Abstract.–Trawl surveys conducted at index sites off the northern Washington coast between 1968 and 1992 indicate that rockfish stocks respond to fishing over very small spatial scales. The abundance of Pacific ocean perch, rougheye rockfish, and total *Sebastes* (all species combined) remained roughly constant between 1968 and 1992, whereas catch rates in an experimental management area only 28 km to the north declined 76–91%, depending on species. Declines in the abundance of Pacific ocean perch in the index area appear to be less drastic than those reported for the U.S. Vancouver–Columbia management area during this same time period. Substantial differences in the abundance, species composition, and status of rockfish stocks can exist over relatively small spatial scales, a characteristic that must be carefully considered in their management. Pacific ocean perch off northern Washington appear to have matured considerably earlier (age 8) in 1992 than they did during 1968–72 (age 10), but growth rate did not change appreciably during the same period.

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Spatial patterns in the dynamics of slope rockfish stocks and their implications for management

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The rockfish assemblage along the Vancouver Island–Oregon continental slope is dominated by Pacific ocean perch (*Sebastes alutus*), rougheye rockfish (*Sebastes aleutianus*), darkblotched rockfish (*Sebastes crameri*), splitnose rockfish (*Sebastes diploproa*), and shortspine thornyhead (*Sebastolobus alascanus*) (Leaman and Stanley, 1993; Weinberg, 1994). It is typically assumed that these species undertake only limited migrations after they have recruited to the adult stock. Because these fish are difficult to tag successfully, this supposition is based primarily on observations of abundance and age composition over area and time. Parasite studies on Pacific ocean perch (Leaman and Kabata, 1987) also indicate that adult migrations are quite limited.

Pacific ocean perch stocks in the Washington–southern Vancouver Island area were heavily exploited by Soviet and Japanese fleets during 1966–68, effectively removing the 1951–53 year classes. Catch per hour in the Washington trawl fleet declined 61% between 1966 and 1968 (Gunderson, 1977). An experimental overfishing program was carried out in Canadian waters off Vancouver Island in 1980–84 (Leaman and Stanley, 1993), resulting in 76–91% reductions in the catch rates for the species dominating the slope rockfish complex in the Canadian trawl survey area (Fig. 1) between 1979 and 1985 (Table 1). That portion of the survey area lying immediately north of the U.S.–Canada line experienced particularly intensive fishing during 1980–84 (Leaman[1]). From 1986 to 1992, annual slope rockfish catches in Canadian waters off southwest Vancouver Island (Richards, 1994) often exceeded those reported during the overfishing experiment, and it is unlikely that the abundance of these stocks increased during this period.

Exploitation rates for slope rockfish in the U.S. Fisheries Conservation Zone were much lower than those off Canada during 1980–92. Pacific Ocean perch are the dominant member of the slope rockfish community and have been managed under a stock rebuilding program in U.S. waters since 1981. This program has attempted to discourage directed Pacific ocean perch fishing and to restrict landings of Pacific ocean perch to levels that would allow incidental catches and yet allow the stock to rebuild over a 20-yr period. In 1994, for example, Pacific ocean perch landings could not exceed 3,000 lb (1,361 kg) per vessel-trip, or 20% of all fish on board, whichever was less, in Pacific ocean perch landings greater than 1,000 lb (454 kg).

[1] Leaman, B. M. 1995. Dep. Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station, Nanaimo, British Columbia, Canada V9R 5K6. Personal commun.

[2] Butler, J. L. 1995. Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. Personal commun.

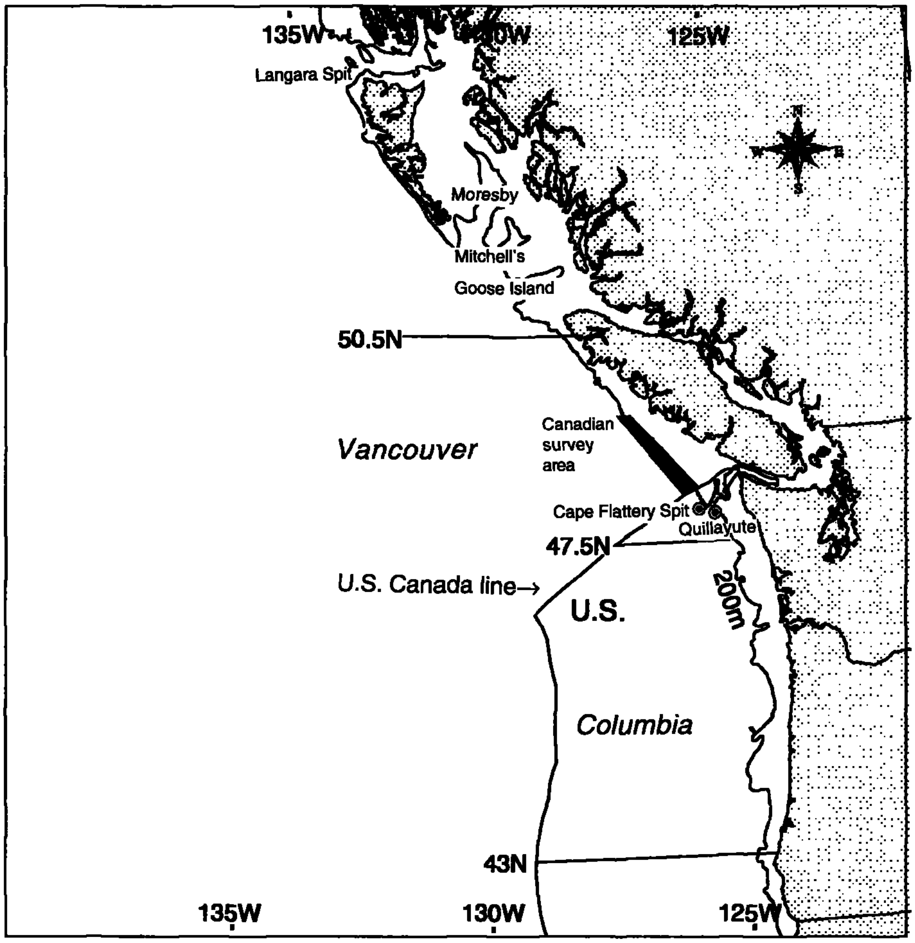

Figure 1

Locations of the northern Washington index sites (Cape Flattery Spit, Quillayute) and the Canadian survey area. Goose Island, Mitchell's, and Moresby Gullies, Langara Spit, and the Vancouver and Columbia management areas are also shown.

In effect, the differential exploitation rates in waters bordering the line separating the U.S.and Canadian Fisheries Conservation Zones (Fig. 1) constitute an unplanned experiment that allows an evaluation of the discreteness of local rockfish stocks and of the spatial impact of intensive removals. If any intermingling takes place between stocks immediately north and south of the U.S.–Canada line, the 1980–84 experimental overfishing program in Canadian waters would also have impacted U.S. stocks.

Two sites off the northern Washington coast, immediately south (28 km) of the experimental overfishing area (Fig. 1), were monitored intensively during 1968–70 (Gunderson, 1974). The principal objective of this study was to resurvey them in 1992 and evaluate the impact of intensive rockfish fishing in adjacent Canadian waters. The 1992 survey also provided an opportunity to see how well abundance trends in the index sites off northern Washington reflected overall changes in the abundance of Pacific ocean perch in the U.S. Vancouver and Columbia management areas and to examine long-term changes in age composition, size at maturity, and growth at the index sites.

Table 1

Catch rates (kg/h) from 1979 and 1985 Canadian trawl surveys in the Vancouver Island experimental fishing area (Leaman and Stanley, 1993).

Species	1979 183–365 m depth	1985 160–439 m depth	Relative change in catch rate (%)
S. alutus	1,149.7	241.5	–78.9
S. diploproa	343.5	35.7	–89.6
S. aleutianus	93.7	8.8	–90.6
S. crameri	31.1	7.5	–75.8
Total *Sebastes*	1,917.2	378.1	–80.3

Methods

The Washington State Department of Fisheries carried out a series of trawl surveys during 1968–70 aimed at monitoring the abundance and age composition of Pacific ocean perch stocks. A 400-mesh eastern otter trawl (28.7-m footrope) of uniform 3.5 -inch (8.9-cm) mesh and with a 1.5-inch (3.8-cm) codend liner was used, with roller gear attached to the footrope in the manner shown in Gunderson (1969). The net was fished with 1.5 m × 2.1 m steel "vee" doors, 18.3-m bridles, and 27.5-m sweeplines. The 20.4-m research vessel *Commando* was used during each survey, which comprised a sampling design of two index sites (Fig. 1) and three depths (219 m, 293 m, and 366 m) at each site. Four 45-min hauls were made at each of these site-depth strata, and an attempt was made to make each haul during a different part of the day (morning, mid-morning, afternoon, or evening). A total of 24 hauls were planned during each cruise, although this target was exceeded in 1969 (Table 2). The trawl, bridles, sweeplines, and doors used in the 1992 survey were nearly identical to those used in the 1968–70 surveys although there were minor differences in the roller gear and in the mesh sizes used in the net (4 inch; 10.2 cm) and codend liner (1.25 inch; 3.2 cm). However, the 30.5-m research vessel *Alaska* was used during 1992, and comparisons of the distance covered during each 45-min haul showed that the average distance traveled by the *Alaska* was 11% greater than that covered by the *Commando*. Effort data for the 1992 survey were consequently adjusted upward by this amount.

Sampling design and gear deployment in 1992 were similar to the 1968–70 protocol although it was not possible to complete the 24 hauls planned in the time allotted (Table 2). The trawl was monitored during fishing operations with a SCANMAR acoustic monitoring system, and the mean horizontal spread (between wingtips) was 13.9 m and the vertical opening was 3.0 m.

Table 2

Cruise dates and number of hauls at each depth for surveys of the northern Washington index sites, 1968–92.

	No. of hauls		
Cruise dates	219 m	293 m	366 m
17 July–28 July 1968	8	8	8
1 July–10 July 1969	9	10	9
27 Sep–4 Oct 1970	8	8	8
7 Oct–10 Oct 1992	7	7	7

An index of abundance for each survey was estimated by weighting each of the six site-depth strata separately (Eq. 5.1, Cochran, 1977):

$$\overline{y_{st}} = \sum_{h=1}^{L} W_h \overline{y_h},$$

where $\overline{y_{st}}$ = mean catch rate (kg/h);
W_h = stratum weight (=1/6 for all strata);
$\overline{y_h}$ = sample mean (kg/h) for stratum h; and
L = number of strata (6).

The variance of this index was estimated by using Equation 5.7 of Cochran (1977):

$$V(\overline{y_{st}}) = \sum_{h=1}^{L} W_h^2 s_h^2 / n_h,$$

where $s_h^2 = \dfrac{1}{n_h - 1}\sum_{i=1}^{n_h}\left(y_{hi} - \overline{y_h}\right)^2$;
n_h = number of hauls in site-depth stratum h; and
y_{hi} = catch rate (kg/h) for haul i.

All rockfish were sorted and weighed by species during the surveys, and all other species were also sorted and weighed in 1992. Sex and length data were obtained for each catch of Pacific ocean perch. For large catches, sex and length data were obtained by sampling an equal portion of the first, middle, and last part of the sorted catch (Westrheim, 1967). All fish were measured to the nearest cm (FL), and otoliths were extracted from random subsamples of the length-sex samples at each depth (Table 3). Ages were determined during 1968–70 by using surface readings of the otoliths, whereas broken and burned cross sections were used in 1992. Because comparative ageing experiments have shown that surface ages are biased for fish older than 17 (Tagart, 1984), all surface-aged fish older than this were pooled. Age-length keys were used to estimate age composition from length data, and separate keys were constructed for each cruise depth-sex stratum. Within a given stratum, size composition data for each haul were weighted by the catch per hour (catch per nmi in 1992) prior to combining them.

The age-length relation for Pacific ocean perch varies with depth so that there is an inverse relation between depth and apparent growth rate (Westrheim, 1973; Gunderson, 1974). As a result, separate curves were fitted for the age-length data at each depth by using a nonlinear least-squares algorithm (EXCEL) to fit the data to the Bertalanffy growth model:

Table 3

Number of Pacific ocean perch sampled for length, sex, and otoliths during surveys of the northern Washington index sites, 1968–92.

	Depth (m)	Length and sex	Otoliths
1968	219	1,316	486
	293	868	392
	366	800	241
	Total	2,984	1,119
1969	219	592	584
	293	2,016	1,518
	366	1,837	1,258
	Total	4,445	3,360
1970	219	1,663	1,120
	293	1,761	1,144
	366	589	564
	Total	4,013	2,828
1992	219	1,432	355
	293	1,366	412
	366	453	391
	Total	3,251	1,158

$$l_t = L_\infty\left(1 - e^{-K(t-t_0)}\right),$$

where l_t = fork length (cm) at age t years;
L_∞ = theoretical asymptotic length;
K = constant expressing rate of approach to L_∞; and
t_0 = theoretical age at which $l_t = 0$.

A total of 453 Pacific ocean perch females were classified as to state of maturity during the 1992 survey, following the criteria described in Gunderson (1977). Maturity observations were obtained from all index site-depth strata, and emphasis was placed on obtaining as many observations as possible from fish less than 38 cm, the size at which the transition from juvenile to adult occurs. A maximum-likelihood algorithm (SYSTAT) was used to fit these data to the logistic model:

$$P_l = \frac{1}{1 + e^{-(\alpha + \beta l)}},$$

where P_l = proportion mature at length l (cm);
α, β = constants; and
$\frac{-\alpha}{\beta} = l_{0.5}$ = length at which 50% of the females are mature.

The variance of $-\alpha/\beta$ was estimated with the delta method (Gunderson, 1977), and the variance estimates for α and β were provided by SYSTAT.

Results

Rockfish dominated the catches in the northern Washington index sites during the 1992 survey (Table 4; Fig. 2), and Pacific ocean perch was the most abundant species present. In contrast to the sharp reductions in rockfish abundance in the Canadian portion of the Vancouver area (Table 1), catch rates for rockfish in the northern Washington index sites (Table 4) indicated little change in abundance between 1968 and 1992. Overlapping approximate 95% confidence intervals (± 2SE) indicated nonsignificant interannual differences in the catch rates for most species, including Pacific ocean perch and rougheye rockfish, the two most abundant species of rockfish (Fig. 3A). Both of these mature relatively late in life and are quite long-lived. The median age at maturity ($t_{0.50}$) for females is about 10 years for Pacific ocean perch (Gunderson, 1977) and about 20 years for rougheye rockfish (McDermott, 1994). Pacific ocean perch can live to be 90, rougheye rockfish to 140 years (Chilton and Beamish, 1982). As a result, reductions in abundance would be expected to be sharp and of long duration if stocks off northern Washington had experienced the same level of fishing as that observed off Canada (Table 1). One species, shortspine thornyhead, actually showed a statistically significant increase in abundance over the period covered by the surveys (Fig. 3B) despite the fact that this species appears to be long-lived (otolith counts indicate that some individuals live at least 100 years; Butler[2]).

Comparison of trends in abundance within the index sites and within the U.S. Vancouver–Columbia area as a whole (as estimated by Stock Synthesis analysis, Ianelli et al.,[3]) are also possible in the case of Pacific ocean perch (Fig. 4). This comparison suggests that the abundance of Pacific ocean perch at the index sites remained at comparable levels between 1968 and 1992, at a time when most stocks in the Vancouver–Columbia area continued to decline from 1962 levels.

Nevertheless, stocks within the index area showed evidence of significant fishing during 1970–92 because the strong 1961 year class present during 1968–70 (Fig. 5) was no longer apparent (as 31-year-olds) in 1992 (Fig. 6). In a lightly exploited stock of

[2] Butler, J. L. 1995. Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. Personal commun.

[3] Ianelli, J. N., D. H. Ito, and M. E. Wilkins. 1995. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 1995. App. B *in* Status of the Pacific coast groundfish fishery through 1995, and recommended acceptable biological catches for 1996. Pacific Manage. Council, Portland, OR, 39 p.

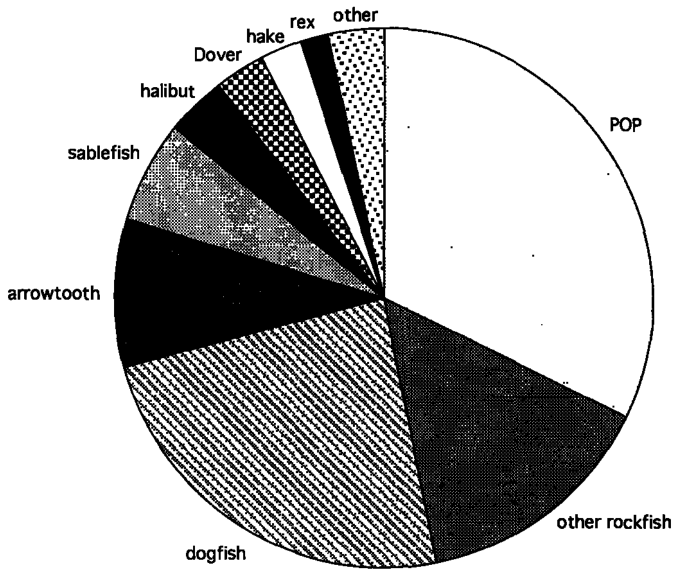

Figure 2

Species composition of the catch (kg) during the 1992 survey of northern Washington index sites. Arrowtooth = arrowtooth flounder; Dover = Dover sole; rex = rex sole; and POP = Pacific Ocean perch.

Table 4

Mean catch rates (kg/h) and their standard error (SE) for surveys of the northern Washington index sites, 1968–92.

	1968		1969		1970		1992	
	kg/h	SE	kg/h	SE	kg/h	SE	kg/h	SE
S. alutus	205.3	56.8	211.6	32.6	230.0	34.8	186.9	25.4
S. aleutianus	9.5	6.6	32.8	11.1	9.0	1.6	28.9	10.1
S. diploproa	19.9	5.9	15.7	4.6	9.8	2.0	16.6	6.7
S. crameri	4.8	0.9	12.6	2.7	13.3	3.2	6.7	1.6
Total *Sebastes*	247.0	59.7	348.5	65.2	276.7	37.0	257.5	35.6
S. alascanus	4.0	0.5	6.6	1.7	8.1	1.1	14.4	1.4
Total catch							592.5	68.0

Pacific ocean perch in Moresby Gully, Leaman (1991) found that the 1952 year class still dominated survey catches as 30-year-olds in 1982 (Fig. 6). A comparison of the 1992 age composition in the northern Washington index area with that of lightly (Moresby Gully) and heavily (Langara Spit) exploited stocks off British Columbia (Fig. 6) suggests that Pacific ocean perch stocks in the index areas still showed signs of heavy exploitiation. Although the catch curve for the index area does not show the truncation at age 40 that characterized the heavily exploited Langara Spit stock, stocks in this area can hardly be classified as lightly exploited. The size composition of stocks at the index sites (Fig. 7) reflects little of the rather substantial interannual changes in age composition seen in Figure 5. This is due to the uninformative nature of the length data in relation to age composition, characteristic of slow-growing fish in general.

Mean length at age declined with depth (Fig. 8), a phenomenon previously reported in a number of studies (Westrheim, 1973; Gunderson, 1974). The results are summarized in terms of predicted length at age 15 with the Bertalanffy growth model, following Gunderson (1974). Age 15 was taken as the reference age because this was generally the oldest age group for which age-length data were available from all sampling depths and reflects the accumulated

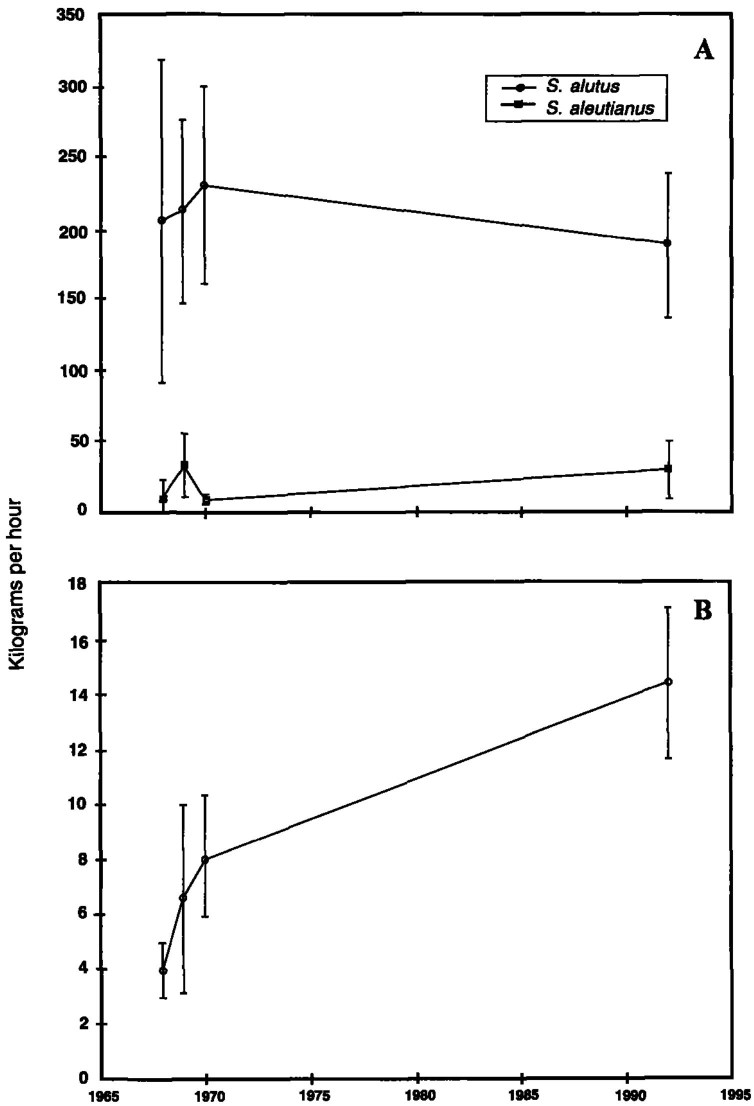

Figure 3

Catch per hour (kg) of (**A**) the dominant species of rockfish (Pacific ocean perch and rougheye rockfish), and (**B**) shortspine thornyheads at the northern Washington index sites, 1968–92. Error bars indicate approximate 95% confidence intervals (2SE).

differences in annual growth in all ages younger than 15. The magnitude of interannual differences in size at age 15 for a given depth and sex were relatively minor (Fig. 8), particularly when differences in age determination technique are considered.

The length-maturity curve for 1992 (Fig. 9) indicates a significant shift toward maturation at a smaller length than was the case in 1968–72 (Table 5; Fig. 9). Both a Z-test (Table 5) and logistic regression analysis (SPSS) showed that the year effect was highly significant ($P<0.001$) statistically. Age at 50% maturity, as predicted from the Bertalanffy growth model presented in Gunderson (1977, Table 3) decreased from 10.1 to 8.1 years over this same period.

Discussion

Although members of the genus *Sebastes* are viviparous and retain their larvae for varying periods prior to releasing them, the larvae can still be transported considerable distances during their 3–6 month pelagic phase, resulting in broad spatial synchrony in recruitment trends (Ralston and Howard, 1995). In

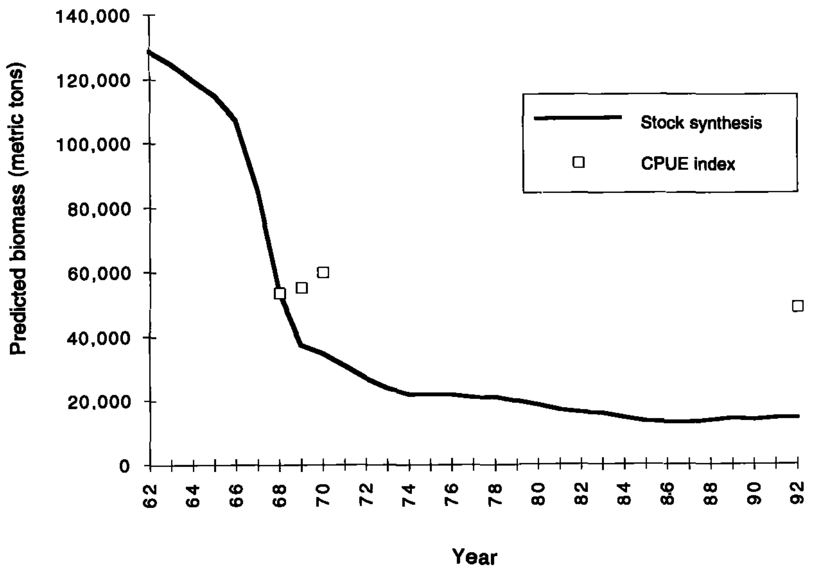

Figure 4

Estimated biomass (t) of Pacific ocean perch in the U.S. Vancouver–Columbia management area based on Stock Synthesis analysis (Ianelli et al.[3]) and extrapolated CPUE (1968 CPUE = $q \times$ 1968 Stock Synthesis biomass, where q is the catchability coefficient) at the northern Washington index sites for the years 1968–92.

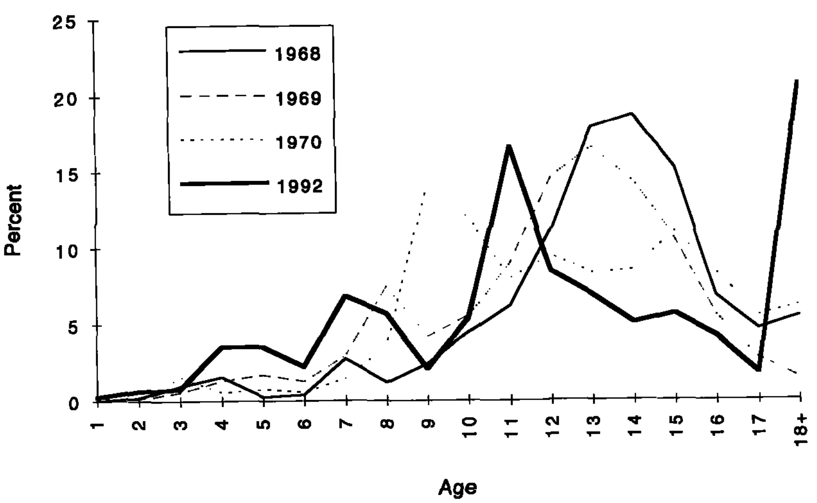

Figure 5

Age composition of Pacific ocean perch in the northern Washington index sites, 1968–92.

the case of Pacific ocean perch, allozyme differences follow a cline from the Washington coast to the Bering Sea rather than show discrete differences between stocks (Seeb and Gunderson, 1988). Strong year classes of Pacific ocean perch tend to occur synchronously throughout the Oregon–British Columbia region (Gunderson, 1977; Hollowed, et al., 1987), indicating recruitment strength is determined by oceanographic conditions operating over broad spatial scales.

However, migrations of adult Pacific ocean perch appear to be quite limited. For example, Westrheim et al. (1974), documented a virtually unexploited stock of Pacific ocean perch in Moresby Gully, B.C., located immediately north of heavily fished stocks in Mitchell's Gully, also within Queen Charlotte Sound (Fig. 1). Pacific ocean perch habitat in Moresby Gully is contiguous with that of Mitchell's Gully at

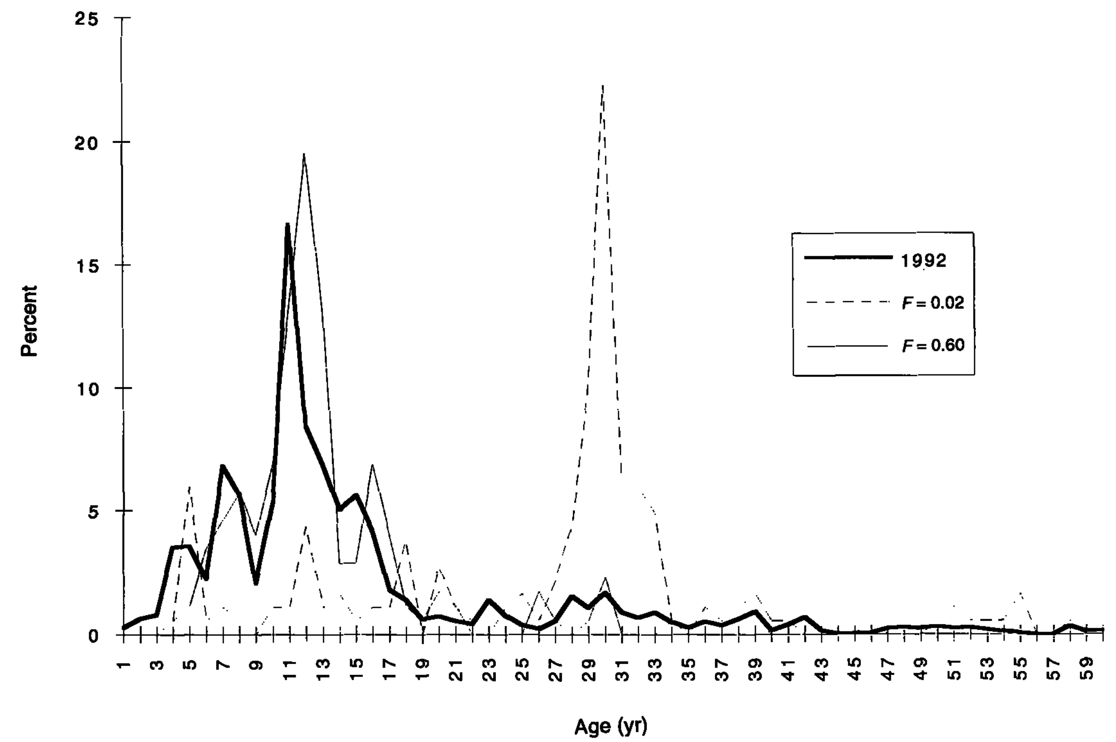

Figure 6

Age composition of Pacific ocean perch in the northern Washington index sites in 1992, contrasted with that of lightly exploited (F=0.02, Moresby Gully, 1982) and intensively exploited (F=0.60, Langara Spit, 1982) stocks (Leaman, 1991).

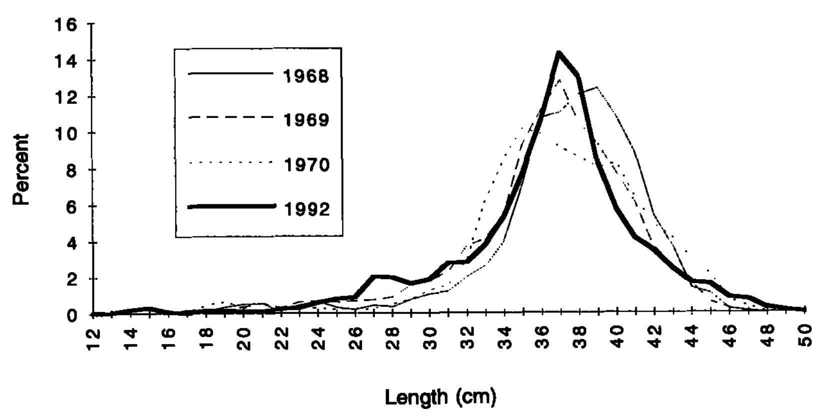

Figure 7

Size composition of Pacific ocean perch at the northern Washington index sites, 1968–92.

the shallower extremes, and the 200-m contours are separated by only about 30 km. Nevertheless, the size and age composition in these two areas differed sharply (Gunderson et al., 1977). The composition of the parasite fauna on adult Pacific ocean perch in Moresby Gully has also been shown to differ significantly from that found on adult ocean perch in Goose Island Gully (immediately south of Mitchell's) (Leaman and Kabata, 1987). It seems clear that, whereas spawner-recruit processes probably operate over broad geographic scales, adult migrations are limited, and changes in abundance and age composition for this species in response to fishing are highly localized.

The results of this study indicate that responses to fishing also occur over very small spatial scales off Oregon–southern Vancouver Island as well as in Queen Charlotte Sound, and that this is true for rougheye, splitnose, and darkblotched rockfish as well as for Pacific ocean perch. The index areas off the northern Washington coast were only 28 km south of the Canadian experimental overfishing zone (Fig. 1), yet rockfish stocks in this area appear to have experienced little change in abundance between 1968 and 1992. Shortspine thornyhead abundance within the 219–366 m depth interval actually increased between 1968 and 1972, although these fish represent only the shallowest part of the range and the younger age groups in a stock that can extend to depths greater than 1,100 m (Ianelli et al.[4]).

Although the rockfish assemblage in the northern Washington index sites was not depleted to the same extent as its counterpart in Canadian waters during 1970–92, it is far from being at pristine abundance. The effects of the overfishing during 1966–68 are still evident because the abundance of fish older than age 15 is still much lower than that characteristic of lightly exploited stocks (Fig. 6). Pacific ocean perch stocks in the index areas appear to have undergone significant exploitation between 1970 and 1992 but have not declined to the same extent as those in Canadian waters to the north (Tables 1 and 4) or in U.S. waters to the south (Fig. 4).

The size and age at maturity for Pacific ocean perch in the northern Washington index areas appear to have declined significantly between 1968 and 1972 (Gunderson, 1977) and 1992. Length at 50% maturity declined from 34.4 cm to 31.6 cm (Table 5), whereas age at 50% maturity declined from 10.1 years to 8.1 years. This shift in size and age at maturation should be viewed with some caution, however, because most adult fish examined in 1992 were still in the"maturing" stage. Only one of the 382 adults examined was in a more advanced

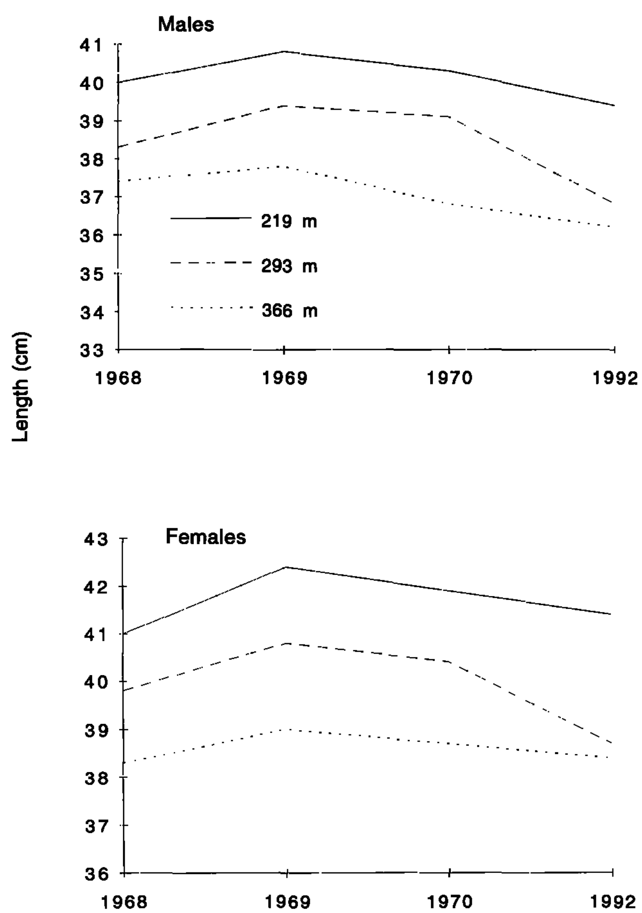

Figure 8

Predicted length (cm) at age 15 of Pacific ocean perch, by sampling depth, at the northern Washington index sites, 1968–92.

[4] Ianelli, J. N., R. Lauth, and L. D. Jacobson. 1994. Status of the thornyhead (*Sebastolobus sp.*) resource in 1994. App. D *in* Status of the Pacific coast groundfish fishery through 1994, and recommended acceptable biological catches for 1995. Pacific Manage. Council, Portland, OR, 58 p.

Table 5

Estimated length and age at maturity for female Pacific ocean perch off the northern Washington coast, 1968–72 versus 1992.

	1968–1972	1992
α	–29.0258	–20.3196
β	0.8439	0.6428
$l_{0.5}$(cm)	34.40	31.61
Var ($l_{0.5}$)	0.0437	0.1498
Z–statistic[1]	6.33	
$t_{0.50}$(years)[1]	10.1	8.1

[1] See Gunderson (1977).

maturation stage, i.e. "fertilized." In contrast, the fish used in constructing the length-maturity curve for 1968–72 were collected during February–June, when Pacific ocean perch are closer to the embryo-release period.

Nevertheless, it appears that after 20 years in a depleted state, the stocks of Pacific ocean perch off Washington have partially compensated for a loss in reproductive potential by reducing their age at maturity from 10 years to 8. Comprehensive studies have shown long-term declines in age at maturity from 10.5 years (1923) to 8 years (1976) in a heavily fished stock of Northeast Arctic cod (Jørgensen, 1990), and from 5–7 years (early 1900's) to 4–5 years in North Sea plaice (Rijnsdorp, 1989). Although a genetic basis for such changes has been documented in some species (Policansky, 1993), disentangling genetic changes and phenotypic plasticity is often difficult. Given the long generation time of Pacific ocean perch and the relatively short time span involved, these changes probably reflect reaction norms of phenotypic plasticity rather than changes in genotype.

In contrast, growth, as reflected in size attained at age 15, showed no substantial changes between 1968–70 and 1992. Although monitoring length-age relationships at fixed bathymetric locations allows the depth effect to be controlled for, it is difficult to maintain the sampling depth within a range of less than about 18 m with trawls on the continental slope. Aggregations of Pacific ocean perch often have different growth characteristics and vary interannually in their availability (Gunderson, 1974), and further sources of bias and variability are inherent in using different age-determination techniques. All of these factors make it difficult to detect changes in growth rates unless they are substantial. Nevertheless it should be kept in mind that interannual variations in food availability can often be more influential than changes in population density in determining growth rates (Rijnsdorp et al., 1991; Rijnsdorp and van Leeuwen, 1992).

Most adult rockfish in the Oregon–Vancouver Island region probably migrate to a very limited extent, and stocks within these regions represent a mosaic of small, highly localized stocks. Nevertheless, practical considerations in terms of data collection, data assessment, and management enforcement often force the geographic scale of fishery management to be relatively broad. For example, although the Pacific Fishery Management Council has at-

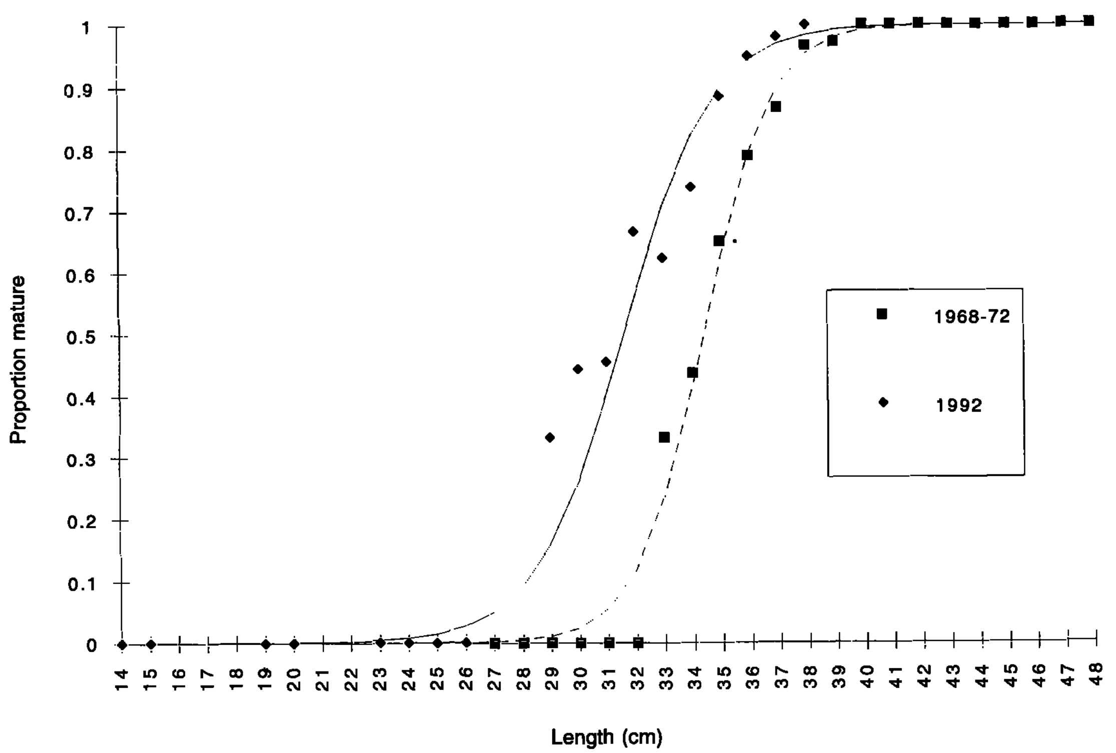

Figure 9
Predicted length-maturity relation for Pacific ocean perch off northern Washington during 1968–72 (solid line) and 1992 (dashed line).

tempted to eliminate directed fishing on Pacific ocean perch in the U.S. Vancouver–Columbia management area, fishermen have been observed fishing for this species in the northern Washington index areas, where Pacific ocean perch and other rockfish are the most abundant fish in catches (Fig. 2). Only distance and time act as disincentives for fishermen, who have yet to achieve their "incidental" allotment of Pacific ocean perch, from moving to areas such as these to "top off" their catch. It is not surprising then that stocks in the index area have failed to rebuild as the Council had hoped. While often ignored in management considerations owing to a lack of information, other species in the slope rockfish assemblage (notably rougheye and splitnose rockfish) have probably experienced the same pattern of overfishing as Pacific ocean perch and should be considered when contemplating future rebuilding plans.

One possible solution to many of the problems that currently exist in managing slope rockfish stocks is to delineate areas such as the index sites, where rockfish dominate the exploitable fish biomass (Fig. 2), and to eliminate all fishing within them. A variety of questions remain as to the optimal size and spatial dispersion of such closed areas (or "refugia"), as well as the enforcement problems associated with maintaining them, but it seems clear that if managers cannot rebuild rockfish stocks in areas of prime habitat, it is unlikely that they will be able to rebuild them over broader scales.

Acknowledgments

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