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STATUS OF THE BLACK ROCKFISH RESOURCE IN 1999
STAT EXECUTIVE SUMMARY

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Introduction

The status of stocks for black rockfish was last determined in 1994 (Wallace and Tagart, 1994). The population was assessed using the age-structured version of the stock synthesis model. The population was regarded as healthy, stock abundance was estimated to be either increasing after passing through a low in the late 1980s or in a gentle decline showing relative stability from 1990 to 1994. The recommended allowable annual yield was 517 mt based on an F45% exploitation strategy. The current analysis reprises estimates based on the 1994 stock synthesis model, introduces a new parameterization of stock synthesis (1998 configuration) and presents a completely new model written in AD Model Builder.

Stock

Tagging data collected by the Washington Department of Fish and Wildlife, suggested that Cape Flattery and Cape Falcon bound a single coastal Washington-northern Oregon black rockfish stock. This hypothesis was corroborated by a recent genetic study that evaluated a set of samples organized into three geographical clusters from California to northern Washington. The northern cluster, encompassing northern Oregon to northern Washington, was found to be significantly different from the southern clusters. We assumed that black rockfish distributed in this area represented a unit stock. All biological parameters, data analysis and yield projections presented in this assessment are intended to describe this portion of black rockfish coast-wide distribution.

Model Inputs:

The stock synthesis models used catch data from 1970 to 1998 for each of three fisheries (trawl, commercial line and sport). The AD model used trawl catch data from 1986 to 1993, line catch data from 1986 to 1995, and sport catch data from 1986 to 1998. The catch data interval corresponded to the period of an active black rockfish fishery for each gear. In addition, AD model also used gear specific estimates of catch variance. For the commercial gears (trawl and line), catch variance was available for each year of catch data. Catch variance for the sport fishery was available for 1990 to 1998.

Age specific inputs included catch-at-age (by numbers or weight), proportion-at-age (by numbers), and proportion-at-age (by weight). The stock synthesis model utilized proportion-at-age in numbers for each fishery weighted by sample size. AD model incorporated proportion-at-age by number for the sport fishery, and proportion-at-age by weight for the trawl and line fishery. Additional AD model inputs were the associated variances for the estimated proportions-at-age.

Revised estimates of weight-at-age and maturity-at-age were generated for the current analysis. We determined that a single weight-at-age vector effectively represented the line and sport fishery, and a separate vector was estimated for the trawl fishery. Inspection of the 1994 stock assessment report revealed that we had inadvertently used the raw proportion mature-at-age data rather than the estimated proportion-at-age from the regression fit to the logistic. Predicted values from the regression were used in this analysis.

Auxiliary data

From 1988 to 1990 and beginning anew in 1998, black rockfish from known areas of high densities were tagged such that the tags were distributed in proportion to perceived relative abundance. Tag release data from 1988 to 1990 and in 1998 and recovery information collected between 1988 and 1994 and in 1998 where used as auxiliary data.

For the 1994 stock synthesis model configuration, two auxiliary data sets were used as black rockfish abundance indicators: tagging CPUE and recreational bottomfish effort (Wallace and Tagart, 1994). Estimates of fishing mortality derived from tag data were used as an effort index to tune the 1998 stock syntheses model configuration. Fishing mortality rates were estimated from the ratio of tags recovered to tags released and adjusted for the fraction of catch that occurred before the tagging study.

In the AD model configuration, tag recovery was modeled explicitly. Auxiliary data inputs were the annual number of tags released, the number of tags recovered stratified by year of release, annual tag loss rate, and tag reporting/recovery rates. Tag reporting rates for the 1988-94 recoveries were unknown. Analyses were conducted to evaluate the sensitivity of estimated abundance to those reporting rates.

Model Description

We used the AD model to assess current black rockfish abundance because the model explicitly included sampling uncertainty and provided the most statistically rigorous model with the fewest set of assumptions. The two stock synthesis model configurations were provided as a basis for comparison; one as a comparison to the previous assessment (1994 configuration) and one as a "parallel" to the AD model (1998 configuration). Neither stock synthesis configuration is presented in detail here.

The two key features of the AD model were (1) the parameterization of the expected catches at age and (2) the definitions of the sampling unit for the different types of data input. The parameterization chosen mostly affected parameter bias whereas the sampling unit designation mostly affected estimator variance. Both bias and variance were components of overall parameter uncertainty. The parameterization and the sampling unit definitions were designed to conform to the actual sampling protocol used, thereby propagating sampling uncertainty through to the final biomass estimates.

The first key feature, parameterization, was designed to minimize assumptions on the population dynamics. A fully parameterized model included (a) yearly fishing mortalities, (b) initial numbers at sex/age, (c) selectivity by fishery/sex/age and (d) natural mortality by sex/age. In a fully parameterized model the fishing mortalities, initial numbers and selectivities were not constrained. Natural mortality was constrained to fit a four-parameter logistic function where two of the parameters were estimated. Simulation studies conducted on fully parameterized models provided empirical evidence that the estimators and estimator variances were approximately unbiased. Additionally, they showed the estimators were approximately normally distributed.

The model for the black rockfish data included constraints on selectivity and natural mortality. When the black rockfish data were introduced into a fully parameterized model, the estimated selectivity parameters showed no discernible patterns by sex or age. Since there was not enough information in these data to estimate selectivity well, we assumed a selectivity pattern and fixed selectivity parameters at a fully selected rate for all but the youngest ages. Based on the assumptions made for the 1994 assessment (Wallace and Tagart, 1994), a constant rate of natural mortality was assumed for males and age specific rate for females. However those rates were estimated internally in the model. The remaining population's dynamics parameters were freely estimated.

The second key feature, sampling unit definition, affected both catch age data as well as tagging data. For the catch age data, the sampling unit was defined as the "basket" or boat rather than the individual fish to mimic the port sampling procedure. The collection of "baskets" yielded empirical estimates of variance among the proportion at age vectors. Those variances were explicitly fixed into the likelihood functions describing catch at age.

For the tagging data, the sampling unit was the individual tag. This designation yielded a multinomial likelihood function where the tag recovery probabilities were calculated from the catch at age population dynamics parameters and an independently estimated tag loss rate. The recovery probabilities were also a function of a tag-reporting rate. However, the reporting rate was unknown in 1988-1994. Because of changes to the tag sampling protocol, the reporting rate in 1998 was equal to the proportion of the catch that was sampled and thus was treated as known.

Testing demonstrated that the final model converged reliably to the same solution. Initial parameter seeds were forced away from the maximum likelihood estimates by randomly generated deviations up to 10% of the original estimate. With this level of perturbation, virtually 100% of runs converged at the original maximum likelihood estimates. With a 50% perturbation approximately two-thirds of the runs converged to the original maximum likelihood estimates.

AD Model Outcomes

Initial attempts to estimate selectivity parameters using the AD model were abandoned after observing that the unconstrained estimates were highly variable from age to age. The apparent instability in these parameter estimates implied that there was too little information within the age data to obtain reliable independent selectivity estimates. Consequently, we fixed the sport and line fishery selectivity parameter values at 50% for age 6, 80% for age 7 and 100% thereafter; and, we fixed the trawl fishery selectivity at 10, 30, 65 and 100% for the age 6 through 9+ age groups. These values were consistent with catch curve estimates as well as estimates from the 1998 stock synthesis model.

Natural mortality was held constant for male black rockfish but was allowed to increase with age for females. The mortality rate was estimated by the model. However, mortality rates varied proportionately with the change in tag reporting rate. Estimated male natural mortality ranged from 0.24 at the 25% tag-reporting rate to 0.41 at the 75% reporting rate. Female mortality estimates at age 6 were lower than those for males but they were nearly double the male rate by age 16+. Female mortality rates ranged from 0.16 to 0.54 for the 25% tag reporting rate, and from 0.34 to 0.70 for the 75% rate. Model estimates of natural mortality were higher than those determined from the 1981 catch curve analysis (0.18 for males and 0.26 for females). It may be that black rockfish experienced more severe environmental conditions over the past decade than they did during the 1970s, the period affecting survival illustrated by the 1981 catch curve.

Total stock biomass varied with tag-reporting rate, with beginning (1986) biomass highly variable and ending biomass nearly constant. In general the biomass trend is shown to have declined since 1986. Minimum stock biomass ranged from 18 to 48% of maximum biomass over the 13 year interval. Beginning biomass ranged from 25 kmt at the 75% tag-reporting rate to 7 kmt at the 25% rate. Ending biomass was approximately constant at just under 6 kmt. At the higher tag-reporting rates (> 25%), 1986 biomass was noticeably greater than that estimated by the previous assessment (Wallace and Tagart, 1994).

Like natural mortality and stock biomass, recruitment varied with tag-reporting rate. Estimated geometric mean number of age 6 recruits ranged from a low 800 thousand, to a high of 2.1 million fish. Recruitment was most variable at the 25% tag-reporting rate demonstrating a 6 fold change from minimum to maximum. The greatest degree of stability among the tagging rates reported was observed at the 50% tag-reporting rate reflecting a 3 fold change from minimum to maximum. The time series of spawner-recruit data is short (7 years) and there is no indication of a definitive spawner-recruit relationship. Estimated value of the Beverton-Holt spawner recruit function shape parameter (A) is 0.76 for data taken from the 50% tag-reporting rate outputs. The non-linear regression R^2 value is 0.07 and clearly not significant.

Spawning biomasses supporting recruitment over the past 7 years are very high in comparison to target spawning biomass estimated by the equilibrium yield model (as much as 10 times greater). Spawning biomass supporting upcoming recruitment is 25-50% of the values in the recent past, but still approximately double the equilibrium target spawning biomass (Table 1). Nevertheless, the reduced level of spawning biomass supporting incoming recruits over the next three years may indicate that lower levels of recruitment should be anticipated.

It should be noted that the number of recovered tags was a function of the total catch used in the model, whereas the actual catch that contributed to the observed tag recoveries, was only a fraction of the total catch. However, the tag reporting rate parameters could compensate for the process error. That is, if the true tag reporting rate were known, the process error could be overcome by multiplying the tag reporting rate by the fraction of the catch that actually contributed to the tag recovery data. The year specific product of reporting rate and correct fraction of the total catch could then be entered as a substitute "tag reporting rate". The new tag-reporting rate would incorporate the necessary adjustment for the portion of the catch that contributed to tag recovery.

Tag recovery data used in the model represent catches landed in Westport. These landings account for approximately 70% of the total black rockfish catch. Available empirical data on tag reporting rate suggest a 95% reporting rate. The "adjusted tag reporting rate" required by the model to evaluate these data is 0.66 (0.7*0.95). This implies that in order to overcome the model process error, outcomes associated with the 0.5 to 0.75 reporting rate would best represent the expectation that actual reporting rate was 0.95. Model runs that used a 50% reporting rate, represent a actual tag reporting rate of 0.71 and those using a 25% reporting rate are representative of an actual tag reporting rate of 0.35.

Projected Yield

Projected yields are calculated from a simple deterministic equilibrium yield model. Data inputs included estimates of 1998 numbers-at-age; age specific schedules for natural mortality, selectivity, weight, and maturity; and, an estimate of annual recruitment. Target exploitation rates were calculated such that 45% of the estimated unfished spawning biomass was preserved.

A decision table was prepared that portrays projected yield (catch biomass), spawning biomass, and total stock biomass over the next 5 years. Lower and upper bounds to the decision table represent adjustments based on the variance associated with total stock biomass. Separate outcomes are reported for four hypothetical tag-reporting rates: 75, 50 and 25% (Table 2). As noted above, model process error affected the actual tag reporting rate associated with each of these model runs; therefore users should focus on results from the 25-75% tag-reporting rate columns to avoid incorporating model process error.

Estimated 1999 stock biomass was 9,500 to 10,100 mt dependent on tag-reporting rate. Spawning biomass in 1998 was 178 to 201% of the equilibrium spawning biomass associated with an F45% exploitation rate. Projected biomass is expected to decline over the next 5 years (Figure 1). Nevertheless, estimated spawning biomass in the year 2001 will still be 130 to 175% of the target biomass. The expected average yield over the next three years ranges from 655 to 864 mt. This is contrasted with the current sport fishing catch biomass of 254 mt.

Under the most pessimistic scenario, current catch exceeded the estimated average yield over the next three years by about 10-20%. Therefore, the black rockfish stock can be characterized as declining in abundance but healthy, i.e., displaying abundance levels in excess of those assumed to promote sustainable production.

Table 1. AD model biomass projections based on a range of tag-reporting rates and +/- 2CV's.

		Tag Reporting Rate								
Model	**Quantity**	**75%**	**50%**	**25%**	**75%**	**50%**	**25%**	**75%**	**50%**	**25%**
+ CV	Total Biomass 1998				10,136	9,747	9,511			
	Spawning Biomass 1998				1,615	1,522	1,463			
	SPB(1998)/SPB(EQ)				201%	199%	178%			
	Total Biomass 2001				8,857	7,886	7,543			
	Spawning Biomass 2001				1,040	1,097	1,435			
	Mean Catch (1999-2001)				1,459	1,274	1,118			
	SPB(2001)/SPB(EQ)				129%	143%	175%			
	SPR Rate				**45%**					
	EQ Recruitment (x1000)				3,509	2,609	1,511			
	EQ Unfished Spawning Biomass				1,786	1,701	1,826			
	EQ Spawning Biomass				804	765	822			
	EQ Fishing Mortality				0.237	0.211	0.166			
	EQ Catch				1,239	980	699			
Mean	Sport Catch Biomass 1998	254			254			254		
	Total Biomass 1998	6,004	5,741	5,575	6,004	5,741	5,575	6,004	5,741	5,575
	Spawning Biomass 1998	957	897	858	957	897	858	957	897	858
	SPB(1998)/SPB(EQ)	226%	224%	200%	201%	199%	178%	181%	179%	160%
	Total Biomass 2001	5,040	4,458	4,242	5,246	4,645	4,421	5,430	4,811	4,582
	Spawning Biomass 2001	570	601	793	616	646	841	657	687	885
	Mean Catch (1999-2001)	987	855	744	864	750	655	753	656	574
	SPB(2001)/SPB(EQ)	135%	150%	185%	129%	143%	175%	124%	137%	165%
	SPR Rate	**40%**			**45%**			**50%**		
	EQ Recruitment (x1000)	2,078	1,536	886	2,078	1,536	886	2,078	1,536	886
	EQ Unfished Spawning Biomass	1,058	1,002	1,070	1,058	1,002	1,070	1,058	1,002	1,070
	EQ Spawning Biomass	423	401	428	476	451	482	529	501	535
	EQ Fishing Mortality	0.283	0.250	0.196	0.237	0.211	0.166	0.199	0.178	0.141
	EQ Catch	807	632	444	734	577	410	663	523	376
- CV	Total Biomass 1998				1,871	1,735	1,639			
	Spawning Biomass 1998				298	271	252			
	SPB(1998)/SPB(EQ)				201%	199%	178%			
	Total Biomass 2001				1,635	1,403	1,300			
	Spawning Biomass 2001				192	195	247			
	Mean Catch (1999-2001)				269	227	193			
	SPB(2001)/SPB(EQ)				129%	143%	175%			
	SPR Rate				**45%**					
	EQ Recruitment (x1000)				648	464	260			
	EQ Unfished Spawning Biomass				330	303	315			
	EQ Spawning Biomass				148	136	142			
	EQ Fishing Mortality				0.237	0.211	0.166			
	EQ Catch				229	174	121			

Abbreviations: CV, coefficient of variation; SPB, spawning biomass; EQ, equilibrium; SPR rate, the fraction of the spawning biomass preserved under equilibrium conditions.

Units: Biomass and catch are in metric tons; Recruitment is in thousands of fish; Fishing mortality is the average instantaneous fishing mortality across all recruitable ages 6 to 16+.

Definition: Equilibrium quantities are values required to sustain production such that a fixed fraction of the unfished spawning biomass is preserved.

Table 2. Biomass trend based on a range of tag-reporting rates and +/- 2CV's.

1999 Black Rockfish AD Model Results

	F45% + CV			F45% Mean			F45% - CV			F40% Mean			F50% Mean		
YEAR	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass
	75% Tag Reporting Rate														
1999	10,354	1,513	1,622	6,133	896	961	1,912	279	300	6,133	893	1,125	6,133	899	820
2000	9,384	1,239	1,426	5,559	734	844	1,733	229	263	5,414	701	959	5,683	762	739
2001	8,857	1,040	1,328	5,246	616	787	1,635	192	245	5,040	570	878	5,430	657	699
2002	8,588	914	1,279	5,087	542	758	1,586	169	236	4,856	491	839	5,297	588	679
2003	8,457	847	1,257	5,009	501	744	1,562	156	232	4,769	450	821	5,232	551	670
	50% Tag Reporting Rate														
1999	9,675	1,494	1,439	5,698	880	848	1,722	266	256	5,698	877	989	5,698	883	726
2000	8,581	1,283	1,252	5,054	755	737	1,527	228	223	4,926	725	836	5,165	782	647
2001	7,886	1,097	1,131	4,645	646	666	1,403	195	201	4,458	601	741	4,811	687	594
2002	7,479	959	1,062	4,405	565	625	1,331	171	189	4,195	514	689	4,597	612	563
2003	7,245	866	1,023	4,267	510	602	1,289	154	182	4,050	458	661	4,469	560	545
	25% Tag Reporting Rate														
1999	9,441	1,604	1,248	5,534	940	732	1,627	277	215	5,534	938	849	5,534	942	629
2000	8,402	1,548	1,118	4,925	907	655	1,448	267	193	4,812	879	741	5,025	932	576
2001	7,543	1,435	988	4,421	841	579	1,300	247	170	4,242	793	642	4,582	885	518
2002	6,915	1,301	894	4,053	763	524	1,192	224	154	3,843	702	573	4,247	819	475
2003	6,445	1,161	825	3,778	681	484	1,111	200	142	3,557	615	525	3,985	743	442

AD Model Results (50% Tag Reporting Rate)

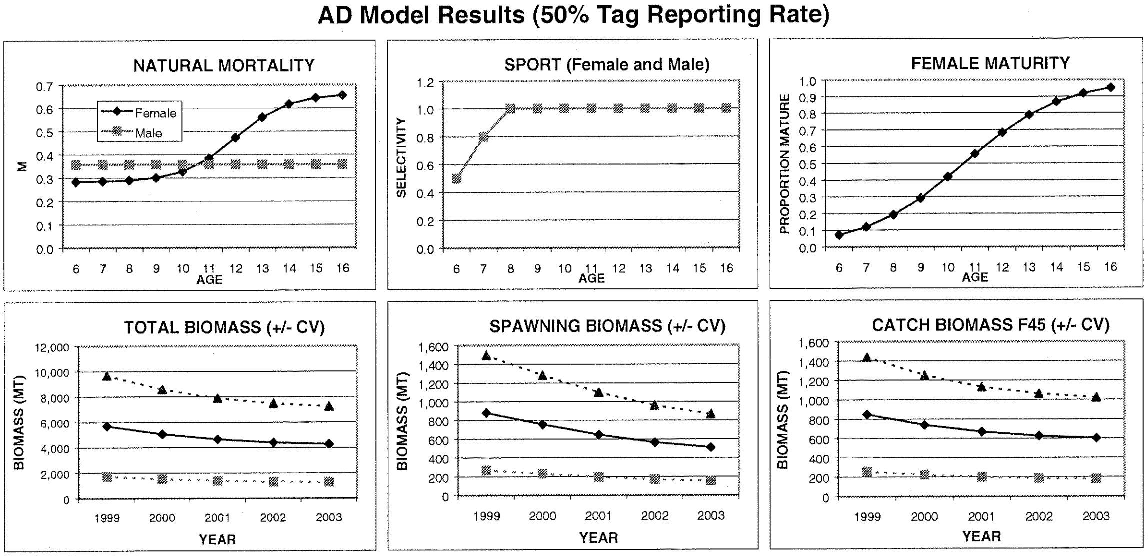

Figure 1. Biomass trend based on a 50% tag-reporting rate.