THE RESPONSE OF ROCKY REEF FISHES TO HARVEST REFUGIA IN PUGET SOUND

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INTRODUCTION

In Puget Sound, a variety of demersal fish resources have been in depressed or declining states in recent years (Schmitt et al., 1994). The causes of the reduction in resources are not clear, but overfishing and habitat degradation are likely contributors. The use of marine harvest refugia or preserves where catch restrictions and habitat protection measures are fully or partially in place has become a popular idea to stabilize or increase fishery resources (Bohnsack, 1993; Roberts and Polunin, 1991; Carr and Reed, 1993). A variety of studies have shown that fish densities and sizes increase after the establishment of harvest refugia or are greater in comparison to the other harvested areas (as reviewed by Roberts and Polunin, 1991; Dugan and Davis, 1993). None of these studies has examined species living on temperate rocky reefs in the North Pacific Ocean.

The application of a refuge system has been discussed and partially implemented for several areas in Puget Sound, but studies have not been conducted to evaluate their efficacy. In 1990, five refugia were established in the San Juan Islands to protect marine fishes (except salmon) and invertebrates from recreational and commercial harvest. The oldest refuge is the Edmonds Underwater Park, which was established in 1970. All resource harvesting is forbidden at this park. The park includes a dry dock, which was sunk in 1935 (A. Olde, City of Edmonds, personal communication, 1993).

The Edmonds Park and one of the harvest refugia in the San Juans were included in a comparative study of lingcod (*Ophiodon elongatus*) and rockfish (*Sebastes*) density, size, and reproductive output among natural and artificial reefs in Puget Sound. Specifically, these variables were compared between harvested and refuge sites established at different times.

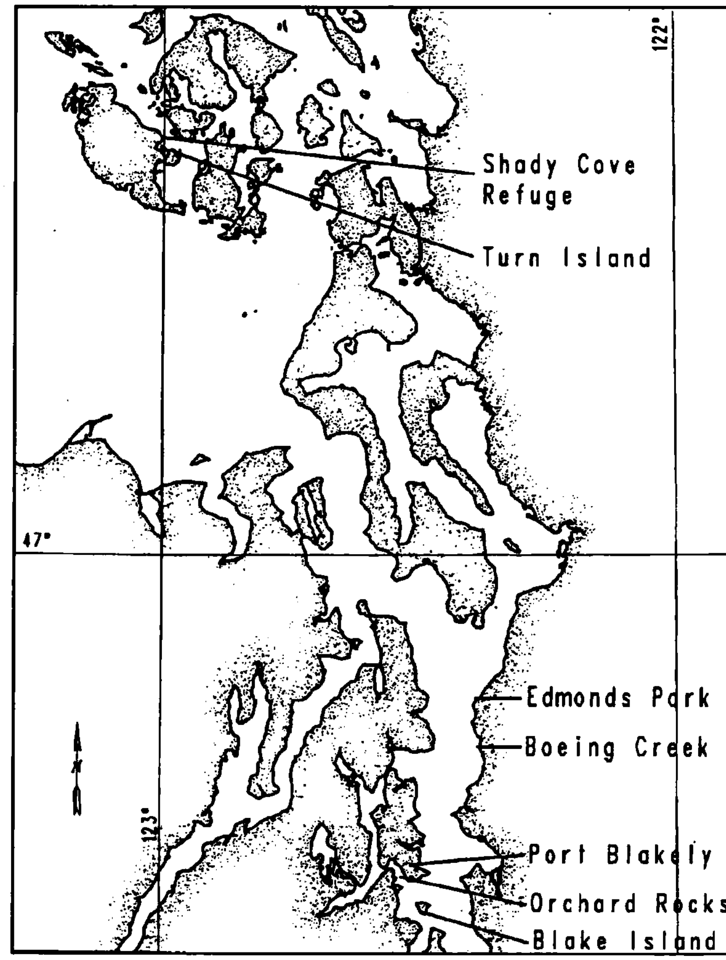

Figure 1. Northern and central Puget Sound study sites

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METHODS

Seven study sites including natural and artificial rocky reefs were surveyed for rockfish and lingcod abundance (Figure 1). Five sites were located in central Puget Sound. Four of these sites are open to fishing and were used by Matthews (1989), who evaluated the relative use of rocky reef habitats by rockfishes. These sites included the natural reefs at Orchard Rocks (OR) and Port Orchard (PB) and the artificial reefs at Boeing Creek (BC) and Blake Island (BI). The fifth site was the sunken dry dock at the Edmonds Underwater Park (EUP). In northern Puget Sound, two natural reefs were investigated. The east face of Turn Island is a fished reef composed of rocks and boulders. The refuge site at Shady Cove (SC) is located 2.7 km to the northwest and is just south of Point Caution along the east side of San Juan Island. The habitat at SC is composed of boulders and rocks.

Two scuba methods were used to obtain density estimates of reef fishes. A strip transect was used to estimate rockfish and lingcod densities at all seven study sites. A line transect method was used to estimate the density of lingcod and their nests at the two study sites in northern Puget Sound.

The strip transect method was similar to that used by Matthews (1989), who placed three fixed transect lines at each study site at approximately the 14 m depth contour (mean low, low water). Each transect line was 30 m long. Two divers swam on either side of the line and enumerated all rockfishes and lingcod within 1.5 m of either side of the line. Special care was taken to look into crevices with a light so sequestered fish could be counted. The divers coordinated their observations to prevent counting the same fish twice. All visible fish were included above the transect path, in contrast to Matthews, who only counted fish within 1 m of the bottom. Strip transects were conducted in two series at the central Puget Sound sites. All central Puget Sound sites were visited within a one-week period during September 1993 and then again during October 1994. In northern Puget Sound, the two sites were each surveyed 16 times during the spring seasons of 1993 and 1994. The surveys were paired so the sites were surveyed within several days of each other.

Line transects were conducted at the two sites in northern Puget Sound to estimate the density of lingcod and their nests. The method was adapted from LaRiviere (1981) and featured a permanent transect line 100 m in length set along the 14 m depth contour (mllw) at each site. One diver swam from the beginning of the line and stopped at 10-meter intervals. The other diver swam from the beginning of the line down and obliquely to a depth of 18 m (mllw). The diver then returned to meet the partner at the 10 m mark. This zig-zag process was repeated for each of the ten 10-meter intervals. During these transects all lingcod and any nests were enumerated and their approximate positions and depths recorded. At the end of the deep leg, the divers ascended to a depth of 5 m (mllw) and swam a straight 100 m path parallel and inshore of the deep leg. A total of 250 m was swum during the inshore and offshore legs. Lingcod and nest densities were estimated by the formula:

$$D=\frac{k}{ZL} \qquad 1)$$

where D is the density, k is the number of observed lingcod or nests, Z is half the measured visibility at 14 m depth, and L is the transect length. Each site was visited a total of 19 times, and SC and TI observations were paired within several days of each other during the winters, springs and summers of 1992, 1993, and 1994.

During any transect by either method, the divers estimated the size of each individual fish they observed. Sizes were estimated to the nearest 10 cm category, and size determinations were aided by a hand-held graduated staff.

The strip transect observations were used to estimate biomass and egg production per transect. The biomass of each observed copper and quillback rockfish and lingcod was estimated using length-weight regressions developed by Wildermuth (1983). These observations were then summed for each transect. Egg production per transect was estimated for copper rockfish (*S. caurinus*) and lingcod. The fecundity of each observed individual was estimated using length-fecundity relationships determined by DeLacy et al. (1964) for copper rockfish and by Hart (1967) for lingcod. The eggs produced for each transect were calculated by summing the fecundity for each observed fish and dividing by half to compensate for an assumed equal ratio of males and females.

Strip transect data did not fit a normal distribution and were subsequently transformed with the square root transformation (Count'= (Count + 0.5)$^{1/2}$) for statistical analysis. Analysis of variance (ANOVA) techniques (Zar, 1984) were applied to strip transect data in order to test for density, size, biomass, and fecundity differences among sites and years. When differences were detected, the Tukey multiple range test was used to determine which treatments were different. Line transect data were compared using the Paired Differences T-test (PDTT) (Zar, 1984). For all statistical tests, null hypotheses were rejected at the 0.05 level of significance.

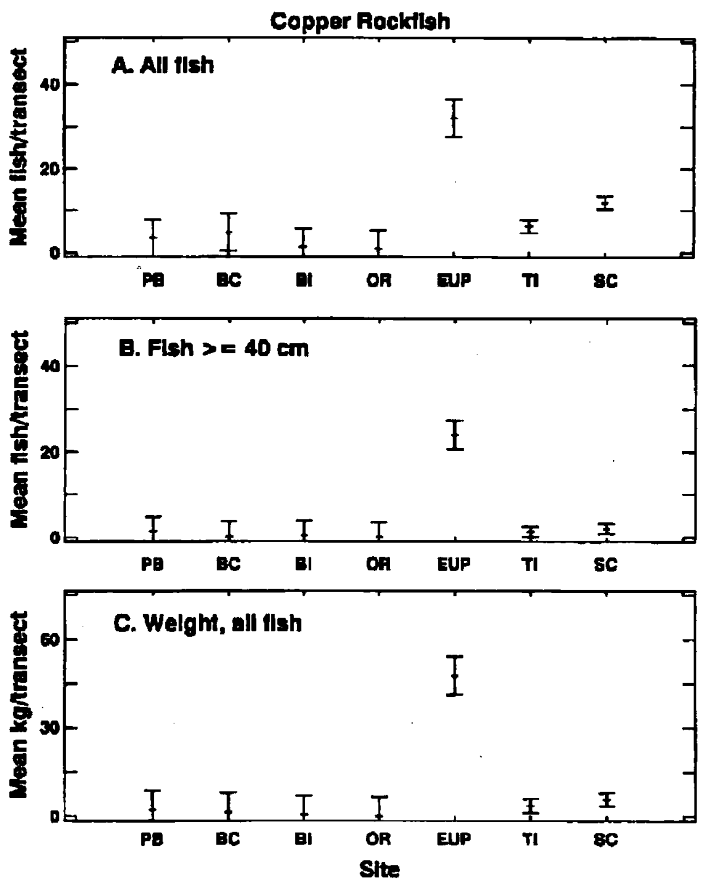

Figure 2. Mean fish densities (and 95% confidence limits) of copper rockfish at seven Puget Sound sites. A. All individuals, B. Individuals at least 40 cm in length, C. Biomass of all individuals.

RESULTS

Eighty dives were conducted to obtain density, size, and reproductive data at the central and northern Puget Sound sites. Thirty-eight dives were made to assess lingcod density in northern Puget Sound; 32 dives resulted in 96 strip transects in northern Puget Sound; and 10 dives resulted in 30 strip transects in central Puget Sound.

Strip Transects

Strip transect surveys provided data that revealed numbers, weights, and sizes of copper and quillback rockfishes and lingcod differed among the five sites in central Puget Sound (square-root transformed values, ANOVA). Multiple range comparisons revealed that the refuge at EUP had more or larger fishes than the four fished sites. There were more copper rockfish at EUP (mean 32.0 fish/90 m^2 transect) than at any of the four fished sites (mean 1.3-3.5/transect) (Figure 2). Copper rockfish measuring 40 cm or more were more common at EUP (mean 24 fish/transect) than at the four fished reefs (mean 0-1.5 fish/transect), and there was greater biomass of all copper rockfish at EUP (mean 47.7 kg/transect) than at the fished sites. For these three variables, the means estimated from the four fished sites were indistinguishable from each other.

In contrast to copper rockfish, quillback rockfish counts at BC (mean 46.5 fish/transect) differed from and were twice the mean count of the quillback rockfish at EUP (Figure 3). Mean counts from these two sites differed from the remaining three sites, which were indistinguishable from each other (mean 0-2.0 fish/transect). The EUP refuge had many more quillback rockfish measuring at least 40 cm (mean 9.5 fish/transect) than any of the fished sites (mean 0-0.5 fish/transect), and the biomass at EUP (15.7 kg/transect) was twice the biomass of quillback rockfish of BC.

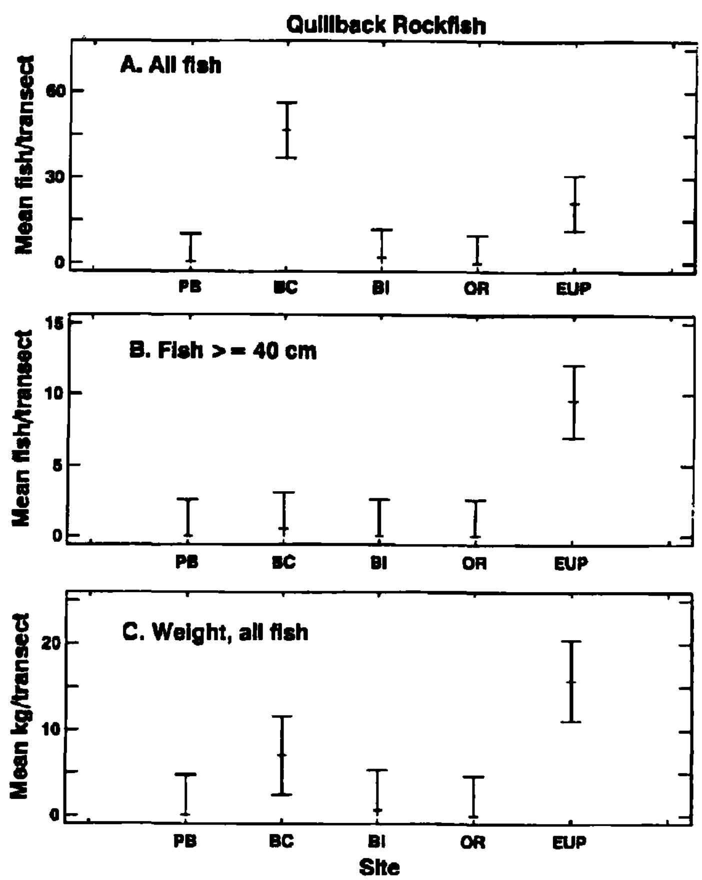

Figure 3. Mean fish densities (and 95% confidence limits) of quillback rockfish at seven Puget Sound sites A. All individuals, B. Individuals at least 40 cm in length, C. Biomass of all individuals.

Multiple range comparisons found that lingcod abundance was greatest at EUP (mean 3.3 fish/transect) but was indistinguishable from BC (mean 1.5 fish/transect) (Figure 4). Lingcod counts at BC were not different from those at PB, BI, and OR (mean 0.5-1.5 fish/transect). All the lingcod at EUP were at least 70 cm in length, while the other sites had either no large lingcod or very few (mean 0-0.3 fish/transect). Multiple range comparisons also revealed that lingcod were more massive at EUP (mean 38.2 kg/transect) than any other site, all of which were indistinguishable from each other (mean 1-2.8 kg/transect).

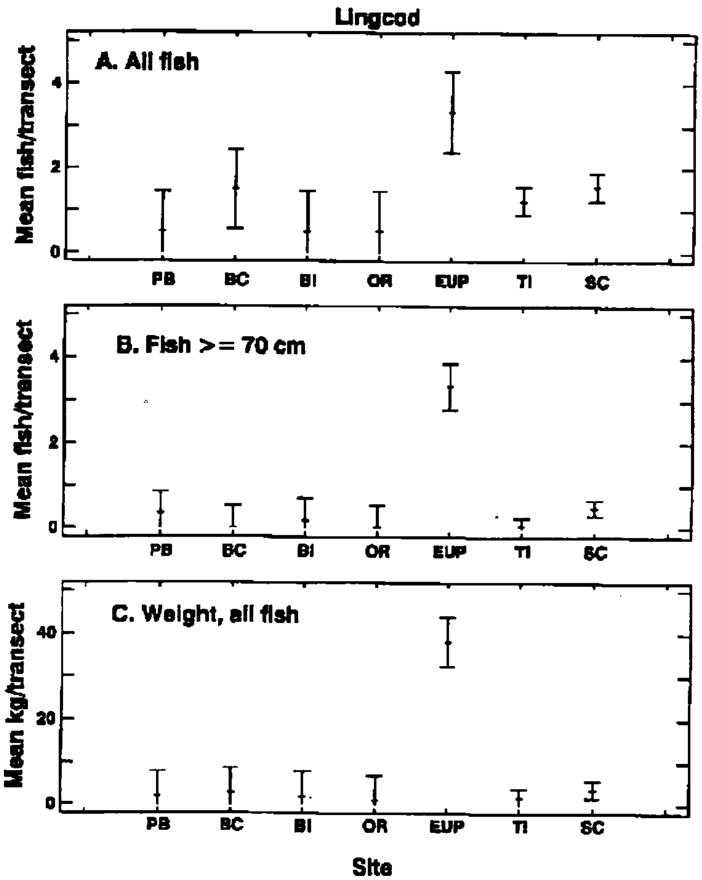

Figure 4. Mean fish densities (and 95% confidence limits) of lingcod at seven Puget Sound sites. A. All individuals, B. Individuals at least 70 cm in length, C. Biomass of all individuals.

The differences in mean counts, counts of large fish, or biomass per transect were not as great between the refuge and fished sites in northern Puget Sound as in central Puget Sound. SC only had twice the density of copper rockfish (mean 11.9 fish/transect vs. 6.3 fish/transect) than TI (square-root transformed values, ANOVA) (Figure 2). Analysis of variance of transformed data also found that SC had about twice the biomass of copper rockfish (mean 5.8 kg/transect) than TI (mean 3.7 kg/transect). The refuge had more copper rockfish greater than 40 cm (mean 1.9 fish/transect) than at TI (mean 1.3 fish/transect) (square-root transformed values, ANOVA). Quillback rockfish were not in sufficient abundance for statistical analysis at these two sites.

Lingcod were equally common at either of the two northern Puget Sound Sites (square-root transformed values, ANOVA) (Figure 4), but lingcod greater than 70 cm were more common at the refuge (mean 0.5 fish/transect) than at the fished site (mean 0.04 fish/transect) (square-root transformed values, ANOVA). Lingcod biomass differed by a factor of 2 (square-root transformed values, ANOVA) with the SC refuge having a mean of 3.6 kg/transect versus the TI fished site with 1.6 kg/transect.

Size differences

On average, the two refugia always had larger sizes of fishes that were either not observed in the five fished areas or were extremely rare (Figure 5). Copper rockfish measuring 50 cm were the most frequent fish observed in the refugia. In contrast, 30 cm individuals were the most common and largest size fish at the fished sites. Copper rockfish averaged 27.0 cm in length in the fished areas (n=364) and averaged 34.6 cm in the refugia (n=763). An average quillback rockfish measured 21.0 cm (n=294) in the fished areas, where 20 cm individuals were the most frequently observed size. Individuals measuring 40 cm or greater were the most common quillback rockfish observed in the refugia, while 40 cm fish were extremely infrequent elsewhere. In the refugia, quillback rockfish averaged 29.8 cm in length (n=127). The refugia most commonly contained lingcod that measured 100 cm or more, whereas the fished areas never had a lingcod exceeding 90 cm. Lingcod averaged 59.4 cm in the fished areas (n=77) and 77.7 cm in the refugia (n=95).

Line Transects for Lingcod

Lingcod densities based on line transect surveys were greater at the SC refuge (mean 160.0 fish/ha) than at the fished site at TI (90.9 fish/ha) (PDTT) (Table 1). While mean density of all fish differed by less than a factor of two, the mean density of fish measuring at least 70 cm at SC exceeded TI by a factor of three (PDTT).

Table 1. Mean densities (no./ha) and C.V.s obtained from line transects for lingcod in northern Puget Sound

Site	All Fish	Fish >=70cm	Nest
Turn Island (fished)			
mean	90.9	18.5	10.1
C.V.	11.2%	14.8%	32.5%
Shady Cove (refuge)			
mean	160.0	57.1	27.8
C.V.	6.4%	12.6%	17.0%

Reproductive Output

Calculated egg production for copper rockfish and lingcod was always greater in the refugia than at the fished sites (Figure 6) (square-root transformed values, ANOVA). Multiple range comparisons for central Puget Sound sites found that copper rockfish egg production did not differ among fished sites (mean 5,000 to 66,000 eggs/transect) but did differ from the EUP refuge (mean 7,600,000 eggs/transect). Lingcod egg production did not differ among the fished sites (mean 13,000-25,000 eggs/transect), but lingcod egg production at the refuge (mean 1,900,000/transect) was greater than at any fished site.

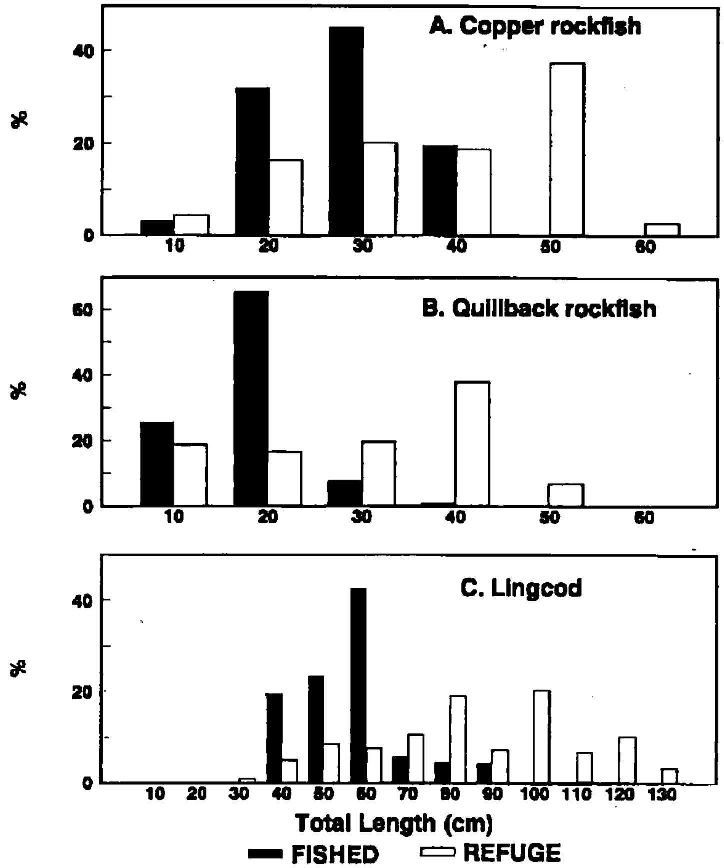

Figure 5. Mean length frequencies of copper and quillback rockfish and lingcod at fished and refuge study sites. A. Copper rockfish, B. Quillback rockfish, C. Lingcod.

Copper rockfish and lingcod egg production was much less in the northern Puget Sound refuge than in central Puget Sound but did differ by a factor of 2 between the SC refuge and the fished area at TI (Figure 6) (PDTT). The line transects for lingcod also revealed a difference in reproduction (Table 1): The SC nest density (27.8 nests/ha) was more than double the nest density at TI (10.1 nests/ha) (PDTT).

DISCUSSION

The site protected from harvest for 24 years showed dramatic differences in the abundance of large copper and quillback rockfish and lingcod compared to harvested areas in central Puget Sound. Copper rockfish density was six times greater in the Edmonds refuge than at the average fished site, and lingcod density in the refuge was twice as great as any fished site. Such responses of abundance and size to protection from harvest are within the same ranges as observed at other marine refugia around the world. Dugan and Davis (1993) found that refuge abundances of fishes and shellfishes were often two to 25 times greater than in surrounding harvested areas. The larger size categories of rockfish and lingcod observed at EUP were completely absent at the fished sites. Other studies of refugia have shown size increases in the absence of fishing. As early as two and one-half to four years after establishing refugia in Australia, groupers were 13 cm larger (Beinssen, 1989; Ayling and Ayling, 1986). Other size-related increases have been observed in parrotfishes, butterflyfishes, and porgies (Roberts and Polunin, 1991), and Dugan and Davis (1993) found fishes were 12 percent to 200 percent larger in refugia than in harvested areas.

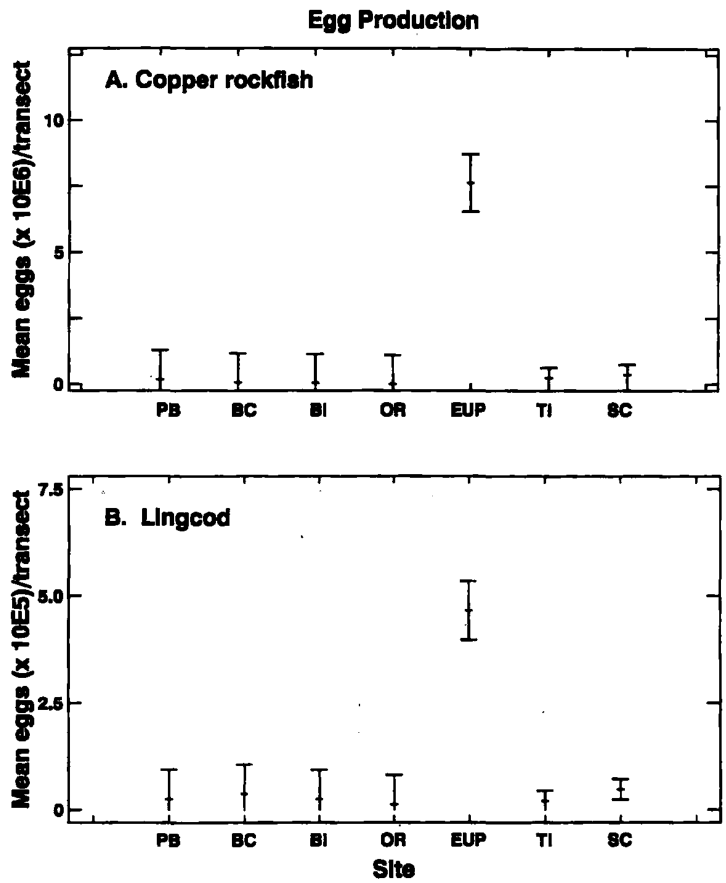

Figure 6. Mean egg production (and 95% confidence limits of copper rockfish and lingcod at seven Puget Sound study sites. A. Copper rockfish, B. Lingcod

The age of the refuge may be a factor explaining why the abundance and size differences were not as great in northern Puget Sound as in central Puget Sound. Copper rockfish densities differed only by a factor of two between SC and TI, compared to the six-fold difference between EUP and the other fished sites. The northern refuge was only four years old, compared to 24 years for EUP. Since rockfish grow slowly, mature late in life, and have low natural mortality rates (Leaman, 1991), the older refuge may have allowed abundance and size composition to recover to unfished conditions. In contrast to fishes in tropical and other temperate refugia (reviewed in Roberts and Polunin, 1991; Dugan and Davis, 1993), the slower growth of northern temperate fishes would necessitate long-term strategies for implementing harvest refugia.

Quillback rockfish densities at EUP were intermediate compared to the fished sites in central Puget Sound. Not all species always increase in abundance after protection. In at least three studies of refugia, the abundances of some species did not differ after refugia were initiated or in comparison to similar fished areas (Buxton and Smale, 1989; Coyle et al., 1990; Bennett and Attwood, 1991). The lack of differences in these studies could be attributed to movement of species in and out of the refuge, age of the refuge, inadequate sampling, or differences in habitat. Similar factors could have affected quillback rockfish abundance; however, sampling was sufficient to detect differences among other species. Movements of this species is an unlikely cause since it has small home ranges and is sedentary (Mathews and Barker, 1983; Matthews, 1990). The higher densities at BC may be attributed to habitat differences favoring small fish or by the harvest of large quillback rockfish.

The observations made on the density, size, and reproductive variables in Puget Sound are influenced by the biases of the visual census technique (Brock, 1982). The rocky nature of north temperate reefs almost assures that fish, especially small ones sequestered in crevices, were underestimated. The densities estimated by this study should be considered minimum estimates of abundance, but the comparative inferences should remain valid if the biases are constant among the different study sites.

The four fished sites in central Puget Sound were those studied by Matthews (1989) but copper and quillback rockfish densities estimated in 1993-94 were two to 25 times lower than those for comparable months in 1986. Reasons for these differences could include differences among observers, change of transect positions, or actual declines in abundance. For most transects, we were certain of the line position because the original lines or buoys were still in place. Matthews (1989) was the only person counting a 3-meter-wide strip, whereas we used two observers to count the transect path. Higher fish counts would be expected by our increased observing effort. The difference in fish densities between studies is likely due to a decline in rockfish abundance over time.

The inference that refugia are more productive than fished sites is limited by the lack of replicate refugia, especially of long-established ones. Although the striking contrasts between the refuge at Edmonds strongly suggest fishing causes drastic changes in the size and density distributions of rockfish and lingcod populations, an alternative hypothesis is that the Edmonds refuge is simply more productive than other sites. The potential utility of refugia is, however, substantiated because differences were observed at the second refuge at Shady Cove. Tracking the progress of the northern Puget Sound refuge over time is warranted as well as a comprehensive program to monitor the effects of any refuge system.

The two refugia had much greater reproductive output than any of the fished sites. Copper rockfish in the northern refuge produced twice the eggs per unit area as the fished site, and two measures of reproductive output showed lingcod in the northern refuge outproduced those in the fished site by a factor of two. In central Puget Sound, the copper rockfish living at a fished site produced only 1 percent of the eggs per unit area as copper rockfish in the refuge. Lingcod living on the fished reefs of central Sound produced only 20 percent of the eggs produced by lingcod living in the refuge. If the population structure of the long-established refuge can be taken as an unfished (virgin) population, then the poor reproduction at the fished sites falls significantly below the "F35" guideline proposed by Clark (1991) and used to manage many groundfish fisheries on the West Coast of North America. Based on the differences in reproductive output, lingcod and copper rockfish populations in central Puget Sound may be stressed.

Few studies on the reproductive effects of no-harvest areas have been conducted. Only five of 31 studies reviewed by Dugan and Davis (1993) addressed the effects of refugia on reproduction, and these studies demonstrated only the effects on invertebrates. Goeden (1978, as cited in Roberts and Polunin, 1991) calculated egg production based on observations of density, size, and fecundity on a seabass and found that this species produced 80% more eggs per unit area in an Australian refuge than from nearby fished reefs. This result was similar to ours but is complicated by sex change with length for this species. Goeden (1978) also noted that the actual egg production in the refuge could be less than calculated because increased densities of large fish could result in competition for food or space thus reducing fecundity or frequency of spawning. Such effects may be possible in Puget Sound refugia, and closer investigation is required to demonstrate the egg production effect. Whether the egg production increases recruitment from Puget Sound refugia is unknown, but Doty et al. (in press, this volume) found the only significant area where young-of-the-year rockfish settled was on the east side of central Puget Sound. The Edmonds

Underwater Park was located in the center of distribution of the settlement, suggesting that EUP is a source of juvenile rockfish within and outside the refuge.

Carr and Reed (1993) discuss the goals and theoretical problems of designing and siting refugia which any policy on implementing harvest refugia should consider. Bohnsack (1993) suggests setting aside from 10 percent to 20 percent of marine habitat as harvest refugia. Although these studies do not provide definitive answers on refuge design, several nations have established pragmatic goals for integrating harvest refugia into fishery management. Australia and New Zealand have already established policies to set aside 10 percent of their coasts as harvest refugia (Dugan and Davis, 1993; Sobel, 1993).

Marine harvest refugia may enhance the production of recreationally or commercially important species. These benefits include increased abundance, increased age and size, increased reproductive output, enhancement of recruitment inside and outside the refugia, maintenance of genetic diversity, and enhanced fishery yields in adjacent fishing grounds (Dugan and Davis, 1993). Some of these benefits have now been documented for rocky reef fishes living in the existing harvest refugia of Puget Sound, but the driving factor for establishing other refugia should be increased fishery production, a factor that has not been documented for Puget Sound. Fishing in areas adjacent to refugia can increase catch rates (Alcala, 1988; Alcala and Russ, 1990), and Puget Sound anglers may similarly benefit from a system of harvest refugia.

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REFERENCES

Alcala, A.C. 1988. Effects of Marine Reserves on Coral Fish Abundances and Yields of Philippine Coral Reefs. *Ambio* 17:194-199.

Alcala, A.C. and G.R. Russ. 1990. A Direct Test of the Effects of Protective Management on Abundance and Yield of Tropical Marine Resources. *Journal Cons. Int. Explor. Mer.* 16:40-47.

Ayling, A.M. and A.L. Ayling. 1986. A Biological Survey of Selected Reefs in the Capricorn Section of the Great Barrier Reef Marine Park. Unpubl. rep. to Great Barrier Reef Marine Park Authority, Townsville. 61 pp.

Beinssen, K. 1989. Results of the Boult Reef Replenishment Area Study. Unpublished report by Department of Conservation, Parks and Wildlife, Queensland National Parks and Wildlife Service, Brisbane. 40 pp.

Bennett, B.A. and C.G. Attwood. 1991. Evidence for Recovery of a Surf-zone Fish Assemblage Following the Establishment of a Marine Reserve on the Southern Coast of South Africa. *Marine Ecology Progress Series* 75:173-181.

Bohnsack, J.A. 1993. Marine Reserves, They Enhance Fisheries, Reduce Conflicts, and Protect Resources. *Oceanus*, Fall 1993:63-71.

Brock, R.E. 1982. A Critique of the Visual Census Method for Assessing Coral Reef Fish Populations. *Bulletin of Marine Science* 32:269-276.

Buxton, C.D. and M.J. Smale. 1989. Abundance and Distribution Patterns of Three Temperate Marine Reef Fish (Teleostei: Sparidae) in Exploited and Unexploited Areas Off the Southern Cape Coast. *Journal of Applied Ecology* 24:441-451.

Carr, M.H. and D.C. Reed. 1993. Conceptual Issues Relevant to Marine Harvest Refuges: Examples from Temperate Reef Fishes. *Canadian Journal of Fishery and Aquatic Sciences* 50:2019-2028.

Clark, W.G. 1991. Groundfish Exploitation Rates Based on Life History Parameters. *Canadian Journal of Fisheries and Aquatic Sciences* 48:734-750.

Coyle, R.G., T.M. Ayling, and R.G. Creese. 1990. Effects of márine reserve protection at Goat Island, northern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 24:197-210.

DeLacy, A.C., C.R. Hitz, and R.L. Dryfoos. 1964. Maturation, Gestation, and Birth of Rockfish (*Sebastodes*) from Washington and Adjacent Waters. Washington Department of Fisheries Fish Research Papers 2(3):51-67.

Doty, D.C., R.M. Buckley, and J.E. West. In Press. Identification and Protection of Nursery Habitats for Juvenile Rockfish in Puget Sound, Washington. Proceedings of Puget Sound Research '95 Conference. State of Washington, Puget Sound Water Quality Authority.

Dugan, J.E. and G.E. Davis. 1993. Applications of Marine Refugia to Coastal Fisheries Management. *Canadian Journal of Fishery and Aquatic Sciences* 50:2029-2042.

Goeden, G.B. 1978. A Monograph on the Coral Trout *Plectropomus leopardus* (Lacepede). Queensland Fisheries Service, *Brisbane Research Bulletin* No. 1, 42 pp.

Hart, J.L. 1967. Fecundity and Length-Weight Relationships in Lingcod. *Journal of the Fisheries Research Board of Canada* 24:2485-2489.

LaRiviere, M.G. 1981. Lingcod (*Ophiodon elongatus*) Population Studies in Northern Puget Sound, Washington. Master of Science Thesis. University of Washington, Seattle.

Leaman, B.M. 1991. Reproductive Styles and Life History Variables Relative to Exploitation and Management of *Sebastes* Stocks. *Environmental Biology of Fishes* 30:253-271.

Mathews, S.B. and M.W. Barker. 1983. Movements of Rockfish (*Sebastes*) in Northern Puget Sound. *Fishery Bulletin* 82:916-922.

Matthews, K.R. 1989. A Comparative Study of Habitat Use by Young-of-the-year, Subadult, and Adult Rockfishes on Four Habitat Types in central Puget Sound. *Fishery Bulletin* 88:223-239.

Matthews, K.R. 1990. An Experimental Study of the Habitat Preferences and Movement Patterns of Copper, Quillback, and Brown Rockfishes (*Sebastes* spp.). *Environmental Biology of Fishes* 29:161-178.

Roberts, C.M. and N.V.C. Polunin. 1991. Are Marine Refuges Effective in Management of Reef Fisheries? *Reviews in Fish Biology and Fisheries* 1:65-91.

Schmitt, C, J. Schweigert, and T.P. Quinn. 1994. Anthropogenic Influences on Fish Populations of the Georgia Basin. In: Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound, and Juan De Fuca Strait. *Canadian Technical Report of Fisheries and Aquatic Sciences* No. 1948:218-252.

Sobel, J. 1993. Conserving Biological Diversity Through Marine Protected Areas. *Oceanus* Fall 1993:19-26.

Wildermuth, D.A. 1983. Length-weight Regression Analysis for Thirty-eight species of sport caught marine fishes. Washington State Department of Fisheries Progress Report No. 189, 7 p.

Zar, J.H. 1984. Biostatistical Analysis. 2nd Ed. Prentice Hall: New Jersey.