RECOVERY POTENTIAL ASSESSMENT OF CANARY ROCKFISH IN BRITISH COLUMBIA WATERS

Figure 1. Canary rockfish (Lynne Yamanaka, DFO)

Figure 2. British Columbia waters

Context :

In November 2007, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed canary rockfish as "Threatened". The Minister of the Environment will forward the assessment to the Governor in Council in early 2010, triggering a nine-month legal deadline. By Fall 2010, the Governor in Council's proposed listing decision, based on a recommendation from the Minister of the Environment in consultation with the Minister of Fisheries and Oceans, will be published in Canada Gazette I. Public comments will be accepted for 30 days. The Governor in Council will then make a final listing decision, which will be published in the Canada Gazette II, at the end of the nine-month timeline. The decision can be to 1) accept the COSEWIC assessment and list the species, 2) decide not to list the species, or 3) send the species assessment back to COSEWIC for further information or consideration. If the recommendation is accepted, a Recovery Strategy will be required within two years.

The general intent of this document is to provide the scientific advice required for development of a Recovery Strategy, should it be deemed necessary. Most of the material in the document is derived from a stock assessment on canary rockfish reviewed by the Pacific Scientific Advice Research Committee in November 2007. The specific intent of this document is to predict the impact of future harvest levels on population trends relative to attaining a target stock status. These predictions will be used for guidance during the consultation process. In this respect, while the stock status and forecasting advice presented in this document are framed to be consistent with the current draft DFO policy, the selection of recovery targets will be done as part of the Recovery Strategy.

SUMMARY

- The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed the canary rockfish population in B.C. as Threatened. A final decision by the Government of Canada is required by December 2010. If the threatened listing is accepted, a Recovery Strategy will be required within two years from the date of acceptance.

- This document provides the scientific advice required for development of the Recovery Strategy. It follows the outline provided in the Revised Protocol for Conducting Recovery Potential Assessment (RPA). The specific intent of this RPA is to predict the impact of future harvest levels on canary rockfish abundance relative to attaining a target stock status. The stock status and forecasting advice are framed to be consistent with the current DFO policy on the Precautionary Approach (PA).

- Canary rockfish is one of over 39 species of rockfish present in B.C. waters. Vernacular names for canary rockfish include rockcod, red snapper, and snapper; however these names are also shared with other species. Female canary rockfish mature at about 14 years of age with a generation time of 20.4 years. The population is assumed to be one designatable unit in B.C.

- Little is known about the distribution of young canary rockfish in B.C. waters although they have been captured by gillnets in nearshore sub-tidal depths. They appear to move deeper as they become older and larger. Most of the late stage juveniles and adult specimens are caught over depths of 100-225 m on the continental shelf. Most canary rockfish will probably die if released after capture. Canary rockfish does not appear to exhibit residence requirements as defined in the SARA legislation.

- A coastwide assessment of canary rockfish was conducted using a catch at age model tuned to five fishery-independent surveys and to age composition data from the commercial fishery. A Bayesian approach was used to explicitly incorporate model and data uncertainty in the assessment results. The model was started from an equilibrium state in 1940 and the available fishery-independent survey data span a period from 1967 to 2007, although not all intervening years are represented with surveys. The full model and results were reviewed in the fall of 2007 at the Pacific Science Advisory Review Committee (PSARC). This RPA was reviewed by PSARC in June 2008.

- The three model runs accepted by PSARC indicate that current spawning biomass is most likely within the cautious zone as defined by the reference points in the draft DFO PA policy documents. The mean expected values for current spawning biomass are estimated to be between approximately 0.15-0.22 of B_0, while the credible range for stock status is broader, spanning between 0.07 and 0.31. The mean estimate of B_{2008}/B_{MSY} ranges from 0.49-0.73 for the three runs. There is, however, large uncertainty around these estimates.

- Harvests in the commercial groundfish fisheries are assumed to be the major current source of human-induced mortality. Total groundfish commercial catch (retained and discarded) was 751 t in the 2007/2008 fishing year. Landings and at-sea catches (retained and discarded) are monitored in all commercial groundfish fisheries with 100% coverage. There is negligible discarding of undersized fish. The catches of canary rockfish in the

salmon troll, First Nations', and recreational fisheries are unknown but are probably relatively small in comparison with commercial groundfish catches.

- Catches in U.S. waters may have an impact on the population of canary rockfish in B.C. waters, but the size of this impact is unknown. Recent U.S. assessments have indicated slow rebuilding of the canary population in U.S. waters.

- Given that canary rockfish appear to be predominantly a semi-pelagic and aggregating species with areas of highest density (for adults) along the edge of the continental shelf; and they appear to be much reduced in abundance from pre-exploitation levels, we know of no basis for assuming that the current quantity of physical habitat is limiting abundance. However, recent unpublished information on observed declines in dissolved oxygen, which appear to be correlated with apparent shifts in distribution of many groundfishes species to shallower depths, may be a source of concern. These observations are preliminary and their longterm significance is unknown. There is no information available to suggest that canary rockfish have residence requirements, as defined in SARA.

- Controlling the commercial harvest of canary rockfish appears to be the most effective way to mitigate threats to this population. It is possible that, under special circumstances, regulation changes to the gear used, or to fishing patterns, might provide modest benefits in addition to general steps to reduce catch. Such scenarios are best discussed during consultation with harvesters.

- While restricting commercial catches appears to be the most practical means at present to minimize harm to canary rockfish in B.C. waters, the mechanisms for implementing catch restriction proposals should be developed in consultation with industry.

- A series of decision tables provided in the document give predictions of stock trends under several fixed harvest rules under a range of modelling assumptions. These tables capture the relative trade-offs required when considering the three recovery targets (i.e. target biomass, time frame, and likelihood of reaching the target). These targets will be developed during the consultation phase.

- While the Bayesian approach used in the assessment provides a mechanism to include uncertainty in estimating the current status of the population, managers and stakeholders are advised that not all sources of uncertainty have been addressed. The true uncertainty is even greater with forecasting adding even more uncertainty. These projections assume the population will respond to the future environment as it did in the past, an assumption which may not hold due the effects of climate change and/or other external processes.

- Notwithstanding the uncertainty in the assessment and forecasts, short-term projections of 1 to 2 years predict that current commercial groundfish catches of about 750 t per year will not place the population in significant additional jeopardy, suggesting that it is not necessary to accelerate the time frame required to implement a Recovery Strategy and Action Plan (if required). However, longer term predictions based on the decision tables suggest that a reduction in harvest from current levels is required to significantly increase the probability of a population increase, as well as to increase the speed of the rebuild.

INTRODUCTION

In November 2007, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed canary rockfish (*Sebastes pinniger*) as "Threatened". According to the current timetable, the Minister of the Environment (MOE) will forward the COSEWIC assessment to the Governor in Council (GIC) in early 2010, triggering a nine-month legal deadline. By fall 2010, the GIC's proposed listing decision, based on a recommendation from the MOE and in consultation with the Minister of Fisheries and Oceans, will be published in Canada Gazette I. Public comments will be accepted for 30 days.

The GIC will then make a final listing decision, which will be published in Canada Gazette II, at the end of the nine-month timeline. The decision can be to 1) accept the COSEWIC assessment and list the species, or 2) decide not to list the species, or 3) send the species assessment back to COSEWIC for further information or consideration. If the recommendation is accepted, a Recovery Strategy will be required within two years.

The general intent of this document is to provide the scientific advice required for development of a Recovery Strategy, should it be required. It follows the outline structure provide in “Revised Protocol for Conducting Recovery Potential Assessment” (DFO 2007a). Most of the material in the document is taken from a stock assessment on canary rockfish reviewed by the Pacific Scientific Advice Research Committee (PSARC) in November 2007 (Stanley et al. 2009). It also includes recommendations from that review (DFO 2007b). This RPA, in turn, was reviewed and approved at a PSARC meeting in May 2008.

The specific intent of this document is to predict the impact of future harvest levels on population trends relative to attaining a target stock status. These predictions will be used for guidance during the consultation process that will lead to a Recovery Strategy. The stock status and forecasting advice presented in this document are framed to be consistent with the current draft DFO policy on the “Precautionary Approach” (DFO 2006 and see below) and Draft Fisheries and Stewardship Sustainability Checklist (DFO 2008). However, the RPA protocol notes that the “….***actual selection of recovery targets will be done as part of the Recovery Strategy”***.

Species Biology

Canary rockfish (*Sebastes pinniger*) is one of over 102 rockfish species of the genus *Sebastes*, 96 of which are found in the North Pacific. There are over 39 species present in B.C. waters. This report treats canary rockfish as a single stock unit in B.C. waters.

In California studies, larvae and pelagic juvenile canary rockfish are reported to occupy the top 100 m for up to 3-4 months after parturition, and then settle to benthic habitats gradually moving deeper as they grow and age (Love et al. 2002). However, little is actually known about the spatial distribution of larval and juvenile stages in B.C. waters. Later stage juveniles and adults are typically captured in B.C. by hook-and-line (HL) or trawl gear over rocky, gravel, or sandy bottom on the continental shelf. Canary rockfish are a marine and sub-tidal species; thus all Canadian habitat is within Federal waters. Most of these waters are exploited by commercial, recreational, and First Nations’ fishers.

Maximum observed length, weight, and age for canary rockfish in B.C. are 68 cm, 5.7 kg, and 84 years respectively (Stanley et al. 2009). Average weight in commercial samples is about 2 kg. Age at 50% maturity for females is about 14 years. They first appear at age five in the fishery and are fully recruited by 12-14 y. This species is vulnerable to fishing prior to reaching maturity.

Pelagic juveniles feed on an array of planktonic items. Adults and subadults primarily eat krill and small fishes. Significant predators probably include lingcod. Like all rockfish, they have closed swim bladders and usually die if released after routine capture. Work in Oregon has shown that movements by adults that exceed 100 km are possible (DeMott 1983). Additional details on canary rockfish biology can be found in Love et al. (2002), Stanley et al. (2005), Stewart (2007a), and Stanley et al. (2009).

ASSESSMENT

Phase I: Assess current/recent species status

1. Evaluate present species status for abundance, range, and number of populations

Canary rockfish are found from northern Baja California to the western Gulf of Alaska (Love et al. 2002), but populations are most abundant between northern California and B.C. No genetics or tagging studies have been conducted to delineate stock boundaries within B.C. The current U.S. assessment reports that there is no genetic evidence of distinct stocks off the U.S. coast and treats the population as one stock from California to Washington (Stewart 2007a).

Commercial and research catches in B.C. indicate that canary rockfish are currently broadly distributed on the edge of the continental shelf as well as within Hecate Strait and Queen Charlotte Sound (Figure 3). There is no known biological basis for assigning more than one distinct population of canary rockfish in B.C. Therefore, we have continued with the suggestion of Stanley et al. (2009) that, with respect to a consideration of extinction risk, the entire canary rockfish population in B.C. waters be treated as one designatable unit. It is likely that there is some overlap with U.S. populations; however, the extent of the overlap is unknown.

A coastwide assessment of canary rockfish was conducted using a catch at age model tuned to five fishery-independent surveys and to age composition data from the commercial fishery (Stanley et al. 2009). A Bayesian approach was used to explicitly incorporate model and data uncertainty in the assessment results. The model was started from an equilibrium state in 1940 and the available fishery-independent survey data span a period from 1967 to 2007 (Table 1), although not all intervening years are represented with surveys.

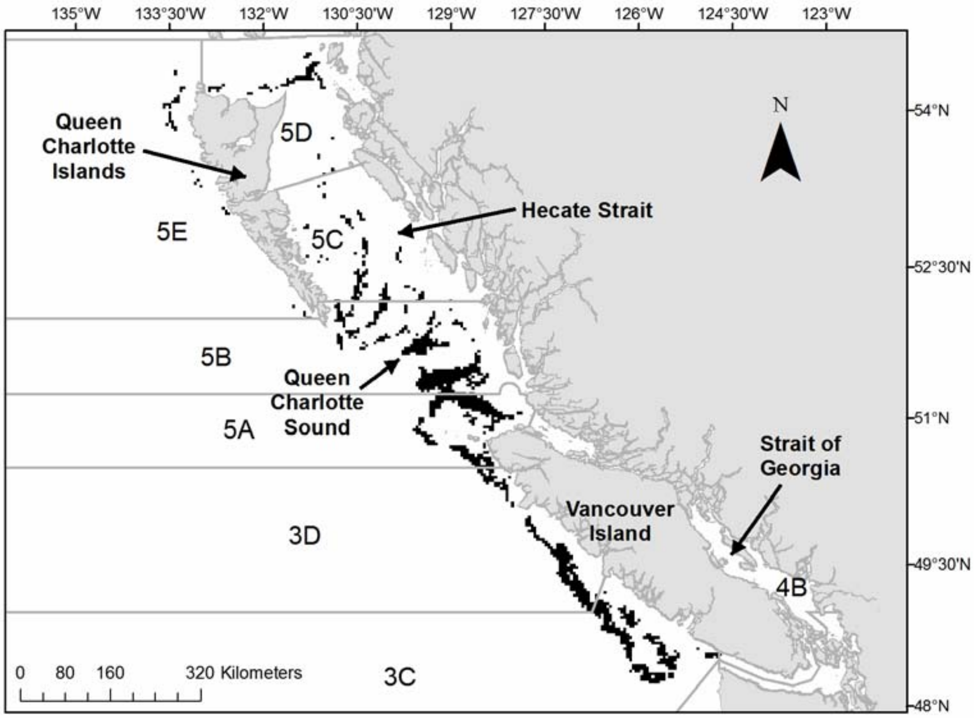

Figure 3. Spatial distribution of canary rockfish catches in B.C. from commercial trawl observer observations (2001-2008). Also shown are the Pacific Marine Fisheries Commission Area (PMFC) designations.

Table 1. Data sets, showing applicable years, used in the canary rockfish catch-age stock assessment model (Stanley et al. in 2009).

Data type	**Years**
Catch	1940–2006
GB Reed historical trawl surveys	1967–1984
WCVI shrimp trawl survey	1975–2007
NMFS Triennial trawl survey	1980–2001
QC Sound shrimp trawl survey	1999–2007
QC Sound groundfish trawl survey	2003–2007
Age composition from commercial trawl fishery	1978–2004

2. Recent species trajectory

A range of model runs were examined in the assessment (Stanley et al. 2009). From the available runs, the PSARC Groundfish Subcommittee recommended that management decisions should be based on the output from Runs 5, 11, and 17 (Table 2) (DFO 2007b). Much of the discussion at that meeting focused on the "steepness" parameter, which regulates the relationship between the parent and succeeding generation in the assumed stock-recruitment relationship. All three runs indicated a significant decline in biomass from virgin biomass (B_0) (Table 3, Figure 4). The mean expected values for current spawning biomass were estimated to lie between 0.15-0.22 of B_0, while the credible range for stock status was broader, spanning from 0.07 to 0.31 (Table 3). The mean estimate of B_{2008}/B_{Msy} (see Tables 5-7) ranged from 0.49-0.73 for the three runs.

Table 2. Specifications for stock assessment runs 05, 11, and 17 (Stanley et al. 2009). All models used the same catch vector and were fitted to the five surveys referenced in (Table 1).

Run number	Catch-at-age data	Recruitment	Commercial selectivity	Steepness
Run 05	Used	Stochastic	Fixed	0.70
Run 11	Used	Stochastic	Estimated	0.70
Run 17	Used	Stochastic	Estimated	0.55

Table 3. Bayesian MCMC derived parameter estimates for model runs 5, 11 and 17. Summary statistics (mean or median, 5th and 95th percentiles) are shown for posteriors corresponding to the selected derived parameters of management interest

	5%	Mean	95%	5%	Mean	95%
	B_0 [1]			B_0^v [2]		
Run05	7,766	8,401	9,122	24,630	26,619	28,904
Run11	7,748	8,395	9,135	23,840	25,865	28,182
Run17	8,058	8,747	9,568	24,831	26,955	29,484
	B_{2008}/B_0			B_{2008}^v/B_0		
Run05	0.07	0.15	0.23	0.09	0.18	0.26
Run11	0.14	0.22	0.31	0.14	0.23	0.32
Run17	0.10	0.17	0.25	0.11	0.18	0.26
	u_{2007}			$u_{\max}$		
Run05	0.10	0.17	0.28	0.15	0.20	0.28
Run11	0.09	0.15	0.23	0.18	0.21	0.29
Run17	0.11	0.18	0.27	0.18	0.23	0.32

[1] female spawning biomass only
[2] female plus male biomass

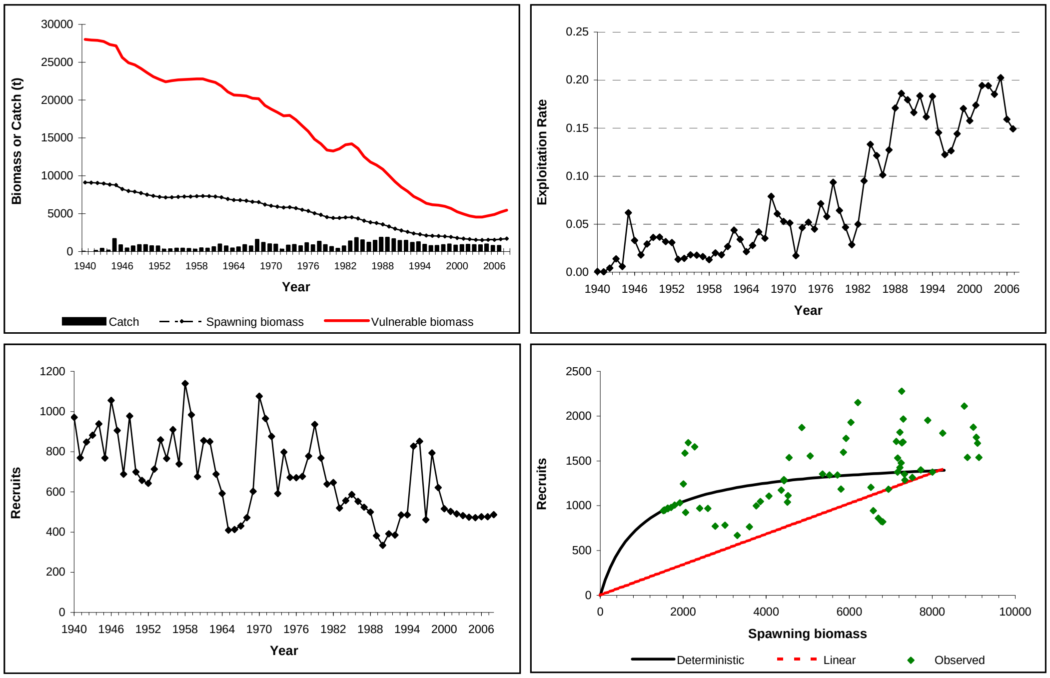

Figure 4. Plots from the MPD fit for Run 11 (the most optimistic of the three runs in Table 2). Vulnerable and female spawning biomass trends [top left], annual catch; [top right]: exploitation rate by year; [bottom left]: female recruitment by year (male recruitment is the same) and stock recruitment function [bottom right].

3. Life history parameters

Life history parameters used in the stock assessment modelling are summarized in Stanley et al. (2009). As explained above, the authors examined runs with steepness values of 0.55 and 0.70 (Table 2), wherein a lower value indicates a stock with a stronger linkage between the parent stock and the subsequent recruitment. Lower values for this parameter result in lower average recruitment at low stock sizes and consequently the average productivity is lower for these stocks. This parameter is poorly estimated in most stock assessment models, and it is common to fix this parameter at several values in the assessment. The authors used estimates for natural mortality and steepness that were consistent with a recent stock assessment performed on canary rockfish in the United States (Stewart 2007a), but did not explore the sensitivity of the assessments results to other life history parameters. Run 05, which fixed selectivity to values similar to those estimated by the US assessment (Stewart 2007), was considered by the authors to be less appropriate than Runs 11 and 17 which estimated selectivity based on the age data collected in B.C. fisheries. The U.S. selectivities were shifted to the left of the B.C.-based selectivities, implying that even younger canary rockfish were being taken in the fishery, which was not supported by the B.C.-collected age data.

4. Habitat requirements and habitat use patterns

Based on commercial and research catch records, adult and late stage juvenile canary rockfish appear to be broadly distributed over the continental shelf with the major catches coming from the edge of the shelf ("break-in-slope") and along the edges of underwater canyons and troughs, for example Queen Charlotte Sound (Figure 3). Fishers report that, while later stage juveniles appear to consistently favour high-relief rocky bottom, adults can also be found over sand or gravel substrates.

Most of the bottom trawl catches (of adults and later juvenile stages) come from bottom depths of approximately 100-225 m. Peak catch rates are found in approximately 150 m (Figure 5), however the depth of highest catch rate varies during the year (Figure 6) with peak catch rates occurring between 100-170 m in August and 160-210 m in February. Depth of capture for recent HL catches appears to also include shallower water (Figure 5).

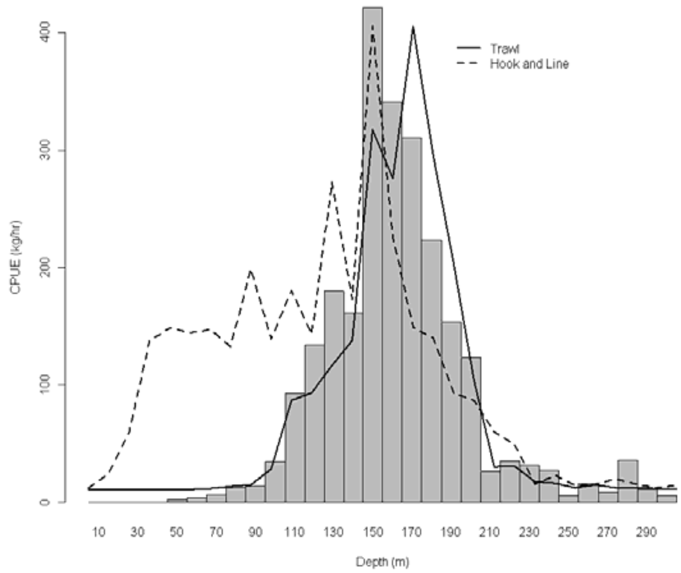

Figure 5. Bottom trawl catch rate (histogram) and relative distribution of total catch in trawl (1,274 t: solid line) and HL gear (13.9 t: dotted line) for the 2007 and 2008 calendar years combined.

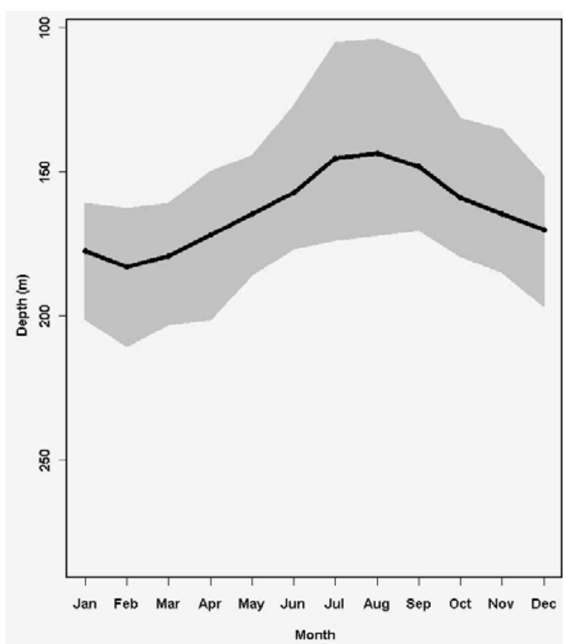

Figure 6. Peak and 5 and 95 percentiles of canary rockfish bottom trawl cpue by depth and month for B.C. commercial bottom trawling (1996-2008 combined).

Mean size (Figure 7) or age (Figure 8) in the canary rockfish samples tends to increase with depth but other than the assumption that juveniles aggregate over hard bottom, there are no known nursery areas. We could not detect any consistent evidence of specialized sites for parturition (release) of live young in the available samples, or evidence of consistent fishing on aggregations of females during parturition.

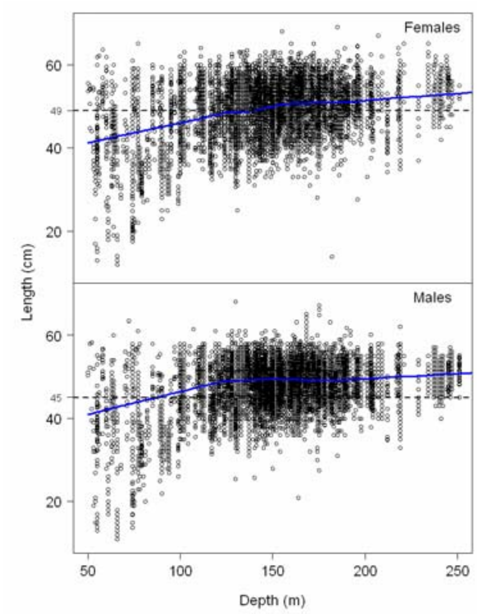

Figure 7. Length of canary rockfish specimens, all B.C. samples combined, by depth and sex. 49 cm (females) and 45 cm horizontal dotted lines correspond to size at 50% maturity.

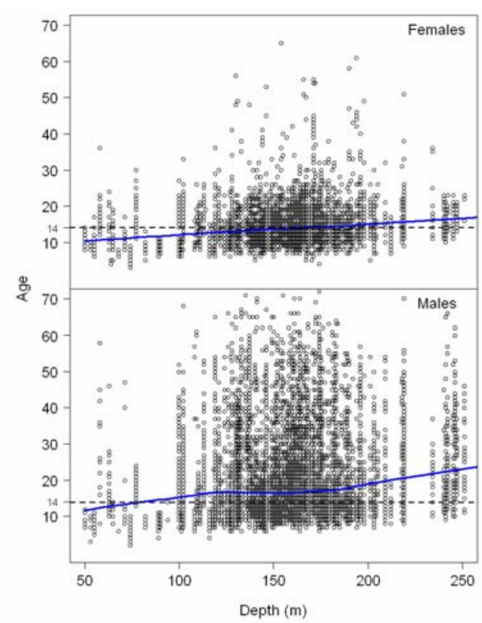

Figure 8. Age of canary rockfish specimens, all B.C. samples combined, by depth and sex. 14 year dotted lines to age at 50% maturity for females (males unknown).

5. Population and distribution targets

DFO is committed to implementing the Precautionary Approach (PA) in fisheries management, and has adopted a harvest strategy policy compliant with the PA (DFO 2006). The strategy includes targets and limits with respect to stock status, and a variable removal reference (RR) that is related to stock status. Stock status is divided into three zones, Healthy, Cautious, and Critical (Figure 9). The boundaries between these zones are defined by two status reference points, the Upper Stock Reference (USR) and the Limit Reference Point (LRP). The USR is determined by the productivity objectives for the fishery and will vary among species and fisheries, and will include biological, social, and economic factors. The removal reference in the Healthy zone is fixed at a level consistent with the productivity objectives. When the stock is in the Cautious zone, the RR is reduced to promote rebuilding toward the Healthy zone. When the stock is in the Critical zone it is considered to be severely depleted and its productivity is sufficiently impaired to potentially cause serious harm. In the Critical zone, the RR is set at the lowest possible level in order to recover the stock from this serious condition. The PA compliant harvest strategy provides guidance for setting total allowable catches (TAC) based on catch forecasts. In all cases, the expected removal rate for a TAC should not exceed the associated RR in a PA compliant harvest strategy.

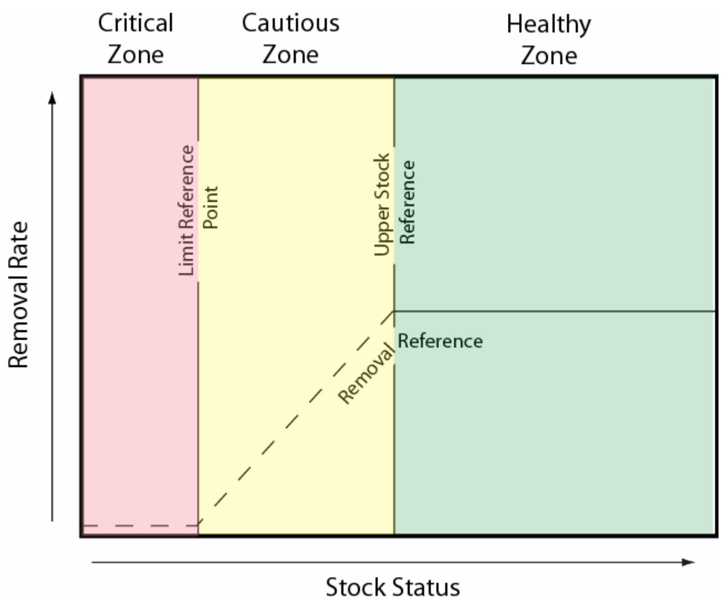

Figure 9. A harvest strategy compliant with the precautionary approach (DFO 2006).

DFO has further circulated a “Fisheries Stewardship and Sustainability Checklist[1]” with suggested proxies for the PA harvest strategy reference points. Quoting from the document:

> *“In absence of precautionary reference points and harvest rules, the following reference points should be used as provisional elements to assess the stock in relation to sustainability.” These include 80% of the biomass which gives maximum sustainable yield (0.8 B_{msy}) for the USR and 40% of B_{msy} as the LRP (0.4 B_{msy}), and the fishing mortality that gives maximum sustainable yield (F_{msy}) as the maximum*

[1] A draft of Version 2 of the Checklist is still in the approval process within DFO. It is due to be released in July 2008.

RR. The checklist advocates using a linear increase in the RR from 0 to F_{msy} *when the stock status is between the LRP and the USR".*

Discussions during PSARC review noted that the assessment model could be used to estimate B_{msy} and therefore the results of the modelling could be recast within the PA policy framework. To accommodate this suggestion for presentation in this document, B_{MSY} was estimated by finding the equilibrium biomass for each sample in the MCMC posterior under fixed annual exploitation rates ranging from 0 to 0.30 (in steps of 0.0025), projecting forward from the unfished virgin biomass under the assumption constant average recruitment[2]. B_{MSY} was the biomass at the exploitation rate which provided the greatest average yield, after reaching an equilibrium defined when successive projection iterations had less than an absolute change of 0.2 kg in the mature biomass. *MSY* was yield achieved at B_{MSY}.

Variability in *MSY* and B_{MSY} was determined by finding the B_{MSY} for each set of parameters for the 1000 samples from the joint posterior distribution for each of Run 05, Run 11, and Run 17. The number of iterations required to reach the defined equilibrium varied considerably between the three runs and across the range of exploitation rates.

These analyses, conducted subsequent to the PSARC review, indicate that, for most of the MCMC draws within each of the runs, current stock status lies in the cautious zone, as defined in DFO 2006 (Figure 10, Table 4). However, the estimates of uncertainty also include the possibility that the population is within the critical zone. These guidelines would lead to harvest recommendations for 2008 of 132 to 570 t, depending on the run, using the mean expected values from the MCMC posterior distributions. The wider credible range of 2008 harvest recommendations using these guidelines is from 0 to 1065 t, across all three runs (Table 4).

6. Expected population trajectories over the target recovery time

The 5-year forecasts and decision tables provided in Stanley et al. (2009) were recast using the recommended LRP and USR from the PA policy (Table 5, Table 6 and Table 7, and Figure 11 and Figure 12). Subsequent to the PSARC review of this document, the Recovery Strategy team requested longer term forecasts over at least two generations. These are shown below for Runs 11 and 17 (Table 8 and Table 9, Figure 13, Figure 14, Figure 15, Figure 16).

[2] The analysis of *MSY* was conducted after the PSARC review therefore details are provided in this document.

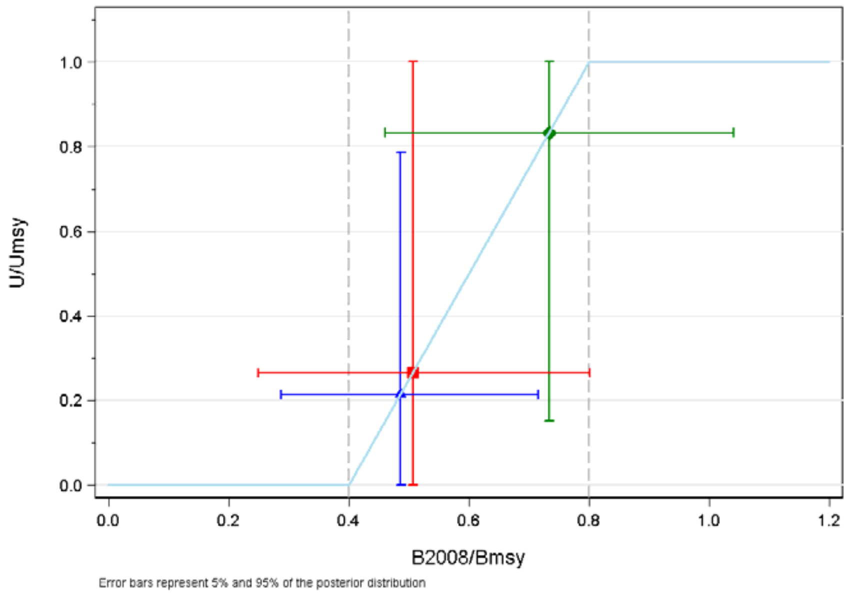

Figure 10. Status of Canary rockfish relative to the PA compliant harvest strategy based on results from the three preferred runs (Run 05■, Run 11♦, Run 17▲). Mean values are designated with indicated symbols and 5 and 95% distributional information are based on the posterior distributions from the MCMC procedure.

*Table 4. Application of the PA compliant harvest strategy to canary rockfish assessment results (units for spawning biomass (B) are in tonnes. Run 05: B_{msy}=0.288*B_0; Run 11: B_{msy}=0.296*B_0; Run 05: B_{msy} =0.356*B_0.*

	5th percentile	**Mean**	**95th percentile**
	$0.4 * B_{MSY}$		
Run05	895	968	1,051
Run11	917	994	1,082
Run17	1,147	1,246	1,362
	$0.8 * B_{MSY}$		
Run05	1,789	1,936	2,102
Run11	1,835	1,988	2,163
Run17	2,295	2,491	2,725
	B_{2008}		
Run05	581	1,237	2,035
Run11	1,095	1,836	2,715
Run17	853	1,524	2,334
	U_{MSY}		
Run05	0.098	0.098	0.098
Run11	0.118	0.122	0.125
Run17	0.078	0.082	0.083
	U_{2007}		
Run05	0.102	0.173	0.283
Run11	0.095	0.149	0.225
Run17	0.108	0.177	0.274
	U_{2008} _ PA compliant		
Run05	0.000	0.031	0.098
Run11	0.018	0.088	0.125
Run17	0.000	0.021	0.064
	Y_{2008} _ PA compliant		
Run05	0	192	703
Run11	65	570	1065
Run17	0	132	474

*Table 5. Decision tables of B_{msy} performance indicators for 1-5 year projections for Run 05. Statistics relate to beginning of year female spawning biomass relative to the female spawning B_{msy} biomass (B_{msy} =0.288*B_0). The probability of biomass in the projection year exceeding one of the suggested reference values (upper two tables) can be compared to the expected value the biomass relative to B_{msy} (lowest table).*

Annual catch strategy	2008	2009	2010	2011	2012	2013
	$P(\tilde{B}_y > 0.4B_{MSY})$					
0	0.709	0.833	0.914	0.966	0.995	1.000
100	0.709	0.810	0.893	0.952	0.978	0.998
200	0.709	0.788	0.869	0.920	0.958	0.979
300	0.709	0.769	0.834	0.887	0.934	0.960
400	0.709	0.744	0.802	0.840	0.876	0.919
500	0.709	0.724	0.753	0.790	0.821	0.851
600	0.709	0.700	0.713	0.729	0.751	0.766
700	0.709	0.678	0.664	0.662	0.667	0.674
800	0.709	0.651	0.624	0.593	0.575	0.581
900	0.709	0.628	0.572	0.530	0.486	0.469
1000	0.709	0.603	0.517	0.456	0.404	0.372
1100	0.709	0.581	0.479	0.390	0.327	0.285
1200	0.709	0.557	0.424	0.327	0.260	0.218
	$P(\tilde{B}_y > 0.8B_{MSY})$					
0	0.051	0.117	0.213	0.352	0.546	0.731
100	0.051	0.111	0.188	0.300	0.448	0.612
200	0.051	0.095	0.162	0.250	0.360	0.512
300	0.051	0.085	0.142	0.204	0.287	0.394
400	0.051	0.071	0.112	0.159	0.222	0.291
500	0.051	0.063	0.087	0.122	0.172	0.226
600	0.051	0.056	0.070	0.083	0.110	0.141
700	0.051	0.051	0.057	0.063	0.074	0.091
800	0.051	0.049	0.047	0.047	0.048	0.053
900	0.051	0.047	0.041	0.036	0.036	0.040
1000	0.051	0.039	0.035	0.033	0.031	0.026
1100	0.051	0.035	0.028	0.026	0.021	0.019
1200	0.051	0.031	0.023	0.017	0.014	0.012
	$E(\tilde{B}_y / B_{MSY})$					
0	0.506	0.573	0.651	0.739	0.834	0.937
100	0.506	0.562	0.629	0.703	0.786	0.875
200	0.506	0.551	0.606	0.668	0.737	0.812
300	0.506	0.540	0.583	0.633	0.689	0.751
400	0.506	0.530	0.561	0.598	0.642	0.690
500	0.506	0.519	0.539	0.564	0.594	0.630
600	0.506	0.508	0.516	0.529	0.548	0.570
700	0.506	0.497	0.494	0.495	0.502	0.512
800	0.506	0.486	0.472	0.462	0.456	0.455
900	0.506	0.475	0.450	0.428	0.412	0.400
1000	0.506	0.465	0.428	0.396	0.369	0.348
1100	0.506	0.454	0.406	0.364	0.328	0.298
1200	0.506	0.443	0.384	0.332	0.288	0.253

*Table 6. Decision tables of B_{MSY} performance indicators for 1-5 year projections for Run 11. Statistics relate to beginning of year female spawning biomass relative to the female spawning B_{MSY} biomass (B_{MSY} =0.296*B_0). The probability of biomass in the projection year exceeding one of the suggested reference values (upper two tables) can be compared to the expected value the biomass relative to B_{MSY} (lowest table).*

Annual catch strategy	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
	$\mathrm{P}\left(\tilde{B}_y > 0.4B_{MSY}\right)$					
0	0.978	0.998	1.000	1.000	1.000	1.000
100	0.978	0.998	1.000	1.000	1.000	1.000
200	0.978	0.996	1.000	1.000	1.000	1.000
300	0.978	0.996	1.000	1.000	1.000	1.000
400	0.978	0.993	0.997	1.000	1.000	1.000
500	0.978	0.992	0.995	0.997	0.999	1.000
600	0.978	0.989	0.994	0.995	0.996	0.997
700	0.978	0.987	0.991	0.992	0.992	0.992
800	0.978	0.982	0.982	0.983	0.984	0.981
900	0.978	0.978	0.978	0.973	0.958	0.945
1000	0.978	0.975	0.968	0.952	0.931	0.909
1100	0.978	0.973	0.957	0.926	0.896	0.863
1200	0.978	0.966	0.940	0.898	0.856	0.802
	$\mathrm{P}\left(\tilde{B}_y > 0.8B_{MSY}\right)$					
0	0.345	0.611	0.814	0.947	0.989	0.998
100	0.345	0.589	0.774	0.913	0.976	0.993
200	0.345	0.566	0.753	0.874	0.948	0.983
300	0.345	0.543	0.706	0.828	0.916	0.953
400	0.345	0.520	0.675	0.776	0.864	0.916
500	0.345	0.499	0.627	0.728	0.802	0.862
600	0.345	0.473	0.590	0.670	0.734	0.788
700	0.345	0.458	0.549	0.610	0.659	0.686
800	0.345	0.431	0.494	0.551	0.578	0.598
900	0.345	0.411	0.457	0.487	0.495	0.503
1000	0.345	0.389	0.414	0.433	0.433	0.415
1100	0.345	0.360	0.373	0.373	0.356	0.343
1200	0.345	0.341	0.338	0.311	0.285	0.246
	$\mathrm{E}\left(\tilde{B}_y / B_{MSY}\right)$					
0	0.733	0.866	1.003	1.143	1.280	1.410
100	0.733	0.854	0.978	1.105	1.228	1.343
200	0.733	0.842	0.954	1.067	1.175	1.276
300	0.733	0.831	0.929	1.028	1.122	1.209
400	0.733	0.819	0.905	0.990	1.070	1.142
500	0.733	0.807	0.880	0.952	1.018	1.076
600	0.733	0.796	0.856	0.914	0.966	1.010
700	0.733	0.784	0.832	0.876	0.914	0.944
800	0.733	0.773	0.808	0.838	0.862	0.879
900	0.733	0.761	0.783	0.801	0.811	0.815
1000	0.733	0.749	0.759	0.764	0.760	0.751
1100	0.733	0.738	0.735	0.726	0.710	0.688
1200	0.733	0.726	0.711	0.689	0.660	0.625

*Table 7. Decision tables of B_{MSY} performance indicators for 1-5 year projections for Run 17. Statistics relate to beginning of year female spawning biomass relative to the female spawning B_{MSY} biomass (B_{MSY} =0.356*B_0). The probability of biomass in the projection year exceeding one of the suggested reference values (upper two tables) can be compared to the expected value the biomass relative to B_{MSY} (lowest table).*

Annual catch strategy	2008	2009	2010	2011	2012	2013
	$\mathrm{P}\left(\tilde{B}_y > 0.4B_{MSY}\right)$					
0	0.729	0.894	0.972	0.998	1.000	1.000
100	0.729	0.882	0.957	0.994	0.997	1.000
200	0.729	0.867	0.939	0.978	0.995	0.998
300	0.729	0.849	0.915	0.956	0.976	0.991
400	0.729	0.825	0.891	0.925	0.953	0.967
500	0.729	0.807	0.863	0.896	0.914	0.926
600	0.729	0.786	0.819	0.856	0.874	0.881
700	0.729	0.765	0.783	0.792	0.787	0.773
800	0.729	0.747	0.751	0.733	0.708	0.670
900	0.729	0.728	0.698	0.659	0.612	0.558
1000	0.729	0.692	0.642	0.570	0.508	0.436
1100	0.729	0.667	0.583	0.505	0.424	0.351
1200	0.729	0.645	0.535	0.443	0.348	0.274
	$\mathrm{P}\left(\tilde{B}_y > 0.8B_{MSY}\right)$					
0	0.016	0.061	0.166	0.358	0.549	0.741
100	0.016	0.052	0.133	0.296	0.456	0.609
200	0.016	0.049	0.114	0.235	0.365	0.477
300	0.016	0.046	0.097	0.178	0.287	0.377
400	0.016	0.042	0.077	0.132	0.212	0.289
500	0.016	0.038	0.064	0.105	0.147	0.189
600	0.016	0.037	0.055	0.077	0.098	0.123
700	0.016	0.035	0.045	0.062	0.072	0.079
800	0.016	0.033	0.039	0.048	0.053	0.054
900	0.016	0.030	0.034	0.033	0.037	0.037
1000	0.016	0.026	0.028	0.028	0.026	0.022
1100	0.016	0.022	0.025	0.021	0.016	0.012
1200	0.016	0.019	0.018	0.014	0.011	0.008
	$\mathrm{E}\left(\tilde{B}_y / B_{MSY}\right)$					
0	0.486	0.572	0.660	0.750	0.836	0.915
100	0.486	0.563	0.641	0.719	0.793	0.861
200	0.486	0.553	0.621	0.688	0.751	0.807
300	0.486	0.544	0.602	0.657	0.708	0.753
400	0.486	0.535	0.582	0.627	0.666	0.700
500	0.486	0.526	0.562	0.596	0.625	0.646
600	0.486	0.516	0.543	0.566	0.583	0.594
700	0.486	0.507	0.524	0.536	0.542	0.542
800	0.486	0.498	0.504	0.506	0.501	0.490
900	0.486	0.488	0.485	0.476	0.460	0.439
1000	0.486	0.479	0.466	0.446	0.420	0.389
1100	0.486	0.470	0.446	0.417	0.381	0.341
1200	0.486	0.460	0.427	0.388	0.343	0.296

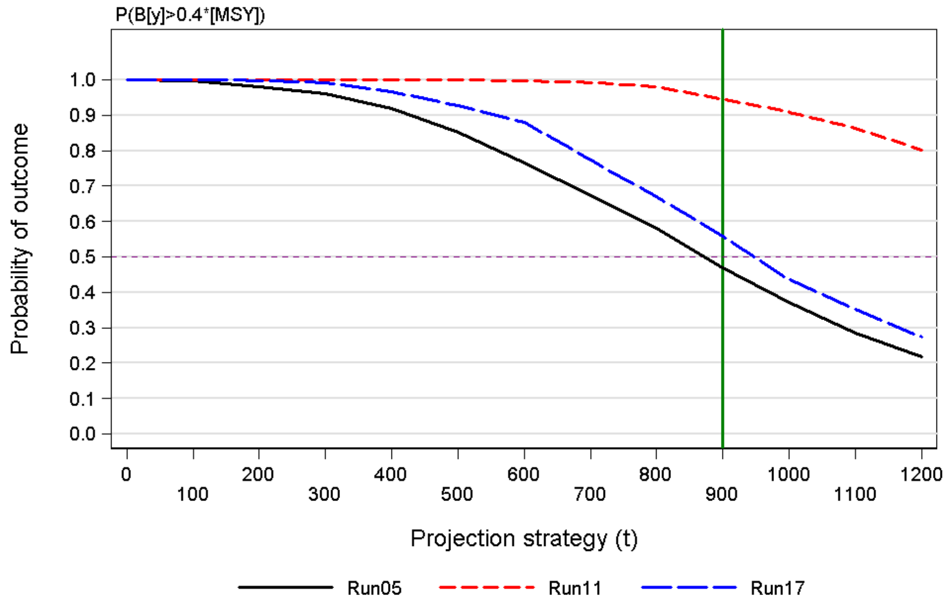

Figure 11. Comparison of the probability of $\tilde{B}_y$ exceeding $0.4B_{MSY}$ by the end of the projection period (2013) for model runs 5, 11, and 17. The green vertical line indicates the approximate position of the mean average catch over the past 5 and 10 years.

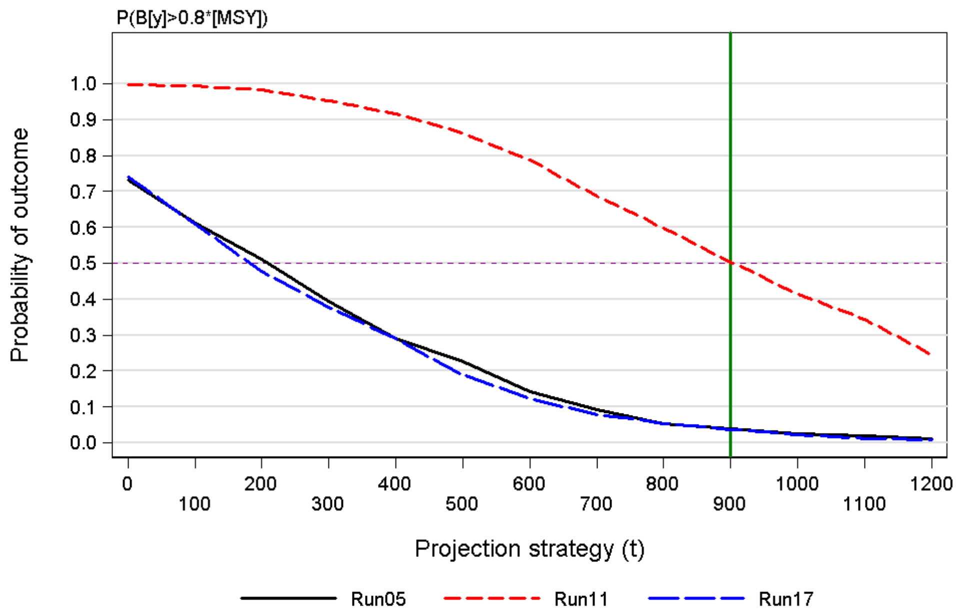

Figure 12. Comparison of the probability of $\tilde{B}_y$ exceeding $0.8B_{MSY}$ by the end of the projection period (2013) for model runs 5, 11, and 17. The green vertical line indicates the approximate position of the mean average catch over the past 5 and 10 years.

*Table 8. Decision tables of B_{MSY} performance indicators for 5 to 40 year projections for Run 11, in 5-year intervals. Statistics relate to beginning of year female spawning biomass relative to the female spawning B_{MSY} biomass (B_{MSY} =0.296*B_0). The probability of biomass in the projection year exceeding one of the suggested reference values (upper two tables) can be compared to the expected value the biomass relative to B_{MSY} (lowest table).*

Annual catch strategy	**Year of Projection**								
	2008	**2013**	**2018**	**2023**	**2028**	**2033**	**2038**	**2043**	**2048**
	$\mathrm{P}\left(\tilde{B}_y > 0.4B_{MSY}\right)$								
0	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
200	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
300	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
400	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
500	0.978	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
600	0.978	0.997	0.999	0.999	0.998	0.997	0.996	0.996	0.997
700	0.978	0.992	0.989	0.975	0.972	0.969	0.970	0.968	0.968
800	0.978	0.981	0.944	0.910	0.895	0.865	0.856	0.847	0.837
900	0.978	0.945	0.865	0.784	0.742	0.700	0.674	0.650	0.617
1000	0.978	0.909	0.755	0.644	0.572	0.504	0.457	0.411	0.372
1100	0.978	0.863	0.632	0.487	0.394	0.314	0.255	0.214	0.179
1200	0.978	0.802	0.507	0.344	0.234	0.169	0.124	0.097	0.072
	$\mathrm{P}\left(\tilde{B}_y > 0.8B_{MSY}\right)$								
0	0.345	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	0.345	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000
200	0.345	0.983	1.000	1.000	1.000	1.000	1.000	1.000	1.000
300	0.345	0.953	0.999	1.000	1.000	1.000	1.000	1.000	1.000
400	0.345	0.916	0.988	0.998	1.000	1.000	1.000	1.000	1.000
500	0.345	0.862	0.947	0.969	0.986	0.992	0.997	0.998	0.999
600	0.345	0.788	0.849	0.881	0.928	0.959	0.973	0.983	0.987
700	0.345	0.686	0.732	0.753	0.799	0.837	0.866	0.884	0.901
800	0.345	0.598	0.609	0.583	0.625	0.654	0.674	0.690	0.692
900	0.345	0.503	0.460	0.440	0.446	0.445	0.459	0.454	0.444
1000	0.345	0.415	0.317	0.277	0.276	0.260	0.258	0.230	0.226
1100	0.345	0.343	0.201	0.161	0.154	0.133	0.122	0.109	0.091
1200	0.345	0.246	0.121	0.085	0.071	0.055	0.044	0.038	0.030
	$\mathrm{E}\left(\tilde{B}_y / B_{MSY}\right)$								
0	0.733	1.410	1.888	2.202	2.537	2.846	3.088	3.268	3.382
100	0.733	1.343	1.763	2.047	2.360	2.653	2.888	3.066	3.182
200	0.733	1.276	1.638	1.889	2.179	2.453	2.678	2.853	2.971
300	0.733	1.209	1.513	1.730	1.993	2.245	2.457	2.627	2.745
400	0.733	1.142	1.388	1.569	1.802	2.027	2.222	2.384	2.500
500	0.733	1.076	1.263	1.406	1.605	1.798	1.971	2.120	2.231
600	0.733	1.010	1.138	1.241	1.400	1.555	1.697	1.826	1.925
700	0.733	0.944	1.014	1.075	1.188	1.295	1.396	1.490	1.563
800	0.733	0.879	0.890	0.907	0.970	1.021	1.071	1.118	1.149
900	0.733	0.815	0.769	0.742	0.753	0.752	0.754	0.755	0.746
1000	0.733	0.751	0.651	0.587	0.554	0.515	0.482	0.451	0.422
1100	0.733	0.688	0.539	0.449	0.388	0.327	0.280	0.242	0.210
1200	0.733	0.625	0.439	0.336	0.261	0.198	0.154	0.121	0.096

*Table 9. Decision tables of B_{MSY} performance indicators for 5 to 40 year projections for Run 17, in 5-year intervals. Statistics relate to beginning of year female spawning biomass relative to the female spawning B_{MSY} biomass (B_{MSY} =0.356*B_0). The probability of biomass in the projection year exceeding one of the suggested reference values (upper two tables) can be compared to the expected value the biomass relative to B_{MSY} (lowest table).*

Annual catch strategy	Year of Projection								
	2008	2013	2018	2023	2028	2033	2038	2043	2048
	$P\left(\tilde{B}_y > 0.4B_{MSY}\right)$								
0	0.729	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
100	0.729	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
200	0.729	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
300	0.729	0.991	0.998	0.999	0.999	1.000	1.000	1.000	1.000
400	0.729	0.967	0.974	0.971	0.981	0.986	0.988	0.990	0.990
500	0.729	0.926	0.921	0.897	0.907	0.910	0.908	0.912	0.914
600	0.729	0.881	0.801	0.735	0.739	0.724	0.697	0.689	0.685
700	0.729	0.773	0.638	0.526	0.506	0.457	0.434	0.411	0.394
800	0.729	0.670	0.455	0.341	0.299	0.246	0.207	0.182	0.163
900	0.729	0.558	0.296	0.201	0.151	0.099	0.082	0.066	0.055
1000	0.729	0.436	0.192	0.100	0.064	0.037	0.027	0.022	0.017
1100	0.729	0.351	0.097	0.048	0.021	0.013	0.005	0.003	0.002
1200	0.729	0.274	0.050	0.017	0.005	0.001	0.000	0.000	0.000
	$P\left(\tilde{B}_y > 0.8B_{MSY}\right)$								
0	0.016	0.741	0.991	1.000	1.000	1.000	1.000	1.000	1.000
100	0.016	0.609	0.944	0.979	0.998	1.000	1.000	1.000	1.000
200	0.016	0.477	0.833	0.912	0.975	0.994	1.000	1.000	1.000
300	0.016	0.377	0.647	0.755	0.876	0.961	0.979	0.987	0.995
400	0.016	0.289	0.441	0.541	0.711	0.814	0.879	0.923	0.948
500	0.016	0.189	0.268	0.335	0.463	0.578	0.631	0.698	0.742
600	0.016	0.123	0.148	0.183	0.264	0.327	0.361	0.412	0.442
700	0.016	0.079	0.073	0.096	0.130	0.144	0.162	0.181	0.188
800	0.016	0.054	0.030	0.039	0.057	0.053	0.062	0.066	0.064
900	0.016	0.037	0.014	0.013	0.018	0.020	0.021	0.021	0.023
1000	0.016	0.022	0.006	0.003	0.004	0.005	0.003	0.004	0.003
1100	0.016	0.012	0.002	0.000	0.001	0.001	0.000	0.000	0.000
1200	0.016	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000
	$E\left(\tilde{B}_y / B_{MSY}\right)$								
0	0.486	0.915	1.180	1.355	1.607	1.884	2.123	2.324	2.482
100	0.486	0.861	1.080	1.228	1.455	1.704	1.924	2.115	2.271
200	0.486	0.807	0.979	1.100	1.298	1.515	1.711	1.889	2.039
300	0.486	0.753	0.879	0.970	1.135	1.316	1.482	1.640	1.779
400	0.486	0.700	0.779	0.838	0.965	1.102	1.231	1.359	1.477
500	0.486	0.646	0.679	0.704	0.789	0.873	0.953	1.038	1.117
600	0.486	0.594	0.580	0.570	0.607	0.635	0.662	0.694	0.722
700	0.486	0.542	0.482	0.440	0.433	0.411	0.396	0.389	0.380
800	0.486	0.490	0.389	0.321	0.281	0.236	0.205	0.182	0.165
900	0.486	0.439	0.303	0.224	0.170	0.124	0.095	0.075	0.060
1000	0.486	0.389	0.229	0.153	0.098	0.062	0.041	0.028	0.020
1100	0.486	0.341	0.172	0.105	0.056	0.032	0.018	0.010	0.006
1200	0.486	0.296	0.130	0.074	0.035	0.019	0.009	0.005	0.002

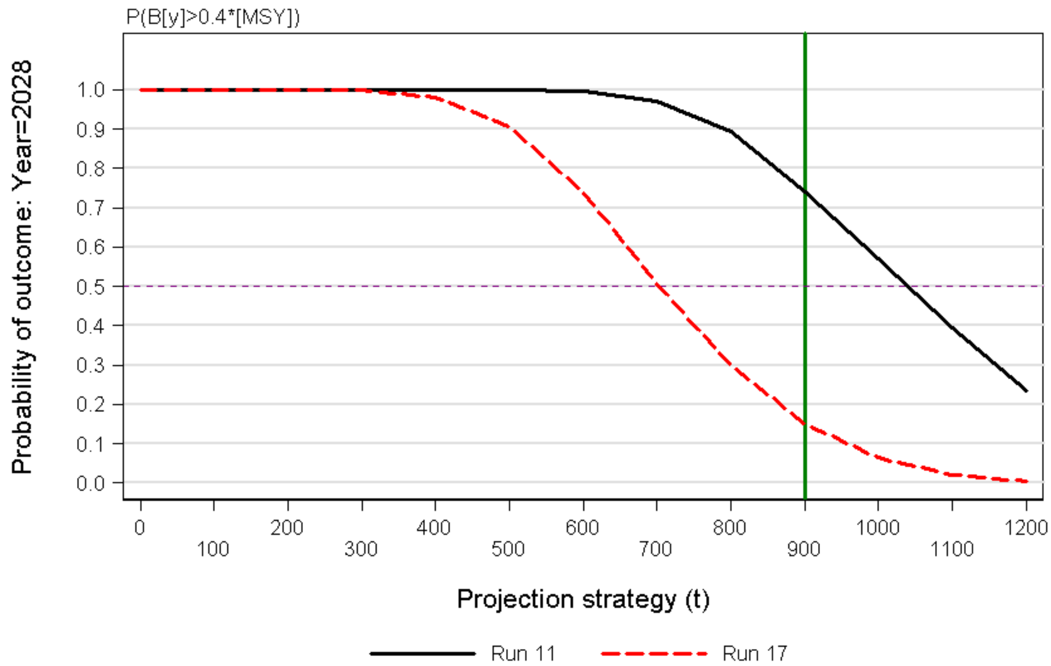

Figure 13. Comparison of the probability of $\tilde{B}_y$ exceeding $0.4B_{MSY}$ by the year 2028 for model runs 11 and 17. The green vertical line indicates the approximate position of the mean average catch over the past 5 and 10 years.

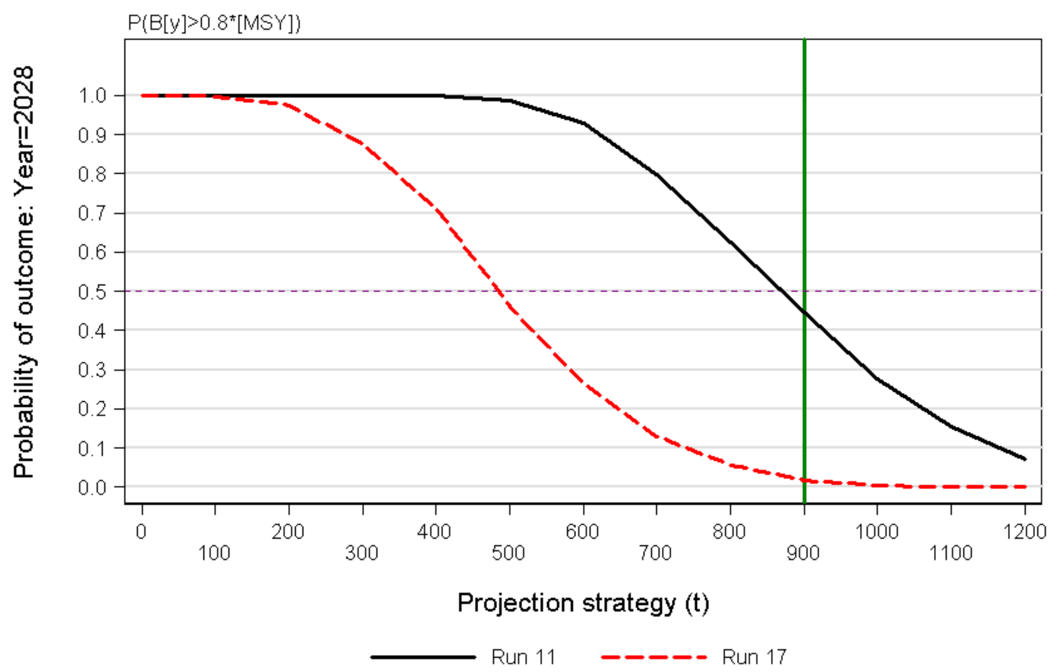

Figure 14. Comparison of the probability of $\tilde{B}_y$ exceeding $0.8B_{MSY}$ by the year 2028 for model runs 11 and 17. The green vertical line indicates the approximate position of the mean average catch over the past 5 and 10 years.

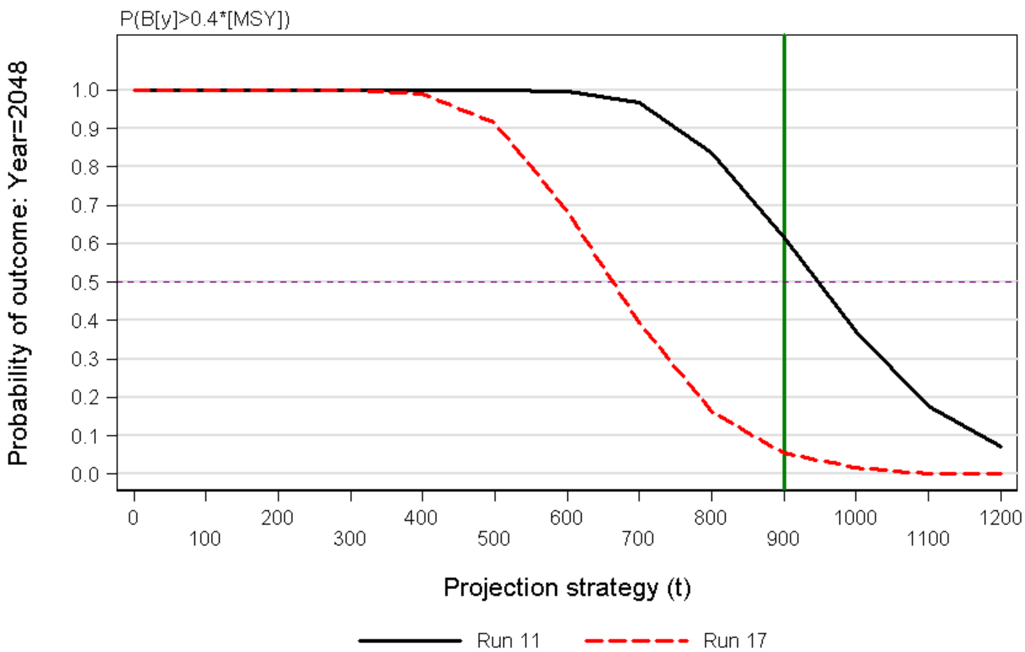

Figure 15. Comparison of the probability of $\tilde{B}_y$ exceeding $0.4B_{MSY}$ by the year 2048 for model runs 11 and 17. The green vertical line indicates the approximate position of the mean average catch over the past 5 and 10 years.

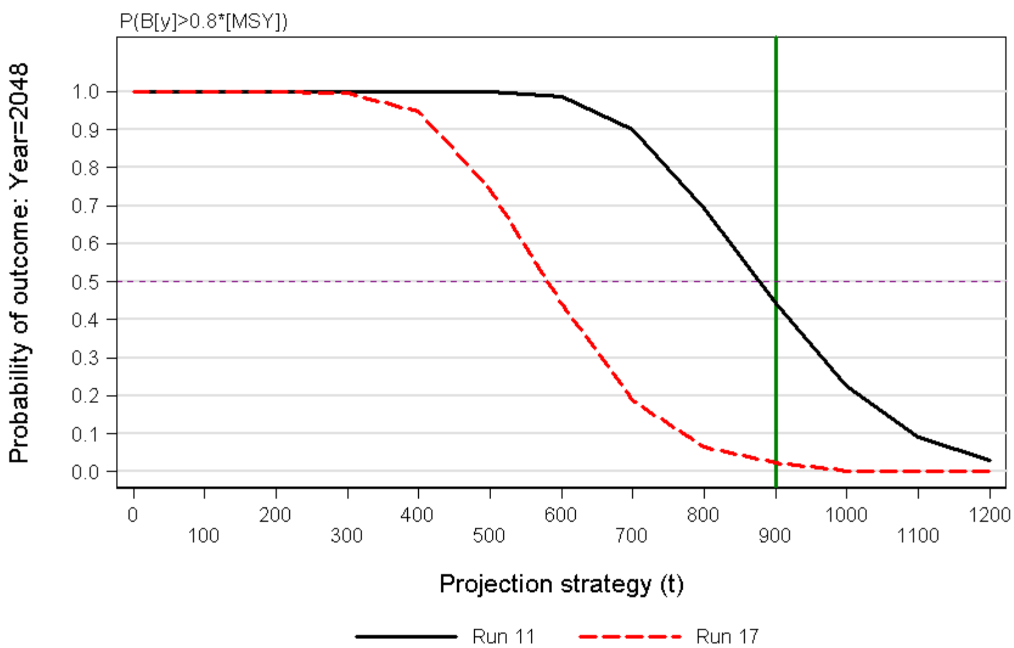

Figure 16. Comparison of the probability of $\tilde{B}_y$ exceeding $0.8B_{MSY}$ by the year 2048 for model runs 11 and 17. The green vertical line indicates the approximate position of the mean average catch over the past 5 and 10 years.

7. Evaluate residence requirements for the species

The SARA legislation defines residence as:

> *"a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" [s.2(1)].*

and notes:

> *"no person shall damage or destroy the residence of one or more individuals of a wildlife species that is listed as an endangered species or a threatened species, or that is listed as an extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada" [s.33].*

As noted above, adult and late-stage canary rockfish tend to be an "off-bottom" aggregating species that often favours high-relief bottom. While catch rates tend to be much higher in specific trawl grounds or even specific bottom trawl tow locations, we assume that these locations are at a much broader spatial scale than that intended in the above definition. We also assume that juvenile or adult canary rockfish do not alter in any manner these preferred locations. We therefore know of no evidence to suggest that canary rockfish exhibit residence requirements as defined above.

Phase II: Scope for management to facilitate recovery.

8. Probability that the recovery targets can be achieved and how that probability would vary with different parameters related to productivity.

The projections shown above examine the impact of two assumptions of productivity on the probabilities of reaching the target reference points in 5-year, 20, and 40 year projections.

9. Quantify the magnitude of each major potential source of mortality

Fishing mortality

In this and previous documents, we have assumed that harvests in the commercial groundfish fisheries are currently the major source of direct human-induced mortality on canary rockfish (Figure 17).

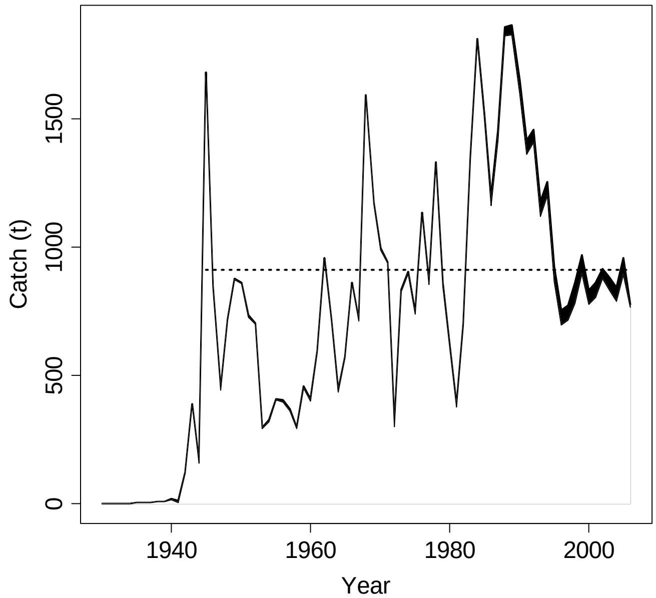

Figure 17. Total estimated canary rockfish catch from B.C. waters from Stanley et al. (2009). Average annual catch since 1945 is approximately 900 t (dashed line). The solid black portion represents hook-and-line catch.

Total catch for the 2007/08 fishing year[3] (retained and discarded) from the combined commercial groundfish trawl and hook-and-line (HL) sectors was 751 t of which 0.3% (2.4 t) was discarded (DFO FOS database). All **landings** from the commercial bottom trawl and HL are monitored with 100% dockside validation[4]. **At-sea** trawl catch (including discards) in the B.C. fishery has been monitored by a 100% coverage at-sea observer program since March 1997. **At-sea** groundfish HL catch has been monitored with 100% at-sea monitoring since April 2006. In general, catches of canary rockfish (retained and discarded) are well monitored in the commercial groundfish fisheries.

Small amounts (a few tonnes) are possibly caught in commercial salmon troll, First Nations' and recreational fisheries. While we suggested in Stanley et al. (2009) that these additional amounts are negligible with respect to the overall analysis of population status, these catches may need to be explicitly considered in a Recovery Strategy. The Recovery Strategy should address the potential for these fisheries to grow rapidly if targeting shifts from salmon to groundfish. If regulations were adopted to further reduce the commercial groundfish catch, the HL catches might be reduced to the extent that they become of similar magnitude to these other fisheries and it is important to note that verifiable catch estimates are not currently available from these fisheries.

The assessment presented by Stanley et al. (2009) does not include minor catches from sources such as First Nations' and recreational fisheries. However they are implicitly considered in the stock assessment because the model is fitted to biomass indices that track

[3] Note that since 1997, year refers to the "fishing year (FY)" such that 2007 actually refers to catches from April 1, 2006-March 31, 2007.

[4] 100% dockside monitoring was initiated in 1990 for the sablefish fishery, 1991 for halibut fishery, 1994 for the trawl fishery, and 1995 for the remaining groundfish hook and line sectors.

the effect on the stock of all mortalities, even those that are not quantified in the analysis. The underlying assumption is that these unquantified catches are constant over the model reconstruction period. Therefore, if catch categories that were not explicitly modelled are included in the Recovery Strategy, they should be added to the allowed mortalities because the model projections only include the catch categories that were explicitly modelled (trawl, and hook and line). Fishery-independent research surveys captured approximately 7 t in 2007. This total will vary in the future with abundance and the number of surveys being conducted; however, this amount should also be considered in the Recovery Strategy (again additional to the allowable mortalities).

Catches in California–Washington waters may have some impact on the B.C. population but we have no knowledge of the degree of overlap in these populations. It should be noted, however, that declines in the U.S. population of canary rockfish led to a declaration of overfishing and severe reductions in trawl effort and the landings of this species from the mid-1990s. We assume that U.S. fisheries do not currently represent a major source of mortality to the B.C. population. Should spawning biomass in these waters continue to increase, it may have a positive effect on the B.C. population but there are no means for predicting the impact. We note that recent U.S. assessments have indicated an increasing biomass of canary rockfish in Washington-California waters (Stewart 2007a) (
Figure ***18***). The current status of the Washington–California stock was summarized as:

> *"Canary rockfish were relatively lightly exploited until the early 1940s, when catches increased and a decline in biomass began. The rate of decline in spawning biomass accelerated during the late 1970s and finally reached a minimum (13% of unexploited) in the mid 1990s. The canary rockfish spawning biomass is estimated to have been increasing since that time, in response to reductions in harvest and above average recruitments in the preceding decade. However this trend is very uncertain. The estimated relative depletion level in 2007 is 32.4% (p. 6, Stewart 2007a).*

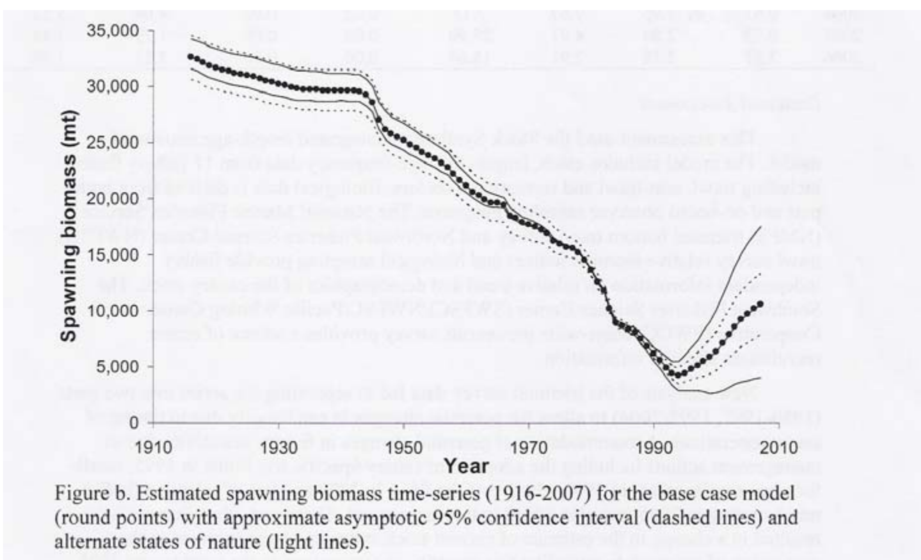

Figure b. Estimated spawning biomass time-series (1916-2007) for the base case model (round points) with approximate asymptotic 95% confidence interval (dashed lines) and alternate states of nature (light lines).

Figure 18. Modelled status of canary rockfish in California–Washington waters (Stewart 2007a, p. 6).

A rebuilding analysis for the U.S. population (California-Washington) is provided in Stewart 2007b).

Non-fishing sources of mortality

We know of no direct evidence of human activities causing significant canary rockfish mortalities other than those caused by fishing.

10. Quantify to the extent possible the likelihood that the current quantity and quality of habitat is sufficient

We assume that that larval canary rockfish occupy the pelagic coastal waters and early juvenile stages occupy a benthic habitat from sub-tidal to a 100-200 m in bottom depth over high-relief rocky bottom. The adults and late-stage juveniles appear to be predominantly an off-bottom (albeit near-bottom) and aggregating species with areas of highest density along the edge of the continental shelf. Given the assumed habitats of each life history stage and that they are considered to be much reduced in abundance from pre-exploitation levels, we know of no basis for assuming that the current quantity of physical habitat is limiting abundance.

11. Threats to habitat have reduced habitat quantity and quality

The lack of information on the ecology of canary rockfish, particularly, for the early life history, renders it problematic to speculate on habitat quality issues as they relate to canary rockfish. However, recent unpublished information (A. Sinclair pers. comm.) on observed declines in dissolved oxygen, which appear to be correlated with apparent shifts in distribution of many groundfishes species to shallower depths, may be a source of concern. These observations are preliminary and their longterm significance is unknown and it is not known if these shifts are outside expected long term variation. This observation could act to reduce both the quality and quantity of available habitat for canary rockfish.

At a more localized level, it is possible that long term effects of fishing gear (trawl and setline) have had an impact on canary rockfish through disturbance to biogenic habitat (i.e. coral and sponges). While these issues have been studied elsewhere, they have received little attention on the B.C. coast and no work has been directed specifically at the interaction of fishing on canary rockfish habitat.

It is also possible that other non-fishing human activities relating to proposed and existing coastal development in B.C. (for example, aquaculture, oil and gas exploration, including oil spills) may have negative impacts on canary rockfish through habitat perturbation, specifically larval and juvenile habitat. However, at this time, with the exception of the comments on dissolved oxygen above, there is no known evidence indicating significant threats to the habitat of canary rockfish.

Phase III: Scenarios for mitigation and alternative to activities

As noted in the RPA template (DFO 2007), items 12-14: **"*should be developed with substantial input from other sectors of DFO, and where appropriate, industries, stakeholders, and public interest groups*}".** Since these discussions have not been conducted at the time of preparing this report, the comments below are provided as a **starting point** for discussion on mitigation methods.

12. Inventory of all feasible measures to minimize/mitigate threats

Commercial catch or area fishing restrictions

Constraining commercial catches appears to be the principal practical means to minimize harm to the B.C. population of canary rockfish. These activities are the only known major source of human-induced mortality. We suggest that the primary means to constrain mortality will be through the management of the commercial fisheries, probably by the imposition of limits to total annual catch. Implementing such management restrictions will be the responsibility of DFO management in consultation with industry.

Other management options may be available in addition to catch restrictions, including temporal/spatial closures to fishing effort. These would be imposed to re-direct fishing effort away from specific fishing grounds and time periods when canary rockfish are most vulnerable to the fishery. However, such additional measures may be unnecessary as this will be the response generated from commercial harvesters as they cope with lower catch limits and are required to avoid canary rockfish to continue fishing other species. Fishers are already aware of most long-term chronic “hot-spots” and other factors (i.e. tides, time of day) which affect catch rates of canary rockfish. Furthermore, they are in constant communication with each other to report instances of where and when canary rockfish show up unexpectedly.

If spatial/temporal closures were adopted **instead of** catch restrictions, then fishers could maintain or exceed current canary rockfish catches as they target other species in the remaining areas and time periods. Since this species is a relatively large, aggregating and somewhat “off-bottom” species, it is presumed to be more wide-ranging than many other rockfish species.

Marine Protected Areas (MPAs) are an integral part of managing populations of nearshore rockfish species in B.C. but this management tool is likely to have limited benefit for canary rockfish. Nearshore species such as yelloweye, tiger, quillback, and copper rockfish tend to stay close to bottom and exhibit restricted movement as adults. Canary rockfish, being more wide ranging, would spend significant parts of their lives occupying exploitable grounds, thus reducing any benefit from the closed areas.

Regulations intended to reduce the harvest of mature females might augment the benefits of harvest controls; however, the limited amount of available biological sampling data have not revealed specific time/space windows where fishing mortality was disproportionately directed at mature females.

Unless exceptional opportunities are identified by industry during consultation, it is likely that little additional benefit will be gained by adding spatial/temporal effort restrictions to any overall catch restrictions. Furthermore, rigid spatial restrictions may exacerbate the hardship caused by catch reductions by reducing the flexibility of fishers to avoid canary rockfish while harvesting other target species.

13. Alternatives to the activities that are threats to the species and its habitat, but with potential for less impact

Changes to fishing gear

Gear and fishing strategy modifications are unlikely to provide commensurate reductions in canary rockfish exploitation rates. For instance, mean size in commercial samples tends to increase with depth and recruitment may be improved if industry targeted canary at greater depths than at present. This tactic might shift the selectivity curve to older, larger fish, taking a greater proportion of males and reducing exploitation on smaller juvenile fish which tend to exhibit a 50:50 sex ratio. However, such a shift to older ages in the catch may be counter-productive because older and larger female rockfish may contribute disproportionately to larval recruitment by producing higher quality larvae and more larvae per unit biomass (Sogard et al. 2008).

As noted earlier, while older juvenile stages are large enough to be retained by commercial trawl gear, they are uncommon in the catches. They are virtually absent from research trawls that use small-mesh liners. Therefore, the use of trawl mesh size changes or small-fish excluders which intend to reduce juvenile catch will probably be ineffective.

Because adult canary rockfish tend to be among the largest of the rockfish captured in bottom trawls, the use of "large-fish" excluders could be considered as a means of reducing incidental catches of canary rockfish in bottom trawl catches. However, the relative size differences between canary rockfish and other desirable target species are much less than in contexts where fish excluders have been used successfully (e.g., shrimp trawls). Although adult canary rockfish are large rockfish, they are smaller than adult female lingcod and similar in size to many other rockfish species. We are not aware of any previous work in this area with respect to rockfish. The potential of this mitigation procedure or other changes to trawl or HL fishing should be discussed with industry.

As shown in Figure 5, HL fisheries generate a higher proportion of their catch in shallow waters, which should lead to a higher proportion of juveniles in their catches. However, the HL fishery only accounts for a very small fraction of the overall canary catch, so reducing a portion of this catch would likely have negligible benefit

Non-fishery related threat mitigation

As noted above, there are currently no demonstrated non-fishery related threats to canary rockfish. Current coastal activities may have adverse effects on some life stages of canary rockfish but there is no current evidence for this and no means available at this time to assess the impact of the various activities.

14. An inventory of all reasonable and feasible activities that could increase the productivity or survivorship parameters

We are not aware of any practical means for increasing the productivity of canary rockfish. Artificial enhancement has yet to be proven practical for rockfish species in B.C. waters owing to highly vulnerable larval states, the slow growth rate, and late maturation in comparison with other species.

Survival rates of rockfish following capture are generally thought to be very low owing to the effects of barotrauma; releasing dead fish would provide no obvious benefits. Under experimental field conditions, the chance of survival can be increased for some other species of rockfish through "de-gassing" or "venting" (i.e. using an empty syringe to remove gas pressure in the swim bladder) or even lowering fish to depth prior to release. However, employing these techniques in routine trawl and HL operations would be problematic.

15. Estimate, to the extent possible, the reduction in mortality rate expected by each of the mitigation measures in step 10 or alternatives in step 11 and the increase in productivity or survivorship associated with each measure in step 12.

As stated above, we view controlling total catch in the commercial groundfish fisheries as the best means to increase the probability that the population will become larger. The predicted impacts of varying catch are shown in the Tables 5-9 and Figures 11-16.

16. Project expected population trajectory over target time frame.

Tables 5 to 9 provide projections of the impacts of a range of fixed catch levels on spawning biomass for the three runs accepted by PSARC from the 2007 canary rockfish assessment relative to the PA guidelines. These projections may be augmented and updated by further runs during the consultation phase.

As noted earlier, commercial catches were 751 t in the 2007/2008 Fishing Year, which was the first projection year in the 2007 canary rockfish assessment. The forecasts provided in Tables 5 to 9 indicate that continued harvests at this level would lead to a modest decline over the next five years, but the population would still continue to lie within the "cautious zone" as defined in the PA. Harvests of this magnitude over the last decade have been associated with a flat trend in abundance (Fig. 2, this document). Notwithstanding the uncertainty in the assessment and forecasts, short-term projections of 1 to 2 years predict that current commercial groundfish catches of about 750 t per year will not place the population in additional jeopardy.

17. Recommend parameter values for population productivity and starting mortality rates, and where necessary, specialized features of population models that would be required to allow exploration of additional scenarios as part of the assessment of economic, social, and cultural impacts of listing the species.

The current assessment document which considers two productivity assumptions provides a reasonable range of scenarios for developing a recovery strategy.

CONCLUSIONS

The three model runs accepted by PSARC indicate that current spawning biomass is most likely within the cautious zone as defined by the provisional reference points in the PA policy documents. However, there is significant uncertainty around these estimates.

The quantity of physical habitat does not appear to be limiting canary rockfish abundance; however, recent unpublished information on observed declines in dissolved oxygen which appear to be correlated with a shift in distribution of many groundfishes species to shallower depths is a source of concern. Current or future coastal activities such as aquaculture, oil and gas exploration, or oil spills, have the potential to affect canary rockfish abundance specifically through impacts on the larval and early juvenile stages.

Controlling the commercial harvest of canary rockfish appears to be the most effective way to mitigate threats to this population. Although under special circumstances, regulations which modify the gear used or the fishing strategy might provide modest benefits in reducing harvests, such benefits are unlikely to be commensurate with the added costs incurred by such regulations. In addition, the limited availability of quota is likely to generate similar benefits without the requirement for additional regulation. Such scenarios are best discussed in consultation with harvesters.

It is possible that harvests in U.S. waters may have an impact on abundance of canary rockfish in B.C. waters; but the degree of overlap in populations is unknown. U.S. trawl landings of canary rockfish and the overall trawl effort have been significantly reduced since the late 1990s and the most recent assessment of the California–Washington canary population indicates that it is starting to increase. At this time, the fishery in U.S. waters does not appear to be posing a threat to the B.C. population. However, given the possibility of overlap in the two populations, it may be beneficial in the future to work towards a harmonized approach in the management of this species.

Biomass targets, recovery timeframes, and acceptable probabilities for reaching the targets will be determined during the Recovery Strategy consultation. A series of decisions tables in this document provide predictions of stock trends under different levels of fixed annual catch under the three model runs accepted by PSARC.

Notwithstanding the uncertainty in the assessment and forecasts, short-term projections of 1 to 2 years predict that current commercial groundfish catches of about 750 t per year will not place the population in significant additional jeopardy. However, longer term predictions based on the decision tables suggest that a reduction in harvest from current levels is required to significantly increase the probability of a population increase, as well as to increase the speed of the rebuild.

Future development of Recovery Potential advice for canary rockfish should also include long-term forecasts under a range of constant harvest rates, as well as the constant catch levels provided in this document. Feedback control rules (often known as “Management Procedures”) can be developed and evaluated using an operating model based on the 2007 stock assessment. Such an operating model can incorporate the uncertainty inherent in the imprecise nature of the data available for canary rockfish.

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This report is available from the:

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Pacific Region
Fisheries and Oceans Canada
Pacific Science Advisory Review Committee
Pacific Biological Station
Nanaimo, B.C.
V9T 6N7

Telephone: 250-756-7208
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E-Mail: psarc@dfo-mpo.gc.ca

ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2009. Recovery assessment of canary rockfish in British Columbia waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/041.