Status of the U.S. canary rockfish resource in 2005

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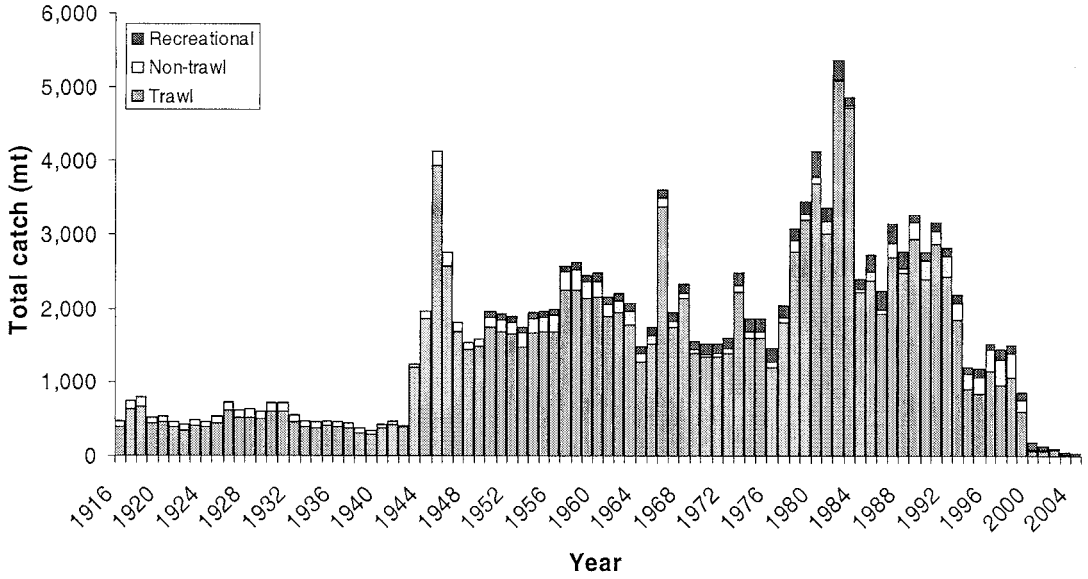
Executive Summary

Stock

This assessment reports the status of the canary rockfish (*Sebastes pinniger*) resource off the coast of the United States from southern California to the U.S.-Canadian border using data through 2004.

Catches

Catch of canary rockfish is first reported in 1916 in California. Since that time, annual catch ranged from 37.5 mt in 2004 to 5,374 in 1982 and totaled almost 150,000 mt over the time-series. Total catches since 1999 have been dramatically reduced relative to previous years in an attempt to rebuild a stock declared overfished in 2000 on the basis of the 1999 assessment. Canary rockfish catches have been primarily from the trawl fleets, on average comprising 85% of the annual catches, with the Oregon fleet removing as much as 3,864 mt in 1982. Historically just 10% of the catches have come from non-trawl commercial fisheries, although this proportion reached 24% and 350 mt in 1997. Recreational removals have averaged just 6% of the catches but have become relatively more important as commercial landings have been substantially reduced in recent years; recreational catches reached 60% of the total with 29 mt caught in 2003.



Catch history by major source, 1916-2004.

Recent commercial fishery catches (mt) by fleet.

Year	Southern California trawl	Northern California trawl	Oregon trawl*	Washington trawl*	Southern California non-trawl	Northern California non-trawl	Oregon-Washington non-trawl
1995	32.54	106.46	544.21	153.76	53.94	60.59	116.36
1996	102.23	116.13	744.34	184.91	84.90	51.48	164.04
1997	32.37	142.41	577.41	204.76	29.83	74.89	248.11
1998	9.52	149.46	712.26	201.23	23.42	56.84	245.13
1999	7.44	97.20	350.41	143.49	8.47	28.29	120.48
2000	1.71	10.92	29.78	28.96	2.52	5.53	7.98
2001	1.32	9.55	29.02	21.80	1.60	4.96	9.62
2002	0.36	14.48	33.51	35.45	0.02	0.08	2.62
2003	0.23	0.40	6.86	6.91	0.00	0.08	4.48
2004	0.80	2.55	13.52	8.04	0.02	0.08	4.89

* Includes at-sea whiting catches.

Data and Assessment

This assessment used the Stock Synthesis 2 model which is an integrated length-age structured model. This assessment includes catch, length- and age-frequency data from 10 fishing fleets, including trawl, non-trawl and recreational sectors. The National Marine Fisheries Service (NMFS) triennial bottom trawl survey biomass index is included to provide direct information on trends in stock abundance.

Several alternative model configurations were investigated in order to best understand the patterns and information in the canary rockfish data. These included specification of age vs. length-based selectivity, incorporating changes in ageing criteria and re-estimating growth parameters to reflect these changes, allowing female selectivity to differ from male selectivity, and other factors. A model configuration with female length-selectivity set equal to male length-selectivity was presented to the STAR panel in August as the proposed base model. This differed from the 2002 assessment that used age-based selectivity and allowed a male-female difference, but was considered a preferred configuration due to the preponderance of length data and the difference in maximum size between males and females. During the STAR panel review, it was found that allowing female length-selectivity to differ from male length-selectivity provided a somewhat better statistical fit to the fishery age and length composition data and this configuration was selected at that time as the base model, documented in the Aug 31, 2005 version of the assessment document, and used for the first draft of the rebuilding analysis in September 2005.

At the SSC review of the canary rockfish assessment (Sept. 27-30, 2005; Seattle, WA) several issues that had not been specifically examined in the assessment (trawl survey catchability, recruitment variability, and juvenile recruitment survey) were considered. The results are summarized in Appendix A to this assessment report. The SSC recommended no major changes to the base model. However, they concluded that the parametric variance around a single base model underestimated the overall uncertainty in the canary rockfish assessment. After re-examining some of the sensitivity

analyses included in the assessment, the SSC concluded that the alternative configuration of the male-female selectivity parameters was plausible to include. The two model scenarios are labeled here as Base (Diff configuration – with female length-selectivity allowed to differ from male length-selectivity) and Alternate (NoDiff configuration - with no difference allowed). After considerable deliberation, the SSC concluded that the Base and Alternate models were equally likely and they supported a statistically based blend of the two models as the basis for the rebuilding analysis. This final version of the canary rockfish 2005 assessment has been revised to include the alternate model and to document the results used in the rebuilding analysis. The rebuilding analysis is configured to incorporate 3 sources of uncertainty: two model configurations, probability profile on the spawner-recruitment steepness for each model configuration, and the annual variability in future recruitments.

Unresolved Problems and Major Uncertainties

Parameter uncertainty is explicitly captured in the asymptotic confidence intervals reported throughout this assessment for key parameters and management quantities. These intervals reflect the uncertainty in the model fit to the data sources included in the assessment, but do not include uncertainty associated with alternative model configurations, weighting of data sources (a combination of input sample sizes and relative weighting of likelihood components). Specifically, there appears to be conflicting information between the length- and age-frequency data regarding the degree of stock decline, making the model results sensitive to the relative weighting of each. This issue is explored in the assessment, but cannot be fully resolved at this time. The final model configuration includes a base model and an alternate model that differs only in the degree of flexibility in some selectivity curves, yet results is a difference in the estimated current stock abundance. The relationship between the degree of dome in the selectivity curves and the increase in female natural mortality with age remains a source of uncertainty, as it has been in previous assessments for both canary rockfish and yellowtail rockfish. We have used an approach to this problem similar to recent assessments, but there is little data available to resolve this issue and it will remain an area for further exploration in future assessments.

Regional Management Concerns

This assessment has addressed the spatial aspects of the coast-wide population through separation of data sources/fleets where possible and consideration of residual patterns that may be a result of inherent stock structure. Previous assessments concluded that separate models for northern and southern stocks produce very similar results to coast-wide analyses for canary rockfish (Methot and Piner, 2002), and we find no compelling cause to divide this assessment into separate spatial areas. As noted in the research recommendations, the STAT team does support investigation of spatial patterns in canary rockfish aggregations and movement toward an assessment that includes the portion of the canary rockfish stock that resides in Canadian waters.

Reference Points

Unfished spawning stock biomass was estimated to be 34,798 mt in the Base model and 33,872 mt in the Alternate model configuration. The blended estimate across the steepness probability distributions and the two models is 34,155 mt. The target stock size (SB40%) is therefore 13,662 mt. Maximum sustained yield (MSY) was estimated in the assessment model to occur at a spawning stock biomass of 15,584 mt (base) to 13,418 mt (alternate) and produce a MSY catch of 822 mt (base) and 1,168 mt in the Alternate. The estimate of generation time is 22.8 years, an increase from the 2002 estimate of 19 years due to the decrease in the estimate of the natural mortality rate for old female canary rockfish from 0.12 to 0.09.

Summary of canary rockfish reference points.

Quantity	Model = DIFF		Model = NODIFF	
	Estimate	~95% Confidence interval	Estimate	~95% Confidence interval
Unfished spawning stock biomass (SB_0, mt)	34,798	32,067-37,529	33,872	30,938-36,806
Unfished summary (age 3+) biomass (mt)	93,315	NA	87,621	NA
Unfished recruitment (R_0, thousands)	4,728	4,326-5,167	4,357	3,982-4,766
Spawning stock biomass at MSY (SB_{msy})	15,584	13,817-17,351	13,418	11,270-15,566
Basis for SB_{msy}	Estimated	NA	Estimated	NA
Recruitment-Spawner steepness	0.329	0.271 – 0.387	0.449	0.349 – 0.550
SPR_{msy}	72.9%	NA	58.1%	NA
Basis for SPR_{msy}	Estimated	NA	Estimated	NA
Exploitation rate corresponding to SPR_{msy}	0.020	NA	0.033	NA
MSY (mt)	822	598-1,046	1,168	905-1,430

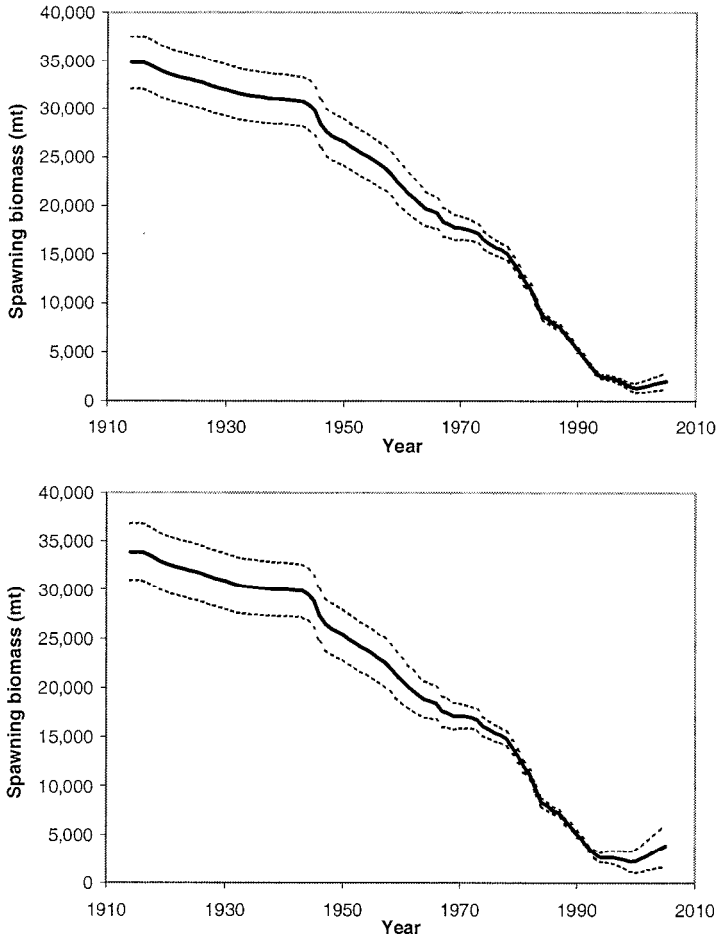
Summary of recent trends in canary rockfish abundance and exploitation levels; all values reported at the beginning of the year

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total catch (mt)	1,190	1,531	1,441	1,513	856	181	123	104	48	38	NA
Landed catch (mt)	1,020	1,298	1,230	1,285	731	141	86	66.5	38.5	22.0	NA
ABC (mt)	1,250*	1,250*	1,220*	1,045*	1,045*	287	228	228	272	256	270
OY	850*	850*	1,000*	1,045*	857*	200	93	93	44	47.3	46.8
Base Model = DIFF											
SPR	0.160	0.114	0.104	0.081	0.130	0.518	0.642	0.705	0.840	0.885	NA
Age 3+ biomass (mt)	7,382	6,933	6,087	5,258	4,287	3,889	4,118	4,368	4,601	4,847	5,066
Spawning biomass (mt)	2,409	2,318	2,060	1,781	1,443	1,319	1,442	1,580	1,717	1,862	1,995
~95% interval	2,177-2,641	2,057-2,579	1,760-2,359	1,433-2,129	1,037-1,850	847-1,791	901-1,983	966-2,195	1,027-2,406	1,100-2,625	1,163-2,827
Recruitment (1000s)	547	374	366	824	276	196	327	380	407	436	466
~95% interval	315-949	204-686	188-710	466-1458	131-585	89-427	138-776	148-978	158-1,051	169-1,127	184-1,182
Depletion	0.069	0.067	0.059	0.051	0.041	0.038	0.041	0.045	0.049	0.054	0.057
~95% interval	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.030-0.077	0.032-0.083
Alternate = NODIFF											
SPR	0.188	0.142	0.144	0.127	0.228	0.687	0.780	0.819	0.913	0.937	NA
Age 3+ biomass (mt)	9,159	9,010	8,510	8,050	7,460	7,439	8,063	8,695	9,289	9,875	10,417
Spawning biomass (mt)	2,658	2,668	2,531	2,395	2,212	2,252	2,544	2,865	3,187	3,518	3,829
~95% interval	2,093-3,222	2,015-3,321	1,772-3,290	1,512-3,278	1,188-3,236	1,069-3,435	1,183-3,905	1,311-4,418	1,435-4,940	1,570-5,467	1,690-5,969
Recruitment (1000s)	1,040	745	728	1,737	605	462	799	966	1,053	1,134	1,182
~95% interval	530-2,039	362-1,531	331-1,601	876-3,448	255-1,439	190-1,125	303-2,106	342-2,728	376-2,949	408-3,152	438-3,190
Depletion	0.078	0.079	0.075	0.071	0.065	0.066	0.075	0.085	0.094	0.104	0.113
~95% interval	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.042-0.165	0.046-0.181

* Covers U.S. Vancouver and Columbia INPFC areas only.

Stock Biomass

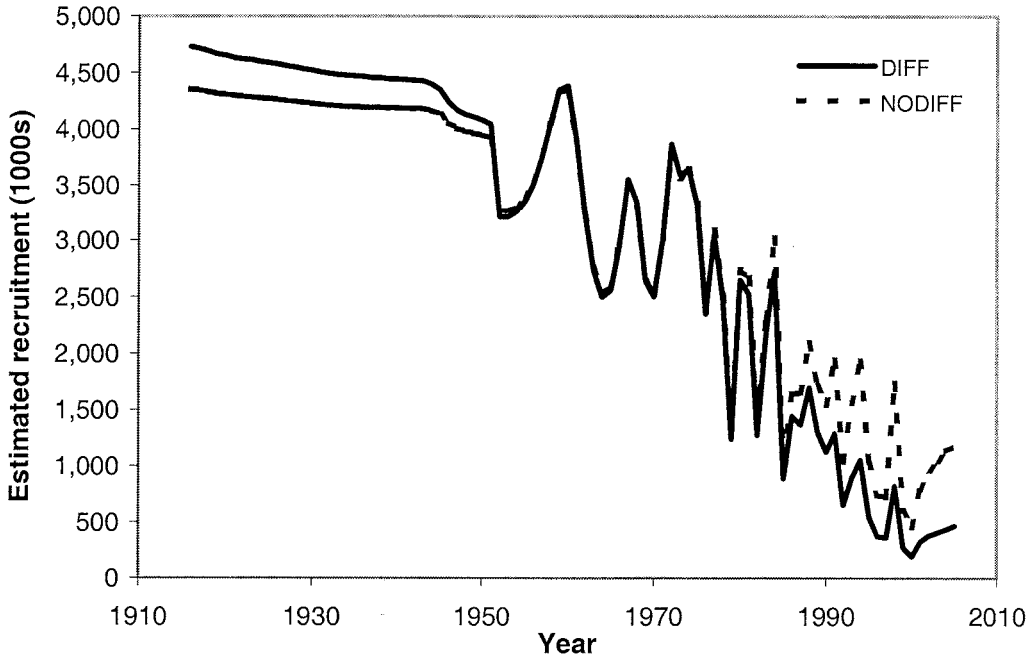
Canary rockfish were relatively lightly exploited until the early 1940's, when catches increased and a decline in biomass began. The rate of decline in spawning biomass accelerated during the late 1970s, and finally stabilized in the late 1990s in response to management measures. The canary rockfish spawning stock biomass reached an estimated low in 2000, but has been increasing since that time. The estimated relative depletion level in 2005 is 5.7% in the base model and 11.4% in the alternate model. The 95% confidence interval is based upon the model's analytical estimate of the variance near the converged solution in the base model configuration. The rebuilding analysis incorporates a fuller range of uncertainty by including both models and the estimated probability distribution of an important parameter, spawner-recruitment steepness, for each model.



Estimated spawning biomass time-series with approximate asymptotic 95% confidence interval for the base-Diff (left) and alternate-NoDiff (right) models.

Recruitment

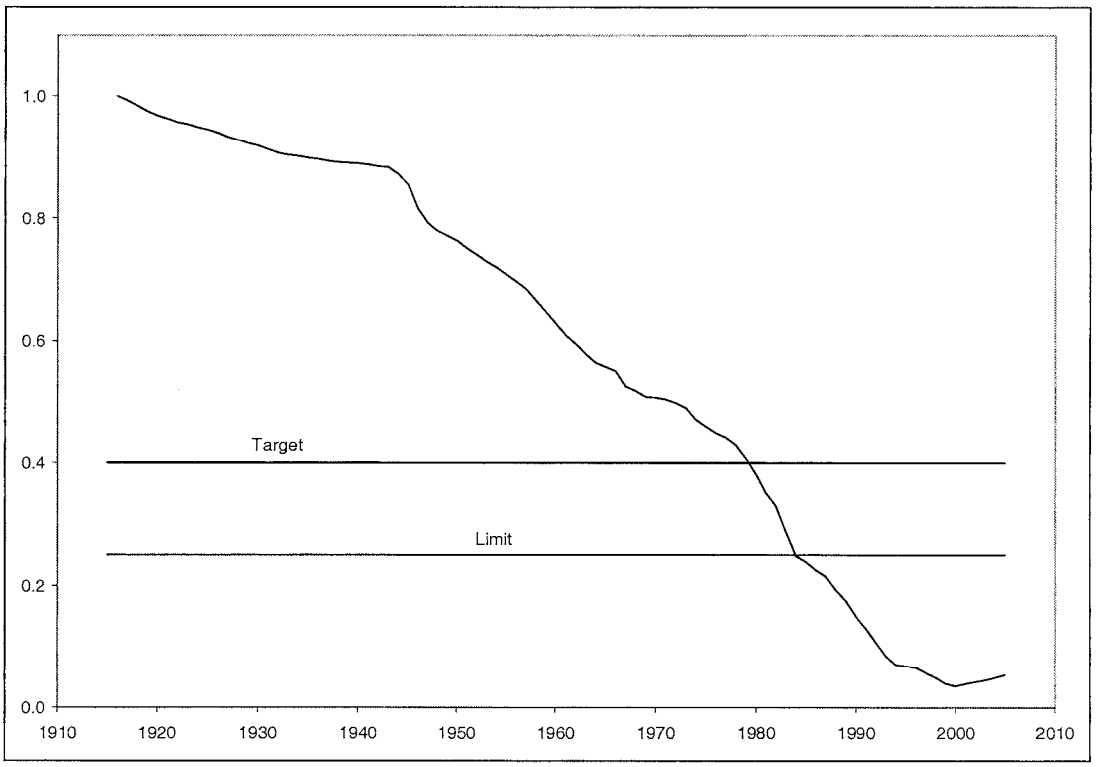
Canary rockfish recruitment has shown a steady decline over the last 50 years, closely tracking the decline in spawning stock biomass. Recent recruitments have generally been low, with 1998 producing the largest estimated recruitment in the last decade. However, there is little information in the available data to inform the assessment model about recruitments subsequent to about 2001, so these estimates largely reflect the stock-recruitment function and will likely be updated in future assessments.



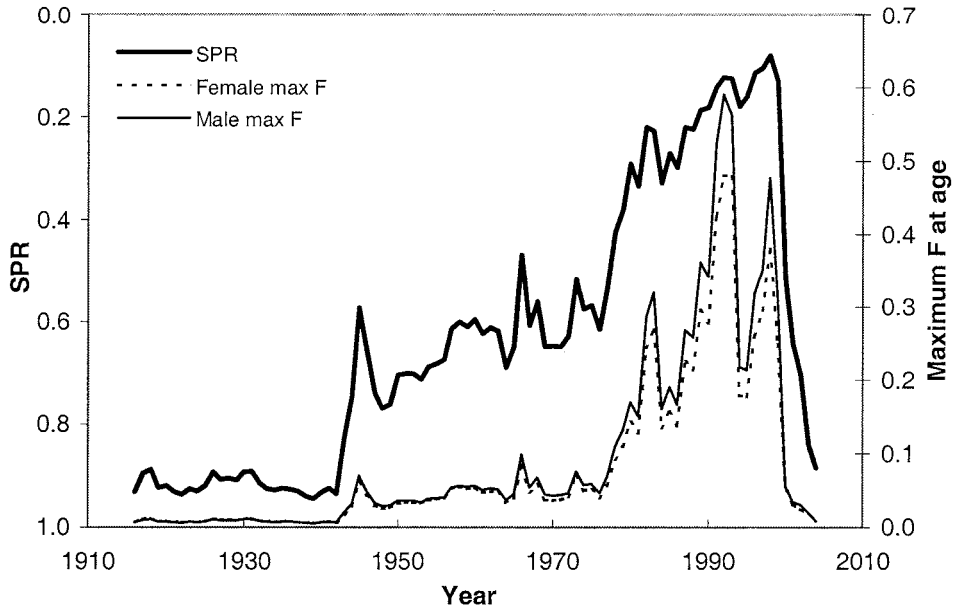
Time series of estimated canary rockfish recruitments.

Exploitation Status

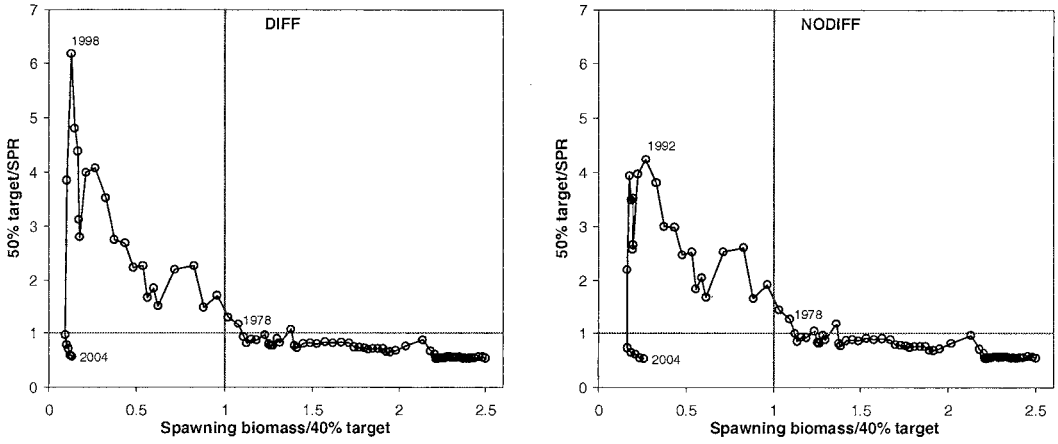
The abundance of the canary rockfish stock was estimated to have dropped below the SB40% management target in the late 1970s and the overfished threshold in the mid-1980s. In hindsight, the spawning stock biomass passed through the B_{msy} level in about 1980, at which time the annual catch was more than double the current estimate of the MSY level. The stock remains depleted, although the spawning stock biomass appears to be increasing. Harvest rates in excess of the current F-target for rockfish of SPR50% is estimated to have begun in the late 1970s and persisted through 1999. Recent management actions appear to have curtailed the rate of removal such that overfishing has not occurred since 1999, and recent SPR values are in excess of 90%.



Time series of depletion level as estimated in the Base model.



Time series of estimated spawning potential ratio (SPR) and maximum age- and sex-specific exploitation rate (labeled F here). Values of SPR below 0.5 reflect harvests in excess of the current F_{MSY} proxy. Only the base model result is shown.



Phase plot of estimated fishing intensity vs. stock abundance. Fishing intensity is the 50% target SPR divided by the annual SPR level. Stock abundance is annual spawner abundance divided by the 40% rebuilding target.

Management Performance

Total catches have decreased dramatically in response to reductions in trip limits and spatial closures driven by the overfished status of canary rockfish declared in 1999 and the corresponding drop in ABC and OY levels. In recent years the total mortality has been near the OY but well below the ABC. Since the overfished determination in 1999, the total 5-year catch (493 mt) has been only 3% above the total OY for 2000-2004. The

current annual catch (~45 mt) is only 1% of the peak catch that occurred in the early 1980's.

Forecasts and Rebuilding Projections

The forecast reported here is taken from the rebuilding analysis. The total catch in 2005 and 2006 is set equal to the established OY for these years. The exploitation rate for 2007 and beyond is based upon an SPR of 88.7%, which approximates the harvest level in the current rebuilding plan. Uncertainty in the rebuilding forecast is based upon inclusion of a base and alternate model with 50% probability each, a probability profile of spawner-recruitment steepness for each model, and random variability in recruitment deviations (sigmaR=0.40) for each rebuilding simulation. The final result blends across this uncertainty, so incorporates the probability that the current stock abundance and the future stock probability will differ from the "best" estimates represented by the base model and the alternate model. These forecasts predict slow and steady increases in abundance and catch. The following table shows the projection of expected canary rockfish catch, spawning biomass and depletion. Calculations are based on the blended base and alternate models as estimated in the rebuilding analysis with status quo exploitation rate.

Year	Total catch (mt)	Spawning biomass (mt)	Depletion
2005	46.8	2743	0.081
2006	47.1	2930	0.087
2007	43.2	3091	0.091
2008	44.5	3225	0.095
2009	45.1	3335	0.099
2010	46.4	3432	0.101
2011	48.6	3528	0.104
2012	51.1	3627	0.106
2013	54.1	3706	0.108
2014	56.5	3798	0.111
2015	58.7	3901	0.114
2016	61.0	4014	0.117

Decision table

A decision table approach is not taken here because of the established rebuilding plan for canary rockfish.

Research and Data Needs

A number of research topics would substantially improve the ability of this assessment to reliably and precisely model canary rockfish population dynamics in the future and provide better monitoring of progress toward rebuilding:

1. Expanded Assessment Region: Given the high occurrence of canary rockfish close to the US-Canada border, we recommend a joint US-Canada assessment in the future.

2. Pre-recruit surveys: Although the central California midwater trawl juvenile rockfish survey was not included in the current assessment, we recommend further work to evaluate its applicability, especially because of recent efforts to expand the geographic scope of this type of survey.
3. Many assessments are deriving historical catch by applying various ratios to the total rockfish catch prior to the period when most species were delineated. A comprehensive historical catch reconstruction for all rockfish species is needed, to compile a best estimated catch series that accounts for all the catch and makes sense for the entire group.
4. Habitat relationships: The historical and current relationship between canary rockfish distribution and habitat features should be investigated to provide more precise estimates of abundance from the surveys, and to guide survey augmentations that could better track rebuilding. This assessment's description of spatial patterns in occurrence of large and small canary rockfish is a start on this investigation. Such studies could also assist determining the possibility of dome-shaped selectivity.
5. Rarity of old females: Given the premise of this and past assessments regarding the difference between age distributions of male and female canary rockfish, efforts should be undertaken that address this issue, including: (1) habitat-specific studies of the distribution of older male and female canary; (2) laboratory-based programs to rigorously evaluate the physiology of the two sexes. Current field studies to investigate occurrence of larger/older females can contribute information also, but comparison to the occurrence of older males will be difficult due to the reduction in occurrence of older males due to the long history of exploitation.
6. Meta-population model: The spatial patterns show patchiness in the occurrence of large vs. small canary; reduced occurrence of large/old canary south of San Francisco; and concentrations of canary rockfish near the US-Canada border. The feasibility of a meta-population model that has linked regional sub-populations should be explored as a more accurate characterization of the coast-wide population's structure.
7. Enhancements in the assessment model are needed to better address the statistical weighting of data from multiple, spatially distinct fishing fleets and the estimation of time-varying selectivity by these fleets.