Status of the U.S. canary rockfish resource in 2009 (Update of 2007 assessment model)

Ian J. Stewart
National Marine Fisheries Service
Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle WA, 98112
206-302-2447 (phone)
206-860-6792 (fax)
Ian.Stewart@noaa.gov

27 May, 2009

Table of Contents

Executive Summary

Stock

This updated 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 2008. As in 2007, the resource is modeled as a single stock.

Catches

The historical period (< 1981) of the catch history for canary rockfish has been substantially revised for this updated assessment. Historical reconstruction estimates from efforts by CDFG and NOAA scientists were made available and replaced existing estimates which dated back to the 2005 and earlier assessments. These older estimates assumed a constant percentage of canary rockfish in the total California landings, whereas the improved estimates now available allowed for changes in this percentage over time and fishing areas accounting for shifts in the fishery and the lower occurrence of canary in Southern California waters. The net result of this revision was a 24% reduction in the total estimated canary catch from 1916-2006 with most of this reduction occurring prior to 1968.

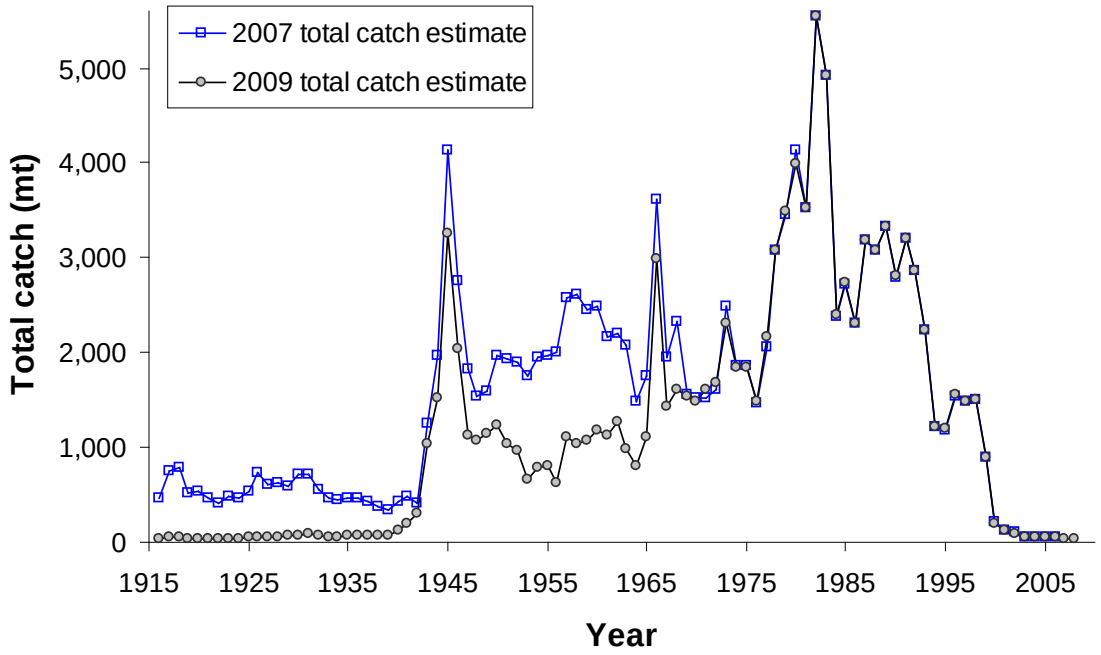

Figure a. Comparison of the 2007 and recently revised canary rockfish catch history, 1916-2008.

Recent canary rockfish catches were revised based on current total mortality estimates (2002-2007) and the GMT scorecard (2008). Where only aggregated catches were available, these were pro-rated to modeled fleets as was done in the 2007 assessment.

Table a. Recent canary rockfish catches (mt).

Year	Commercial trawl	Commercial non-trawl	At-sea whiting bycatch	Recreational	Research
1999	632.47	160.72	5.63	99.89	0.00
2000	12.63	18.29	2.35	95.52	0.00
2001	10.87	17.57	4.05	46.71	1.61
2002	16.13	5.26	5.24	17.34	0.13
2003	4.73	3.50	0.93	30.21	1.08
2004	2.24	9.35	5.22	16.35	2.24
2005	6.06	2.99	1.44	10.31	4.54
2006	6.53	3.55	1.09	22.01	7.78
2007	7.80	4.28	2.00	14.44	2.50
2008	8.47	6.20	5.96	12.50	2.90

Data and Assessment

This updated assessment used the newest version of Stock Synthesis available (3.03a, released 30 April 2009). Change in assessment results from 2007 due to Synthesis updates was negligible. The model data sources are unchanged, including updated catch, length- and age-frequency data from 11 fishing fleets. Biological data is derived from both port and on-board observer sampling programs. The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center (NWFSC) trawl survey relative biomass indices and biological sampling provide updated fishery independent information on relative trend and demographics of the canary stock. The Southwest Fisheries Science Center (SWFSC)/NWFSC/Pacific Whiting Conservation Cooperative (PWCC) coast-wide pre-recruit survey provides an updated source of recent recruitment strength information. The use of time varying selectivity (for commercial fisheries) and catchability (Triennial survey) is unchanged from the 2007 assessment.

As in 2007, the base case assessment model includes parameter uncertainty from a variety of sources, but underestimates the considerable uncertainty in recent trend and current stock status. For this reason, in addition to asymptotic confidence intervals (based upon the model's analytical estimate of the variance near the converged solution), two alternate states of nature regarding stock productivity (via the steepness parameter of the stock-recruitment relationship) are presented. The base case model (steepness = 0.51) is considered to be twice as likely as the two alternate states (steepness = 0.35, 0.72) based on the results of a 2007 meta-analysis of west coast rockfish (M. Dorn, personal communication). In order to best capture this source of uncertainty, all three states of nature will again be used as probability-weighted input to the rebuilding analysis.

Stock biomass

Updating all data sources through 2008 and including revised estimates of recent catch (1981-2008) could be considered the simplest form for an updated assessment. These new data resulted in a slightly more pessimistic view of the recent stock recovery trajectory, just inside the lower 95% confidence interval from the 2007 assessment. This downward revision of recent spawning biomass was not attributable to a single data source, but appears to be incrementally informed by each updated series.

Addition of the fully revised catch history reduced the scale of the entire time-series estimate of spawning biomass by an average of 14% (19% in the first 10 years of the series and 47% in the last 10). The central portion of the time-series estimates remained largely unchanged (~1960-1990).

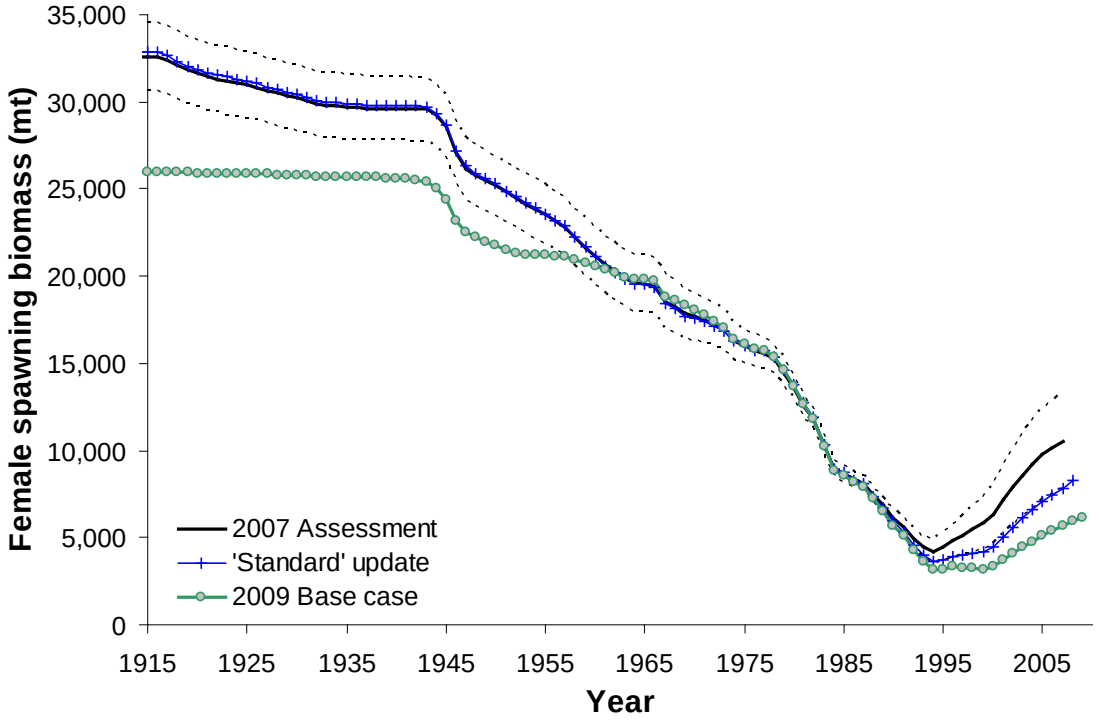

Figure b. Estimated spawning biomass time-series (1916-2009) for the 2007 assessment base case model (solid line) with approximate asymptotic 95% confidence interval (dashed lines), results of 'standard' update of recent data and catches (crosses), and 2009 base case model (round symbols).

Based on the revised catch series, canary rockfish were very lightly exploited until the early 1940's, when catches increased and a decline in biomass began. The spawning biomass experienced an accelerated rate of decline during the late 1970s, and finally reached a minimum (12% of unexploited, slightly below the estimate of 13% from the 2007 assessment) in the mid-1990s. The canary rockfish spawning stock biomass is estimated to have been gradually increasing since that time, in response to reductions in harvest and above average recruitment in the preceding decade. However, this trend is very uncertain. The estimated relative depletion level in 2007 is 21.7% (below the estimate of 32.4% from the 2007 assessment) and 23.7% in 2009 (~95% asymptotic interval: 16-28%, ~75% interval based on the range of states of nature: 9-40%), corresponding to 6,170 mt (5,642 in 2007, 54% of the 2007 estimate of 10,544 mt). The base model asymptotic interval for 2009 spawning biomass remains broad: 4,385-7,955 mt, and the states of nature interval: 2,459-10,244.

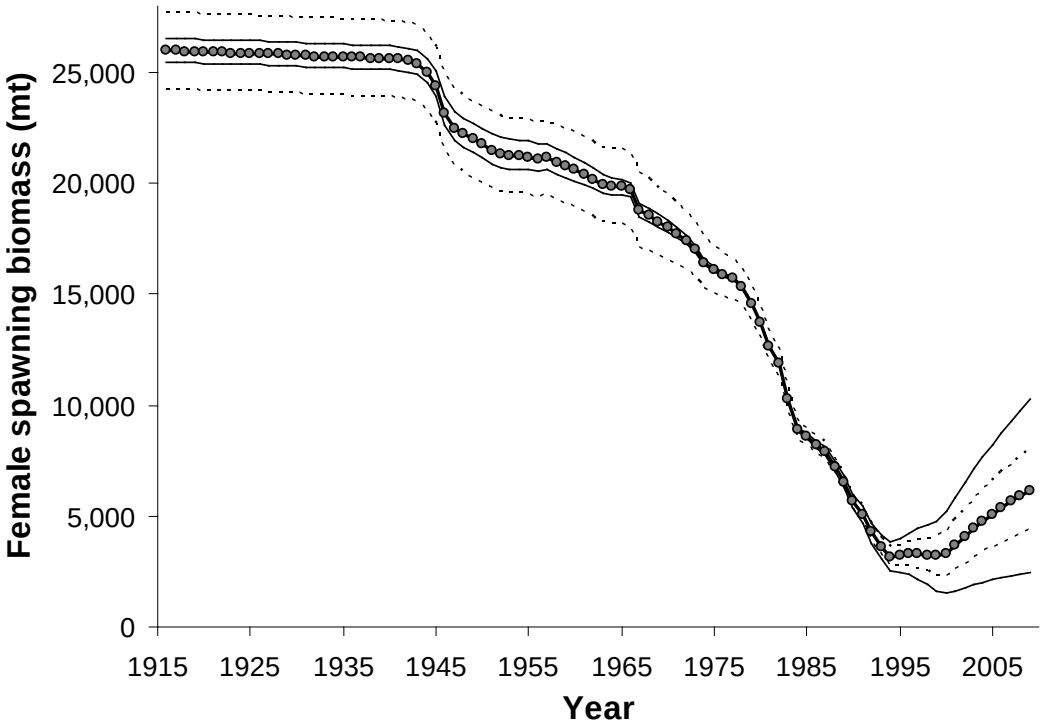

Figure c. Estimated spawning biomass time-series (1916-2009) for the base case model (round points) with approximate asymptotic 95% confidence interval (dashed lines) and alternate states of nature (light lines).

Table b. Recent trend in estimated canary rockfish spawning biomass and relative depletion level.

Year	Spawning biomass (mt)	~95% confidence interval	Range of states of nature	Estimated depletion	~95% confidence interval	Range of states of nature
2000	3,316	2,331-4,302	1,507-5,182	12.8%	9.2-16.4%	5.7-20.3%
2001	3,699	2,592-4,805	1,639-5,835	14.2%	10.2-18.3%	6.2-22.9%
2002	4,080	2,856-5,304	1,774-6,485	15.7%	11.2-20.2%	6.7-25.4%
2003	4,440	3,108-5,772	1,899-7,107	17.1%	12.2-21.9%	7.1-27.9%
2004	4,781	3,353-6,210	2,023-7,696	18.4%	13.2-23.6%	7.6-30.2%
2005	5,091	3,577-6,604	2,131-8,240	19.6%	14.1-25.1%	8.0-32.3%
2006	5,372	3,783-6,960	2,222-8,748	20.7%	14.9-26.4%	8.4-34.3%
2007	5,642	3,984-7,301	2,305-9,247	21.7%	15.7-27.7%	8.7-36.3%
2008	5,912	4,187-7,636	2,386-9,751	22.7%	16.5-29.0%	9.0-38.2%
2009	6,170	4,385-7,955	2,459-10,244	23.7%	17.3-30.2%	9.3-40.2%

Recruitment

The degree to which canary rockfish recruitment declined over the last 50 years is closely related to the level of productivity (stock-recruit steepness) modeled for the stock. High steepness values imply little relationship between spawning stock and recruitment, while low steepness values cause a strong positive correlation. After a period of above average recruitments, recent year-class strengths (1997-2008) have generally been low, with only 4 of the 12 years (1999, 2001, 2006, and 2007) producing large estimated recruitments (the 2009

recruitment is based only on the stock-recruit function). Because of the limited number of years they have been observed, the strengths of the 2006-2007 year classes are subject to greater uncertainty than other strong recruitment events in the last 30 years. As the larger recruitments from the late 1980s and early 1990s move through the population in future projections, the effects of recent poor recruitment may tend to slow the rate of recovery.

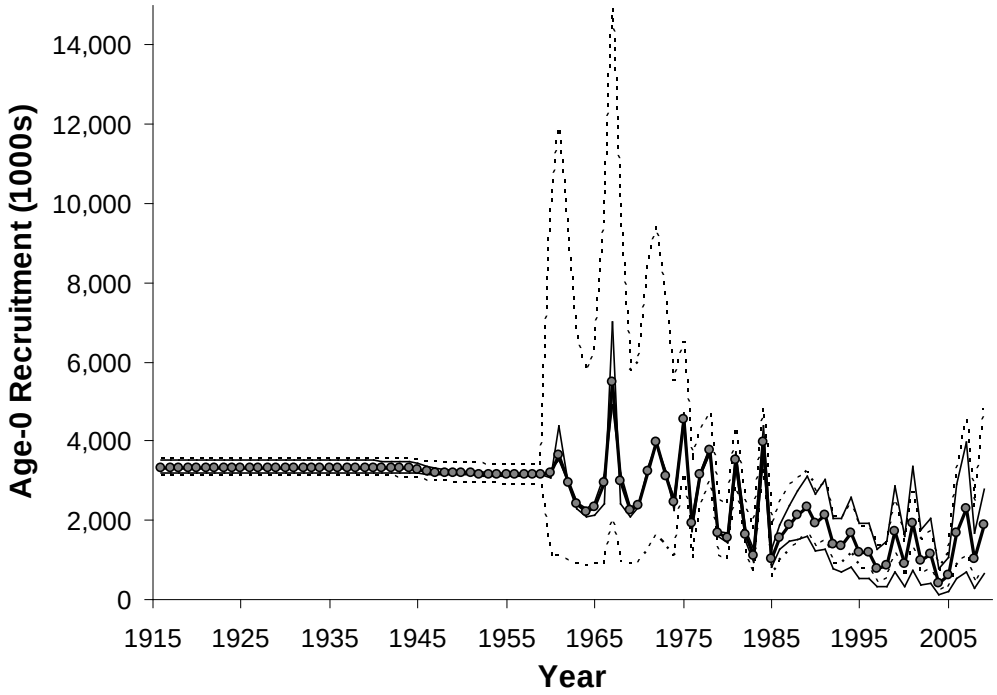

Figure d. Time series of estimated canary rockfish recruitments for the base case model (round points) with approximate asymptotic 95% confidence interval (dashed lines) and alternate states of nature (light lines).

Table c. Recent estimated trend in canary rockfish recruitment (1000s age-0).

Year	Estimated recruitment (1000s)	~95% confidence interval	Range of states of nature
2000	904	559-1,460	335-1,025
2001	1,936	1,361-2,754	735-2,491
2002	1,004	661-1,524	359-1,220
2003	1,148	761-1,733	400-1,416
2004	422	245-725	137-452
2005	594	306-1,156	185-556
2006	1,679	872-3,231	546-1,539
2007	2,276	1,143-4,530	715-2,004
2008	1,012	441-2,319	301-737
2009	1,886	734-4,848	636-1,104

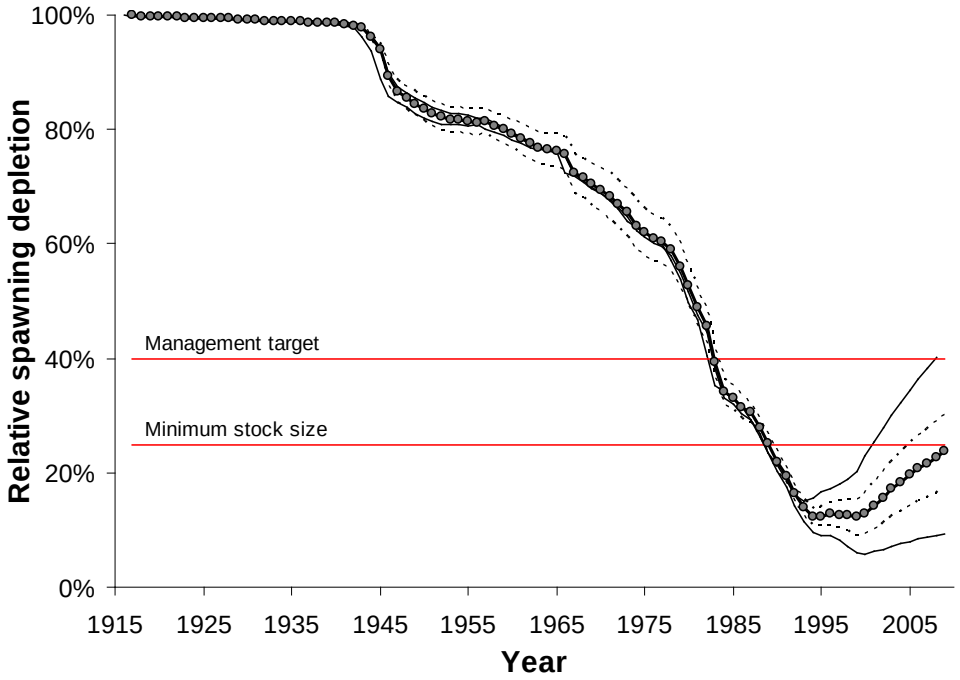

Figure e. Time series of depletion level as estimated in the base case model (round points) with approximate asymptotic 95% confidence interval (dashed lines) and alternate states of nature (light lines).

Reference points

Unfished spawning stock biomass was estimated to be 25,993 mt (down from the 2007 estimate of 32,561 mt) in the base case model. The target stock size ($SB_{40\%}$) is therefore 10,397 mt and the overfished threshold ($SB_{25\%}$) is 6,498 mt. Maximum sustained yield (MSY) applying current fishery selectivity and allocations (a 'bycatch-only' scenario) was estimated in the assessment model to occur at a spawning stock biomass of 9,928 mt and produce an MSY catch of 937 mt (down from 1,169 mt estimated in the 2007 assessment). This sustainable yield is achieved at an SPR of 53.0%, nearly identical to the estimate from the 2007 assessment (52.9%). This is nearly identical to the yield, 936 mt, generated by the SPR (54.4%) that stabilizes the stock at the $SB_{40\%}$ target. The fishing mortality target/overfishing level (SPR = 50.0%) generates a yield of 931 mt at a stock size of 8,909 mt. When selectivity and allocation from a 'target-fishery' in the mid 1990s (1994-1998) was applied, the MSY yield increased to 960 mt from a slightly larger stock size (9,949 mt), but nearly the same rate of exploitation (SPR = 53.0%). This is due to higher relative selection of older and larger fish when the fishery was targeting instead of avoiding canary rockfish. These yields are somewhat lower than those from the 2007 assessment.

Exploitation status

The abundance of canary rockfish was estimated to have dropped below the $SB_{40\%}$ management target in 1983 and the overfished threshold in 1990. In hindsight, the spawning stock biomass passed through the target and threshold levels at a time when the annual catch was averaging more than twice the current estimate of the MSY. The stock remains slightly below the overfished threshold (unlike the 2007 estimate), although the spawning stock biomass still appears to have been increasing since 1999. The degree of increase is very sensitive to the value

for steepness (state of nature), and is projected to slow as recent (and largely below average) recruitments begin to contribute to the spawning biomass. Fishing mortality rates in excess of the current F-target for rockfish of $SPR_{50\%}$ are 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 70% (> 90% since 2003). Relative exploitation rates (catch/biomass of age-5 and older fish) are estimated to have been less than 1% since 2001. These patterns are largely insensitive to the three states of nature.

Table d. Recent trend in spawning potential ratio (SPR) and relative exploitation rate (catch/biomass of age-5 and older fish).

Year	Estimated SPR (%)	Range of states of nature	Relative exploitation rate	Range of states of nature
1999	31.2%	14.5-42.7%	0.0928	0.1855-0.0613
2000	73.0%	50.8-81.6%	0.0204	0.0453-0.0130
2001	81.6%	63.8-87.9%	0.0127	0.0289-0.0080
2002	86.7%	72.8-91.3%	0.0088	0.0205-0.0055
2003	91.1%	80.3-94.4%	0.0051	0.0121-0.0032
2004	93.0%	84.3-95.6%	0.0040	0.0096-0.0025
2005	92.6%	83.4-95.3%	0.0046	0.0111-0.0028
2006	92.2%	81.9-95.2%	0.0044	0.0109-0.0027
2007	94.5%	86.7-96.7%	0.0031	0.0076-0.0019
2008	95.0%	87.9-97.0%	0.0027	0.0067-0.0016

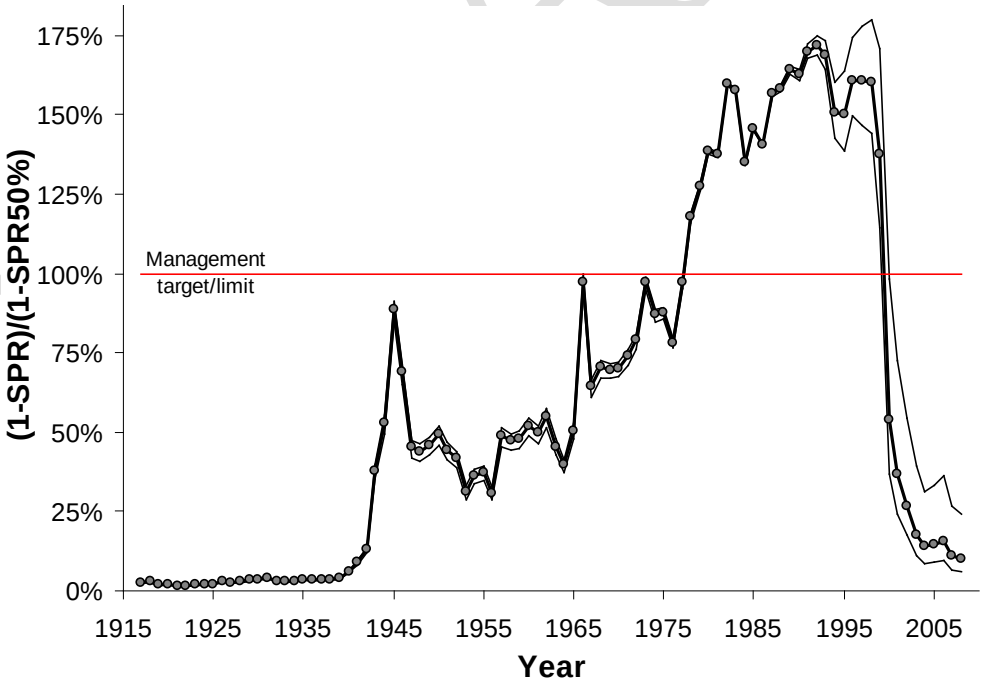

Figure f. Time series of relative spawning potential ratio ($1\text{-SPR}/1\text{-SPR}_{Target=0.5}$) for the base case model (round points) and alternate states of nature (light lines). Values of relative SPR above 100% reflect harvests in excess of the current overfishing proxy.

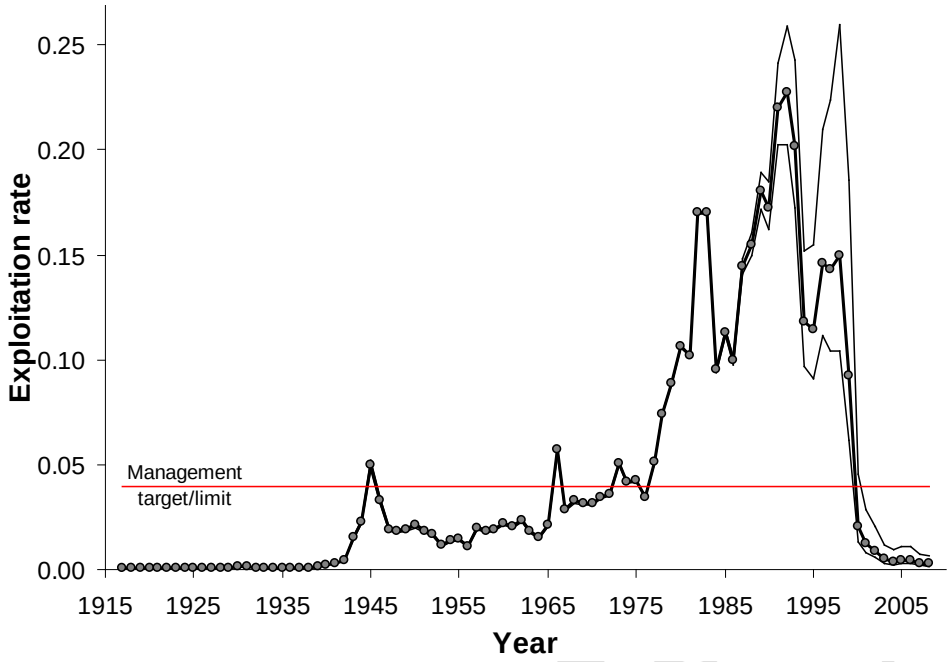

Figure g. Time series of estimated exploitation rate (catch/age 5 and older biomass) for the base case model (round points) and alternate states of nature (light lines). Horizontal line indicates the overfishing limit/target ($F_{50\%}$) from the base case.

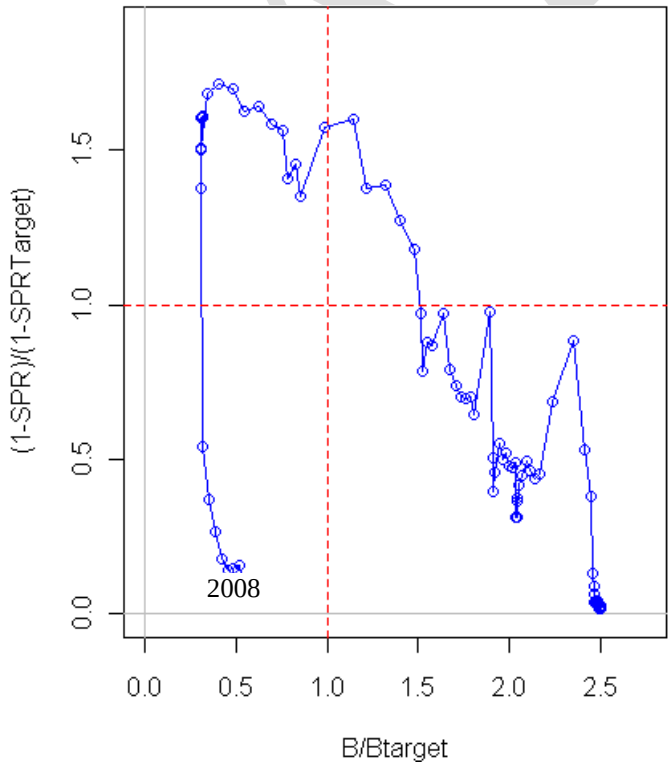

Figure h. Estimated relative spawning potential ratio relative to the proxy target/limit of 50% vs. estimated spawning biomass relative to the proxy 40% level from the base case model. Higher biomass occurs on the right side of the x-axis, higher exploitation rates occur on the upper side of the y-axis.

Management performance

Following the 1999 declaration that the canary rockfish stock was overfished, the canary OY was reduced by over 70% in 2000 and by the same margin again over the next three years. Managers employed several tools in an effort to constrain catches to these dramatically lower targets. These included: reductions in trip/bag limits for canary and co-occurring species, the institution of spatial closures, and new gear restrictions intended to reduce trawling in rocky shelf habitats and the coincident catch of rockfish in shelf flatfish trawls. In recent years, the total mortality has been slightly above the OY (higher in retrospect based on current methods used for total mortality estimates), but well below the ABC. Since the overfished determination in 1999, the total 9-year catch (749 mt) has been only 14% above the sum of the OYs for 2000-2006. This level of removals represents only 34% of the sum of the ABCs for that period. The total 2008 catch (40.5 mt) is <1% of the peak catch that occurred in the early 1980s.

Table e. Recent trend in estimated total canary rockfish catch and commercial landings (mt) relative to management guidelines.

Year	ABC (mt)	OY (mt)	Commercial landings (mt)[1]	Total Catch (mt)
1999	1,045[2]	857[2]	666.3	898.7
2000	287	200	55.7	199.9
2001	228	93	42.6	133.0
2002	228	93	47.8	98.1
2003	272	44	8.6	59.9
2004	256	47.3	10.7	50.3
2005	270	46.8	12.0	60.4
2006	279	47	7.3	62.0
2007	172	44	12.1	44.7
2008	179	44	9.4	40.5

[1]Excludes all at-sea whiting, recreational and research catches.
[2]Includes the Columbia and Vancouver INPFC areas only.

Unresolved problems and major uncertainties

As in the 2007 assessment, 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), or fixed parameters. 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 was not revisited as part of the update. The relationship between the degree of domed shape in the selectivity curves and the increase in female natural mortality with age remains a source of uncertainty that is included in model results, as it has been in previous assessments for canary rockfish. Uncertainty in the steepness parameter of the stock-recruitment relationship is significant and will likely persist in future assessments; this uncertainty is included in the assessment and rebuilding projections through explicit consideration of the three states of nature. Given the

change in this update caused by the revised historical California catch estimates, future assessments are likely to be sensitive to additional revised estimates from ongoing efforts in Oregon and Washington should they prove appreciably different from the time-series used here.

Forecasts

The forecast reported here will be replaced by the rebuilding analysis to be completed in September-October 2009 following SSC review of the stock assessment. In the interim, the total catch in 2009 and 2010 is set equal to the OY (105 mt). The exploitation rate for 2011 and beyond is based upon an SPR of 92.2%, which approximates the harvest level in the current rebuilding plan. As in 2007, uncertainty in the rebuilding forecast will be based upon the three states of nature for steepness and random variability in future recruitment deviations for each rebuilding simulation. Current medium-term forecasts predict slow increases in abundance and available catch, with OY values for 2011 and 2012 lower than those predicted from the 2007 assessment. The following table shows the projection of expected canary rockfish catch, spawning biomass and depletion.

Table f. Projection of potential canary rockfish ABC, OY, spawning biomass and depletion for the base case model based on the SPR = 0.922 fishing mortality target used for the last rebuilding plan (OY) and $F_{50\%}$ overfishing limit/target (ABC). Assuming the OY of 105 mt is achieved exactly in 2009 and 2010.

Year	ABC[1] (mt)	OY[1] (mt)	Age 5+ biomass (mt)	Spawning biomass (mt)	Depletion
2009	*981*	*105*	15,483	6,170	23.7%
2010	*980*	*105*	15,687	6,379	24.5%
2011	627	69	16,129	6,548	25.2%
2012	661	73	16,825	6,694	25.8%
2013	690	76	17,229	6,828	26.3%
2014	718	79	17,862	6,975	26.8%
2015	749	83	18,554	7,152	27.5%
2016	780	86	19,300	7,365	28.3%
2017	812	90	20,094	7,616	29.3%
2018	843	93	20,925	7,904	30.4%
2019	874	96	21,783	8,224	31.6%
2020	905	100	22,658	8,567	33.0%

[1]ABC/OY values for 2009 and 2010 have already been adopted, and are not based on the results of this update.

Decision table

The format of this decision table is unchanged from the 2007 assessment. Because canary rockfish is currently managed under a rebuilding plan, this decision table is only intended to better compare and contrast the base case with uncertainty among states of nature. The results of the rebuilding plan will integrate these three states of nature as well as projected recruitment variability. Further, various alternate probabilities of rebuilding by target and limit time-periods as well as fishing mortality rates will be evaluated in the rebuilding analysis. Relative probabilities of each state of nature are based on a meta-analysis for steepness of west coast rockfish (M. Dorn, AFSC, personal communication). Landings in 2009-2010 are 105 mt for all cases. Selectivity and fleet allocations are projected at the average 2006-2008 values.

Table g. Decision table of 12-year projections for alternate states of nature (columns) and management options (rows) beginning in 2011. Relative probabilities of each state of nature are based on a 2007 meta-analysis for steepness of west coast rockfish (M. Dorn, AFSC, personal communication). Landings in 2009-2010 are 105 mt for all cases. Selectivity and fleet allocations are projected at the average 2006-2008 values.

			State of nature					
			Low steepness (0.35)		Base case (steepness = 0.51)		High steepness (0.72)	
Relative probability			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)	Depletion	Spawning biomass (mt)
Rebuilding SPR 92.2% catches from low steepness state of nature	2011	25	9.4%	2,509	25.2%	6,548	43.3%	11,052
	2012	26	9.5%	2,535	25.8%	6,711	44.7%	11,397
	2013	27	9.6%	2,553	26.4%	6,862	46.0%	11,722
	2014	28	9.7%	2,572	27.0%	7,029	47.3%	12,068
	2015	29	9.8%	2,600	27.8%	7,228	48.8%	12,453
	2016	30	9.9%	2,639	28.7%	7,464	50.5%	12,876
	2017	31	10.1%	2,693	29.8%	7,741	52.3%	13,331
	2018	32	10.4%	2,761	31.0%	8,055	54.2%	13,813
	2019	33	10.7%	2,843	32.3%	8,403	56.1%	14,312
	2020	34	11.0%	2,934	33.8%	8,776	58.1%	14,820
Rebuilding SPR 92.2% catches from base case	2011	69	9.4%	2,509	25.2%	6,548	43.3%	11,052
	2012	73	9.5%	2,519	25.8%	6,694	44.6%	11,381
	2013	76	9.5%	2,519	26.3%	6,828	45.8%	11,688
	2014	79	9.5%	2,519	26.8%	6,975	47.1%	12,013
	2015	83	9.5%	2,525	27.5%	7,152	48.5%	12,376
	2016	86	9.6%	2,542	28.3%	7,365	50.1%	12,774
	2017	90	9.7%	2,571	29.3%	7,616	51.8%	13,205
	2018	93	9.8%	2,614	30.4%	7,904	53.6%	13,659
	2019	96	10.0%	2,668	31.6%	8,224	55.4%	14,131
	2020	100	10.3%	2,731	33.0%	8,567	57.3%	14,610
Rebuilding SPR 92.2% catches from high steepness state of nature	2011	118	9.4%	2,509	25.2%	6,548	43.3%	11,052
	2012	124	9.4%	2,500	25.7%	6,676	44.6%	11,362
	2013	129	9.3%	2,481	26.1%	6,790	45.7%	11,649
	2014	133	9.3%	2,460	26.6%	6,915	46.9%	11,952
	2015	137	9.2%	2,444	27.2%	7,069	48.2%	12,291
	2016	142	9.2%	2,437	27.9%	7,257	49.7%	12,665
	2017	146	9.2%	2,442	28.8%	7,483	51.3%	13,070
	2018	151	9.3%	2,460	29.8%	7,746	52.9%	13,498
	2019	155	9.4%	2,489	30.9%	8,039	54.7%	13,944
	2020	159	9.5%	2,526	32.1%	8,356	56.5%	14,397
Status quo (catch = 105 mt)	2011	105	9.4%	2,509	25.2%	6,548	43.3%	11,052
	2012	105	9.4%	2,507	25.7%	6,683	44.6%	11,369
	2013	105	9.4%	2,496	26.2%	6,806	45.7%	11,665
	2014	105	9.4%	2,485	26.7%	6,941	47.0%	11,978
	2015	105	9.3%	2,480	27.3%	7,106	48.3%	12,329
	2016	105	9.3%	2,485	28.1%	7,306	49.9%	12,715
	2017	105	9.4%	2,503	29.0%	7,546	51.5%	13,134
	2018	105	9.5%	2,536	30.1%	7,824	53.2%	13,578
	2019	105	9.7%	2,582	31.3%	8,135	55.1%	14,041
	2020	105	9.9%	2,637	32.6%	8,471	56.9%	14,514

Research and data needs

Progress on 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, a joint US-Canada assessment should be considered in the future.
2. Many assessments (including this one) have derived historical catch by applying various ratios to the total rockfish catch prior to the period when most species were delineated. Based on the sensitivity of this update to the revised catch history for California, a comprehensive historical catch reconstruction for all rockfish species is needed for Washington and Oregon as well.
3. 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 through targeted application of newly developed survey technologies. Such studies could also assist determining the possibility of dome-shaped selectivity, aid in evaluation of spatial structure and the use of fleets to capture geographically-based patterns in stock characteristics.
4. 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. Tagging of other direct information on adult movement will be essential to this effort.
5. Increased computational power and/or efficiency is required to move toward fully Bayesian approaches that may better integrate over both parameter and model uncertainty.
6. Additional exploration of surface ages from the late 1970s and inclusion into or comparison with the assessment model, or re-aging of the otoliths could improve the information regarding that time period when the stock underwent the most dramatic decline. Auxiliary biological data collected by ODFW from recreational catches and hook-and-line projects may also increase the performance of the assessment model in accurately estimating recent trends and stock size.
7. Due to inconsistencies between studies and scarcity of appropriate data, new data are needed on both the maturity and fecundity relationships for canary rockfish.
8. Re-evaluation of the pre-recruit index as a predictor of recent year class strength should be ongoing as future assessments generate a longer series of well-estimated recent recruitments to compare with the coast-wide survey index.
9. Meta-analysis or other summary of the degree of recruitment variability and the relative steepness for other rockfish and groundfish stocks should be ongoing, as this information is likely to be very important for model results (as it is here) in the foreseeable future.

Rebuilding projections

The rebuilding projections will be presented in a separate document after the assessment has been reviewed in June 2009.

Table h. Summary of recent trends in estimated canary rockfish exploitation and stock levels from the base case model; all values reported at the beginning of the year.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Commercial landings (mt)[1]	55.7	42.6	47.8	8.6	10.7	12	7.3	12.1	9.4	NA
Total catch (mt)	199.9	133	98.1	59.9	50.3	60.4	62	44.7	40.5	NA
ABC (mt)	287	228	228	272	256	270	279	172	179	981
OY	200	93	93	44	47.3	46.8	47.0	44	44	105
SPR	73.0%	81.6%	86.7%	91.1%	93.0%	92.6%	92.2%	94.5%	95.0%	NA
Exploitation rate (catch/age 5+ biomass)	0.0204	0.0127	0.0088	0.0051	0.004	0.0046	0.0044	0.0031	0.0027	NA
Age 5+ biomass (mt)	9,783	10,502	11,114	11,698	12,513	13,106	13,945	14,542	15,145	15,483
Spawning biomass (mt)	3,316	3,699	4,080	4,440	4,781	5,091	5,372	5,642	5,912	6,170
~95% Confidence interval	2,331-4,302	2,592-4,805	2,856-5,304	3,108-5,772	3,353-6,210	3,577-6,604	3,783-6,960	3,984-7,301	4,187-7,636	4,385-7,955
Range of states of nature	1,507-5,182	1,639-5,835	1,774-6,485	1,899-7,107	2,023-7,696	2,131-8,240	2,222-8,748	2,305-9,247	2,386-9,751	2,459-10,244
Recruitment (1000s)	904	1,936	1,004	1,148	422	594	1,679	2,276	1,012	1,886
~95% Confidence interval	559-1,460	1,361-2,754	661-1,524	761-1,733	245-725	306-1,156	872-3,231	1,143-4,530	441-2,319	734-4,848
Range of states of nature	335-1,025	735-2,491	359-1,220	400-1,416	137-452	185-556	546-1,539	715-2,004	301-737	636-1,104
Depletion	12.8%	14.2%	15.7%	17.1%	18.4%	19.6%	20.7%	21.7%	22.7%	23.7%
~95% Confidence interval	9.2-16.4%	10.2-18.3%	11.2-20.2%	12.2-21.9%	13.2-23.6%	14.1-25.1%	14.9-26.4%	15.7-27.7%	16.5-29.0%	17.3-30.2%
Range of states of nature	5.7-20.3%	6.2-22.9%	6.7-25.4%	7.1-27.9%	7.6-30.2%	8.0-32.3%	8.4-34.3%	8.7-36.3%	9.0-38.2%	9.3-40.2%

[1]Excludes all at-sea whiting, recreational and research catches.

Table i. Summary of canary rockfish reference points from the base case model. Values are based on 1994-1998 fishery selectivity and allocation to reflect the performance of recent targeted fishing rather than the current bycatch-only environment.

Quantity	Estimate	~95% Confidence interval	Range of states of nature
Unfished spawning stock biomass (SB_0, mt)	25,993	24,266-27,719	25,500-26,575
Unfished 5+ biomass (mt)	68,539	64,536-72,542	66,349-71,606
Unfished recruitment (R_0, thousands)	3,335	3,101-3,570	3,203-3,529
Reference points based on $SB_{40\%}$			
MSY Proxy Spawning Stock Biomass ($SB_{40\%}$)	10,397	9,706-11,088	10,200-10,630
SPR resulting in $SB_{40\%}$ ($SPR_{SB40\%}$)	54.4%	NA	45.8-67.9%
Exploitation rate resulting in $SB_{40\%}$	0.0353	NA	0.0213-0.0469
Yield with $SPR_{SB40\%}$ at $SB_{40\%}$ (mt)	959	882-1,036	599-1,248
Reference points based on SPR proxy for MSY			
Spawning Stock Biomass at SPR (SB_{SPR})(mt)	8,909		1,772-11,377
$SPR_{MSY\text{-}proxy}$	0.5	NA	NA
Exploitation rate corresponding to SPR	0.0409	NA	0.0406-0.0409
Yield with $SPR_{MSY\text{-}proxy}$ at SB_{SPR} (mt)	954	877-1,030	191-1,209
Reference points based on estimated MSY values			
Spawning Stock Biomass at *MSY* (SB_{MSY}) (mt)	9,949	9,315-10,582	8,105-11,629
SPR_{MSY}	53.0%	52.8-53.2%	38.4%-69.9%
Exploitation Rate corresponding to SPR_{MSY}	0.0369	0.0352-0.0387	0.0196-0.0596
MSY (mt)	960	883-1,037	602-1,278

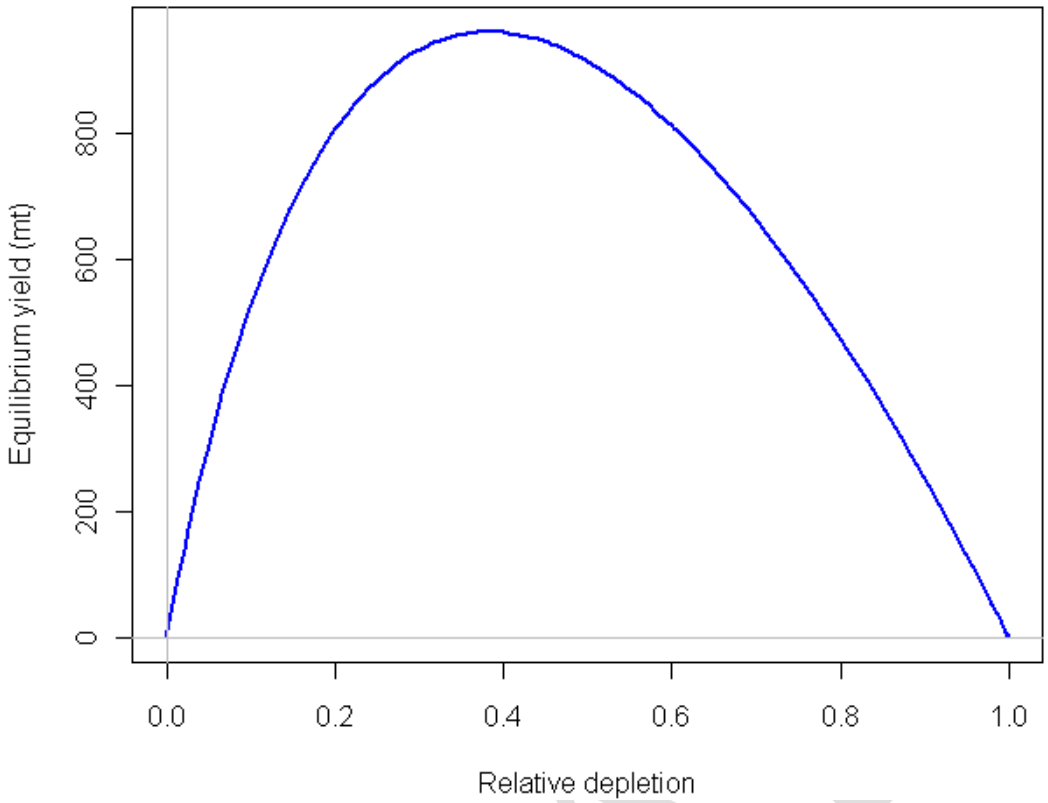

Figure i. Equilibrium yield curve for the base case model. Values are based on 1994-1998 fishery selectivity and allocation to reflect the performance of a targeted fishery.