REDUCTION IN MEAN LENGTH AND EXPLOITATION OF CENTRAL AND NORTHERN CALIFORNIA ROCKFISH

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Recent results presented in Pearson and Ralston (1990) show that average lengths of many species of rockfish (Sebastes spp.) in the California groundfish fishery have declined since 1978. In some cases the reduction in mean total length (TL) has been marked (e.g., S. flavidus and S. pinniger), whereas in others it has been slight (S. melanostomus). One means of measuring the extent to which rockfish length composition has changed is to calculate the reduction in mean size that has occurred during the 1978-88 time period. To accomplish this, COMCAL data from the California cooperative rockfish survey (Sen 1986) were combined among 6 central and northern California ports (Morro Bay, Monterey, San Francisco, Bodega Bay, Fort Bragg, and Eureka) and, for each of the 20 species-sex combinations considered by Pearson and Ralston (1990), weighted (by catch numbers) and unweighted linear regressions of mean annual TL on year were calculated (Table 1). The proportionate size of fish in 1988, relative to 1978, was then estimated as $\hat{\ell}_{88}/\hat{\ell}_{78}$, where $\hat{\ell}_{78}$ and $\hat{\ell}_{88}$ are regression equation predictions of average TL for the two years in question. Results show that reductions in mean length to a level equivalent to 90-94% of that prevailing in 1978 have been commonplace. Note that, because these regressions were performed on the annual means of an 11 year time series, (1) the statistical power for rejecting the H_0: $\beta = 0$ was relatively low and (2) the significance levels reported may be misleading due to serial correlation in the data. Nevertheless, the general result of $\hat{\ell}_{88}/\hat{\ell}_{78} < 1.0$ in 16 of the 20 cases reported, in combination with 7 statistically significant negative estimates of slope and no significant positive estimates, presents a clear and pervasive pattern of declining mean length.

A natural question arises from these findings, i.e., have these observed declines in average length been brought about by substantial or even excessive fishing pressure? In an attempt to answer this question we performed two simple calculations. First we assumed: (1) constant recruitment and mortality rates, (2) knife-edged age at entry to the fishery ($t_{\rho'} = 0$ or 6 yr), (3) von Bertalanffy growth ($L_\infty = 40$ cm TL; $K = 0.20$ yr^{-1}; $t_0 = -0.20$ yr) with Gaussian length variation at age ($\sigma_\ell = 2.50$), and (4) a natural mortality rate in the range 0.10-0.30 yr^{-1}. Results show (Fig. 1) that when $t_{\rho'} = 6$, substantial fishing pressure (as indicated by an F/M ratio of 2.00) produced only a modest decline in average length. In this case, at equilibrium the mean length of the catch, relative to the virgin situation, was 0.923 when $M = 0.20$ yr^{-1}.

Table 1. -- Reduction in the average total length of 11 species of rockfish (Sebastes spp.) landed at central and northern California ports during the period 1978-88.

		Unweighted Regression			Weighted Regression (N)		
Species	Sex	Student's t $H_o: \beta=0$	P	$\hat{l}_{88}/\hat{l}_{78}$	Student's t $H_o: \beta=0$	P	$\hat{l}_{88}/\hat{l}_{78}$
S. aurora	combined	1.245	0.245	1.053	0.254	0.805	1.009
S. chlorostictus	combined	-0.477	0.645	0.983	-1.135	0.286	0.957
S. crameri	male	-2.790	0.021	0.926	-3.317	0.009	0.918
	female	0.465	0.653	1.036	-0.525	0.612	0.972
S. diploproa	male	-0.887	0.398	0.959	-1.540	0.158	0.921
	female	1.039	0.326	1.027	-0.136	0.895	0.996
S. entomelas	male	-3.354	0.008	0.921	-3.486	0.007	0.904
	female	-1.583	0.148	0.949	-2.708	0.024	0.898
S. flavidus	male	-6.602	0.001	0.868	-5.457	0.001	0.867
	female	-5.130	0.001	0.860	-4.583	0.001	0.856
S. goodei	male	-0.814	0.436	0.981	-0.745	0.475	0.984
	female	-2.370	0.001	0.901	-2.319	0.045	0.898
S. melanostomus	male	-0.089	0.931	0.997	0.160	0.876	1.005
	female	-0.852	0.416	0.972	-0.339	0.743	0.986
S. paucispinis	male	-0.420	0.685	0.966	0.038	0.970	1.003
	female	-0.173	0.867	0.983	0.351	0.734	1.038
S. pinniger	male	-3.964	0.001	0.911	-3.039	0.014	0.923
	female	-1.963	0.081	0.911	-1.449	0.181	0.914
S. rufus	male	-1.225	0.252	0.958	-1.489	0.171	0.931
	female	0.133	0.897	1.007	-0.605	0.560	0.962

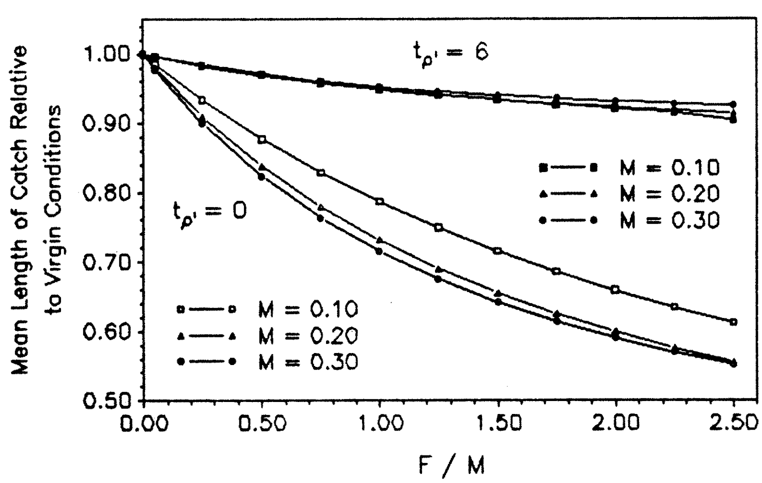

Fig. 1 -- Expected exploitation effects on mean length when entry to the fishery is age dependent ($t_{\rho'}$).

In the second set of calculations we utilized the basic length-based mortality formulation developed by Beverton and Holt (1956):

$$Z/K = (L_\infty - \bar{\ell})/(\bar{\ell} - \ell_c)$$

where $\bar{\ell}$ is the average length of fish in the catch greater than the knife-edged length at entry ℓ_c. This equation was derived from assumptions of von Bertalanffy growth with no length variation at age (i.e., $\sigma_\ell = 0.0$) and constant mortality and recruitment rates. In this case ℓ_c was scaled to L_∞ (i.e., 0.25, 0.50, or 0.75) and the ratio of natural mortality to the von Bertalanffy growth coefficient ranged from M/K = 0.50-2.00 in increments of 0.50. Again, results showed (Fig. 2) that only modest equilibrium reductions in average length will occur in the face of significant fishing (F/M > 1.00), if entry to the fishery occurs at a length ≥ 50% of L_∞.

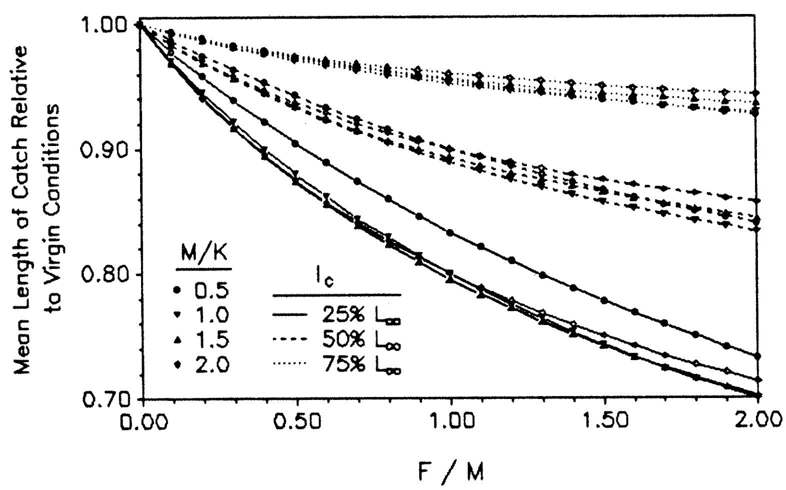

Fig. 2 -- Expected exploitation effects on mean length when entry to the fishery is length dependent (ℓ_c).

We draw the reader's attention to two aspects of these results. First, because many of these rockfish stocks already had a history of exploitation in 1978 and because they likely had yet to reach an equilbrium size structure by 1988, the values presented in Table 1 are probably conservative estimates of the extent of size reduction that will occur. That is, mean TL statistics for the 1978 base year are apt to be less than expected for unexploited stocks and, even with no change in the amount of fishing, further reductions in length are expected. Second, both the hypothetical population models presented assume knife-edged entry to the fishery, whether age or length dependent, and the imposition of a constant age or size specific fishing mortality rate thereafter. Together, these features imply a rectangular shaped selectivity curve, when in fact dome-shaped selectivity curves have often been shown to characterize rockfish stocks (e.g., widow rockfish; Hightower and Lenarz 1989). Thus, to produce the declines in size evident in Table 1, even higher rates of exploitation are necessary than those implied by Figs. 1 and 2.

On a cautionary note, other factors besides the rate of fishing can influence the mean length of fish in the catch. Results from a recently completed analysis (Bence et al., In prep., Status of the bocaccio fishery, NOAA, NMFS, SWFSC Tiburon Laboratory) show clearly a highly variable pattern in the recruitment of Sebastes paucispinis, which has led to an oscillation in average annual length (Pearson and Ralston 1990). Likewise, alterations in selectivity curves (i.e., increased harvest of small fish) could cause the average size of landed fish to decline. Still, we believe that the general pattern of size reductions evident in Table 1 is largely the result of increased fishing pressure in recent years.

We conclude from the results presented here that many rockfishes currently under harvest in California are subjected to substantial fishing pressure. In particular, we note the following stocks of potential concern: male S. crameri, male S. diploproa, both sexes of S. entomelas, both sexes of S. flavidus, female S. goodei, both sexes of S. pinniger, and male S. rufus. Especially alarming are the statistics for yellowtail rockfish (S. flavidus) and canary rockfish (S. pinniger), which show declines in average length ranging from 13.2-14.4% and 7.7-8.9%, respectively. Given that, with the exception of S. entomelas, no overall annual limit exists on the catch of these stocks from areas south of Coos Bay, Oregon (Anonymous 1990), we believe that additional assessments are urgently needed to determine the condition of these stocks.

Literature Cited

Anonymous. 1990. Federal regulations applying in the exclusive economic zone (3-200 miles) for the U. S. commercial and recreational groundfish fisheries off the coasts of Washington, Oregon, and California. U. S. Dept. Comm., NOAA, National Marine Fisheries Service, Northwest Regional Office, Seattle, Washington, 44 p.

Beverton, R. J. H., and S. J. Holt. 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapp. et Proc.-Verb. Réun., Cons. Int. l'Explor. Mer 140: 67-83.

Hightower, J. E., and W. H. Lenarz. 1989. Status of the widow rockfish fishery. Appendix C In: Status of the Pacific Coast groundfish fishery through 1989 and recommended acceptable biological catches for 1990. Pacific Fishery Management Council, Portland, Oregon.

Pearson, D. E., and S. Ralston. 1990. Trends in landings, species composition, length-frequency distributions, and sex ratios of 11 rockfish species (genus Sebastes) from central and northern California ports (1978-88). U. S. Dept. Comm., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-145, 65 p.

Sen, A. R. 1986. Methodological problems in sampling commercial rockfish landings. Fish. Bull., U. S. 84(2): 409-421.