POPULATION DYNAMICS OF YELLOWTAIL ROCKFISH (*Sebastes flavidus*) STOCKS IN THE NORTHERN CALIFORNIA TO SOUTHWEST VANCOUVER ISLAND REGION

by

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EXECUTIVE SUMMARY

This analysis represents the fifth and most comprehensive installment in a continuing effort to develop a knowledge of yellowtail rockfish population dynamics. In this analysis, I have examined catch and biological data through 1987, incorporating previously unused data from California and British Columbia. The analysis begins with the assumption that yellowtail rockfish can be divided into four operational stocks: 1) Eureka/S. Columbia (including PMFC area 1C, 2A, 2B and 2C); 2) Northern Columbia (PMFC area 3A); 3) Southern Vancouver (including PMFC areas 3B, 3CS and 3CN); and, 4) Charlotte/N. Vancouver (including PMFC areas 3D, 5A, 5B, 5C, 5D and 5E). In this analysis, I estimate abundance for stocks 1-3. Estimates of total, exploitable and spawning biomass, recruitment, and fishing mortality are obtained from stock synthesis (SS) analysis. I have also estimated stock abundance using cohort analysis, however, cohort analysis results are essentially presented to provide a bridge for persons familiar with this method while comparing these estimates with those obtained from SS analysis.

Included in this analysis is an extensive review of the life history of yellowtail rockfish. Yellowtail rockfish are semi-pelagic residing hard on bottom as well as off bottom at the 50 to 100 fm depth stratum. Throughout their range, yellowtail demonstrate a similar reproductive cycle. Males and females aggregate in fall to mate, typically during September and October. Females bear live young which are spawned in early spring usually March and April. Larval fishes are initially pelagic until settling to the bottom during summer at approximately 50 cm in size. Little is know about the distribution of yellowtail after settling to the bottom and prior to recruitment by the fishery. Recruitment begins at approximately 4 years of age. Full recruitment, i.e. the age class which is completely susceptible to fishing, occurs at 8 to 12 years of age depending on sex and stock. Female yellowtail rockfish first reach maturity at 6 years of age, 50% of the 10 year old fish are mature and 100% are mature by age 18. There is a common length/weight relationship for all stocks from the INPFC Columbia to Charlotte area. Growth rates are similar among stocks, although I use a separate function for each stock. There are indications that the mean size at age has declined for N. Columbia area fish. I obtained significant negative slopes for a regression of size versus year for fish aged 7 and 10 years old. I also obtained a significant negative slope for 10 year old

fish from the Eureka/S. Columbia area. Nevertheless, the decline in mean size at age was very modest. Proportion mature at age was estimated from a functional relationship developed by Gunderson, et. al (1980). Comparison of Gunderson's estimates with those obtained from analysis of samples collected by WDF in 1989 indicated the WDF samples imply a slightly earlier maturation. However, fishes were classified as mature in slightly different ways in the two analyses and results from the recent samples can't be interpreted as representing compensatory changes in maturation.

To justify the parameterization of the stock synthesis model, I conducted a step by step procedure which begins with a SS model parameterization that emulates cohort analysis. I demonstrate that SS can mimic the results of cohort analysis, then I systematically relax the assumptions of cohort analysis by changing or adding parameters to SS and demonstrate continuous improvements to component and total likelihood in the SS model. First I test the effect of specifying different ages of full recruitment, showing no difference in likelihoods for a range of age from 10 to 16. Next, I demonstrate that recognition of ageing error can substantively improve the fit to the SS model's fishery age and total likelihood. Further improvement to the fishery age likelihood is achieved through full parameterization of the selectivity functions. I demonstrate clearly that male yellowtail rockfish experience asymptotic selectivity, but that selectivity patterns for females are dome shaped. I then explore assumptions regarding female natural mortality and develop two models to reflect alternative assumptions. One hypothesis states that older female yellowtail rockfish are alive and unavailable to the commercial fishery, therefore, the dome shaped selectivity pattern is appropriate. An alternative hypothesis, assumes older females are dead and that the selectivity function for these fish should be asymptotic. To obtain the asymptotic selectivity function I model an age specific natural mortality rate for females. These two hypotheses regarding female natural mortality become the foundation for optimistic (older females alive but unavailable) and pessimistic (older females are dead) views of stock abundance. As I examine natural mortality assumptions for females, I review and corroborate the previous estimate of natural mortality ($M=0.11$). There is little empirical evidence to support the notion of a different natural mortality rate between males and females, and none which demonstrates increasing age specific natural mortality for females. Nevertheless, in nearly 15 years of sampling there is no evidence of the existence of older female yellowtail rockfish. Finally, I estimate a density dependent parameter value for the spawner/recruit relationship. In this exercise, there are no significant relationships between spawner abundance and recruitment. Generally, recruitment has varied substantively over a narrow range of spawning stock biomass. Despite the lack of a significant correlation, I estimate a value which I propose as an upper estimate of density dependence between spawner and recruit. The value tends to maximize the spawner/recruit likelihood function. I claim that the Beverton-Holt spawner/recruit function shape parameter should be $0.659 \leq A < 1$.

After setting the parameters of the SS model, I explore the weighting factors for the component likelihoods. Component likelihoods used in the model are catch biomass, fishery age composition, survey age composition, survey biomass and the spawner/recruit relationship. By independently varying by plus or minus one order of magnitude one component likelihood weighting factor at a time, I show that all likelihoods can be assigned a weighting factor of 1.0 except the spawner/recruit likelihood which is assigned a value of 0.001.

From northern California to southwest Vancouver Island since the mid 1970s yellowtail rockfish abundance has been declining. In the Eureka/S. Columbia area, total population biomass in 1967 was estimated between 21,600 and 25,000 t, by 1991 the optimistic estimate of total biomass was 20,100 t and the pessimistic estimate 13,100 t. The estimate of 1991 spawning biomass is 68% of the unfished spawning biomass under the optimistic model and 49% under the pessimistic model. This stock is regarded as healthy, nevertheless, we have a short history of age structured data for this stock and the last strong year class was seen in 1980. Consequently, I propose using the biomass estimate from the pessimistic model of stock abundance to determine ABC. Estimates of yield for 1991 are derived by assuming a 1991 fishing mortality rate equivalent to the mortality which causes the equilibrium spawning biomass per recruit to drop to 35% of the unfished spawning biomass ($F_{0.35}$=0.25). The recommended ABC in 1991 is 1348 t. This level of catch would exceed the known catch of record of 1281 t in 1983 and compares with 1088 t landed in 1989.

In the N. Columbia area, 1967 total biomass estimates range from 60,200 to 78,700 t. By 1991, total biomass was estimated to be 54,400 t under the optimistic model and 25,200 t under the pessimistic model. Spawning biomass in 1991 is estimated to be 64% of the unfished spawning biomass under the optimistic model and 28% under the pessimistic model. Historically, fishing pressure has been greatest in the N. Columbia area. The most recent age data (1987) indicate that the fishery is dominated by 10 year old fish from the 1977 year class. Since 1977, only the 1980 year class is above average and it is barely above average. Full recruitment in the N. Columbia area occurs at age 8 for males and 9 to 10 for females. Since females are only 50% mature by age 10, the fishery is dependent on age classes which have had little opportunity to reproduce. Consequently, I recommend using the pessimistic model of stock abundance and the $F_{0.35}$ fishing mortality rate, 0.18, and would set the 1991 ABC at 2085 t. The recommended 1991 ABC is a few tons greater than the 2048 t landed in 1989.

Stock condition in the S. Vancouver area is the most difficult to pinpoint. Total biomass estimates for 1967 vary from 74,500 to 54,000 t under the optimistic and pessimistic models respectively. By 1991, total biomass declined to 38,800 under the optimistic model and 20,000 t under the pessimistic model. Spawning biomass is 48% of the unfished spawning biomass under the optimistic model but only 23% under the pessimistic model. I again recommend using the pessimistic model of stock abundance to set 1991 ABCs. Using $F_{0.35}$=0.225, the 1991 recommended ABC for the entire S. Vancouver area is 2044 t. From a release of 9417 tagged yellowtail rockfish in the S. Vancouver area only 24 fish have been recovered. Among recoveries, there is clear evidence of movement across the US/Canada provisional boundary. I have recommended an allocation between the US and Canada of the 1991 ABC based on recent history of landings. Over the past five years, US fishermen have landed as much as 74% and as little as 53% of the total harvest in this area. I am suggesting an allocation based on a 60% share to US fishermen or 1200 t in 1991. US fishermen landed approximately 1400 t in 1989.

Table 1. Summary of critical yellowtail rockfish population dynamics parameters as determined by stock synthesis analysis for "A" the optimistic model and "B" the pessimistic model. (Biomass and yield in t, recruitment in thousands of fish)

	Eureka/S. Columbia		N. Columbia		S. Vancouver	
Parameter	A	B	A	B	A	B
Constraint on F_{87}	Estimated	Fixed	Estimated	Estimated	Estimated	Estimated
F_{87}	0.126	0.200	0.094	0.179	0.102	0.176
Male M	0.11	0.11	0.11	0.11	0.11	0.11
Female M	0.11	0.111/0.256	0.11	0.111/0.256	0.11	0.113/0.376
I (Male/Female)	15/11	16/16	8/9	8/10	13/10	12/12
Age 50% Mat.(Female)	10.1	10.1	10.1	10.1	10.3	10.3
B^{*}_{67}	24988	21598	78704	60169	74504	53986
B^{*}_{90}	20417	13423	53778	24312	39724	20641
SPB^{*}_{0}	8656	4882	26432	13036	26505	10195
R_0	1950	1996	6040	5403	6047	5609
Mean Rec:67-87	2297	1991	7292	5592	4841	4046
F_{msy}, A=0.659	0.075	0.100	0.070	0.075	0.070	0.090
F_{msy}, A=0.889	0.165	0.240	0.145	0.170	0.150	0.205
$F_{0.1}$	0.235	0.260	0.220	0.215	0.210	0.230
$F_{0.35}$	0.165	0.250	0.150	0.180	0.160	0.225
SPB^{*}_{msy}, A=0.659	3307	1885	10185	5229	11212	4275
SPB^{*}_{msy}, A=0.889	2343	1359	7404	3701	7831	3029
$SPB^{*}_{0.1}$	2186	1651	6109	3857	6995	3480
$SPB^{*}_{0.35}$	3044	1699	9222	4517	9328	3545
B^{*}_{91}	20090	13123	54404	25156	38768	19966
EXB^{*}_{91}	11183	6336	31656	13332	18272	10606
SPB^{*}_{91}	5848	2409	16984	3605	12770	2315
SPB^{*}_{91}/SPB^{*}_{0}	0.676	0.493	0.643	0.277	0.482	0.227
Y^{*}_{91} @ F_{msy}, A=0.659	769	570	2037	907	1364	891
Y^{*}_{91} @ F_{msy}, A=0.889	1632	1299	4089	1977	2826	1876
Y^{*}_{91} @ $F_{0.1}$	2260	1397	6015	2454	3857	2085
Y^{*}_{91} @ $F_{0.35}$	1632	1348	4221	2085	3001	2044