Puget Sound. In: Puget Sound Research. Puget Sound Water Quality Authority, Olympia, WA, 2001.

Parrish R. Marine reserves for fisheries management: why not. CalCOFl Rep. 1999; 40: 77-86.

Roberts CM, Bohnsack JA, Gell F, Hawkins JP, Goodridge R. Effects of marine reserves on adjacent fisheries. Science. 2001; 30: 1920-1923.

Russ GR, Alcala AC. Marine reserves: long-term protection is required for full recovery of predatory fish populations. Oecoloia. 2004; 138: 622-627.

Skagit County Marine Resources Committee. www.skagitcounty.net/Common/Asp/ Default.asp?d=PublicWorksMRC&c=General&p=smrcmain.htm. Accessed: April 6, 2005.

Spalding M, Kelleher G, Boucher T, Fish L. How protected are Coral Reefs? Letters to Sci. 2006; 314: 758.

Tuya FC, Soboil ML, Kido J. An assessment of the effectiveness of marine protected areas in the San Juan Islands, Washington, USA. ICES Journal of Marine Science. 2000; 57: 1218-1226.

Weis LJ. The effects of San Juan County, Washington, marine protected areas on larval rockfish production. M.S. Thesis, University of Washington. Seattle, Washington, 2004.

Weispfenning AJ. Survey of nearshore demersal fishes within candidate marine reserves in Skagit County, Washington. M.S. Thesis, Western Washington University, Bellingham, Washington, 2006.

Worm B, Barbier EB, Beaumont N, Duffy JE, Folke C, Halpern BS, Jackson JBC, Lotze HK, Micheli F, Palumbi SR, Sala E, Selkoe KA, Stachowicz JJ, Watson R. Impacts of biodiversity loss on ocean ecosystem services. Science. 2006; 314: 787-790.

Wright N, Kum J, King C, Knaggs E, Leos B, Perez C. Kelp greenling, *Hexagrammos decagrammus,* rock greenling *Hexagrammos lagocephalus,* whitespotted greenling, *Hexagrammos sterelli* 1993-1999 commercial catch by ports and blocks. Marine Fisheries Profiles: Volume 1: Nearshore. California Department of Fish and Game, 2001.

Yoklavich MM. Marine harvest refugia for west coast rockfish: a workshop. NOAA Technical Memorandum NMFS, Pacific Fisheries Environmental Laboratory, Pacific Grove, CA, 1998: 64-73.