RECOVERY POTENTIAL ASSESSMENT OF BOCACCIO IN BRITISH COLUMBIA WATERS

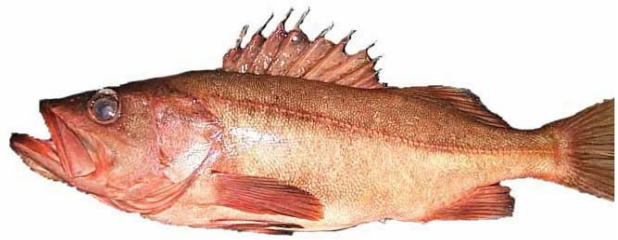

Figure 1. *Adult bocaccio (DFO)*

Figure 2. British Columbia waters

Context :

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed bocaccio 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 accept the COSEWIC assessment and list the species, decide not to list the species, or 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 bocaccio rockfish reviewed by the Pacific Scientific Advice Research Committee in November 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. 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 actual selection of recovery targets will be done during development of the Recovery Strategy.

SUMMARY

- The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed the bocaccio 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) and is derived partly from a stock assessment on bocaccio reviewed by the Pacific Scientific Advice Research Committee (PSARC) in October 2008. The specific intent of this RPA is to predict the impact of future harvest levels on bocaccio 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).

- Bocaccio are one of over 39 species of rockfish present in B.C. waters. Other vernacular names for bocaccio include rock salmon, salmon rockfish, Pacific red snapper, Pacific snapper, and Oregon snapper, however these names are shared with other species. Female bocaccio mature at about 7 years of age with a generation time of about 20 years. The population is assumed to be one designatable unit in B.C.

- Little is known about the distribution of young bocaccio in B.C. waters although they have been captured in nearshore sub-tidal depths. California studies indicate that young of the year reside near the surface for a few months then settle to the littoral and demersal habitat in late spring and summer. Most of the late stage juveniles and adult specimens are caught over bottom depths of 60-340 m on the continental shelf. Most bocaccio die if released after capture. Bocaccio does not appear to exhibit “residence requirements” as defined in the SARA legislation.

- A coastwide assessment of bocaccio was conducted using a Bayesian surplus production model that was fitted to six fishery-independent surveys, commercial bottom trawl CPUE and a catch reconstruction starting in the 1930s. The assessment was reviewed by PSARC in October 2008. This document includes analytical revisions to the model formulation causing a recalculation of the main results. These are provided in this document.

- The overall long-term trend in the updated version has changed very little from the version presented to PSARC, with the biomass showing a progressive decline since the 1930s and the steepest decline occurring between 1985 and 1995. The estimates of stock status lie within the reference critical zone according to the DFO PA and the current absolute and relative status is estimated to be lower than when presented to PSARC. The mean and median estimates of 2008 biomass are now estimated to be 3,022 t and 2,324 t respectively, with the previous comparable estimates being 4,383 and 3,252 t. The updated posterior mean and median estimates of relative stock status (B_{08}/B_{MSY}) are 0.155 and 0.111 respectively, which were previously 0.229 and 0.166.

- Harvests in the commercial groundfish fisheries are assumed to be the major current source of human-induced mortality. Total catch in the 2007/2008 fishing year was 135 t and 17 t in the groundfish trawl and hook & line (HL) fisheries, respectively. These catches

are incidental while targeting on other species. 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 First Nations and recreational fisheries are unknown but likely relatively small.

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

- Given that bocaccio appear to be predominantly a semi-pelagic 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 bocaccio rockfish have residence requirements, as defined in SARA**.**

- Restricting commercial catches appears to be the most practical means at present to minimize harm to bocaccio in B.C. waters. How catch restrictions are implemented should be developed in consultation with industry.

- Recovery targets (i.e. target biomass, the time frame, and likelihood of reaching the target) must be developed through the consultation phase. A series of decision tables provided in the document give predictions of stock trends under several harvest rules under a range of modelling assumptions. These tables capture the relative trade-offs required over these dimensions.

- 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 and the true uncertainty is even greater with the 20-y and 40-y forecasting adding even more uncertainty. These projections assume the population will respond to the future environment as it did to the past environment, an assumption which may not hold due to the effects of cyclical or longterm 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 150 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 in this document suggest that a reduction in harvest from current levels is required to significantly increase the probability of a population increase.

INTRODUCTION

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed the bocaccio (*Sebastes paucispinis*) population in British Columbia waters as "Threatened"[1]. A "Regional Listing Recommendation" is required from Department of Fisheries and Oceans (DFO) in early 2010 to assist the Federal Minister of the Environment in reviewing this designation. This review will be followed by a "Proposed Listing Decision" in the fall of 2010 and a "Final Listing Decision" by December 2010. If the Threatened status is accepted, a Recovery Strategy will be required within two years (DFO 2007).

The general intent of this document is to provide the scientific advice required for development of the Recovery Strategy. It follows the outline provided in the "Revised Protocol for Conducting Recovery Potential Assessments" (DFO 2007). The material in this document is derived from a stock assessment on bocaccio rockfish reviewed by the Pacific Scientific Advice Research Committee (PSARC) in October 2008 (Stanley et al. 2009). It also includes recommendations and corrections resulting from and following the PSARC review.

The specific intent of this Recovery Potential Assessment (RPA) 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 process of developing a Recovery Strategy, should this be deemed necessary. In this respect, while the stock status and forecasting advice presented in this document are framed to be consistent with the current DFO policy on the "Precautionary Approach" (DFO 2006, DFO 2008), the RPA protocol notes that the "….***actual selection of recovery targets will be done as part of the Recovery Strategy*****"**.

Species Biology

Bocaccio 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. Bocaccio is distinguished from other rockfish by its large jaw and size. Vernacular names for bocaccio include rock salmon, salmon rockfish, Pacific red snapper, Pacific snapper, and Oregon snapper, although these names are shared with other species.

Bocaccio are live-bearers like all members of their genus. Fecundity ranges up to 2,300,000 eggs and increases with the size of the female. Copulation occurs in early fall and parturition (release of live young) occurs in late winter in B.C. waters (Westrheim 1975). Growth of is rapid; juveniles can reach 24 cm by the end of their first year (MacCall et al. 1999).

Stanley et al. (2009) report that female age and length at 50% maturity in B.C. is about 7 years and 55-60 cm respectively. Maximum recorded size is 97 cm and 8.9 kg for females, and 85 cm and 9.0 kg for males in B.C. waters. Maximum recorded age in B.C. waters is 52 and 57 years for females and males respectively. Specimens captured in the fisheries average about 4.0 kg. Stanley et al. (2009) estimated generation time as 17.9 years, rounded to 20 years for recovery planning.

[1] http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=740

ASSESSMENT

Phase I: Assess current/recent species status

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

Bocaccio are found in the eastern Pacific Ocean from Stepovak Bay, Alaska (west of Kodiak Island), to Baja California, Mexico (Eschmeyer et al. 1983). Commercial trawl fishery catches indicate that bocaccio are present along the entire outer Pacific coast of B.C. waters (Figure 3). Most commercial groundfish fishing is conducted on the outer coast near the continental shelf break as well as within Hecate Strait and Queen Charlotte Sound. There is little information on species distribution in the inlets and nearshore waters of B.C., but they have been reported from the Strait of Georgia, Juan de Fuca Strait, and other inlets and enclosed waters (Figure 3).

There are no obvious trends in the distribution of bocaccio catches in the outer coast trawl fishery since 1996 (Stanley et al. 2001), but longer-term, fine-scale comparisons of the distribution are not possible owing to the lack of adequate geospatial data prior to 1991 (see Rutherford 1999) and the lack of species composition data prior to 1967. There is no known biological basis for assigning more than one distinct population for bocaccio in B.C., therefore, with respect to the risk of extinction, the bocaccio population in BC is assumed to be one designatable stock unit (Stanley et al. 2009).

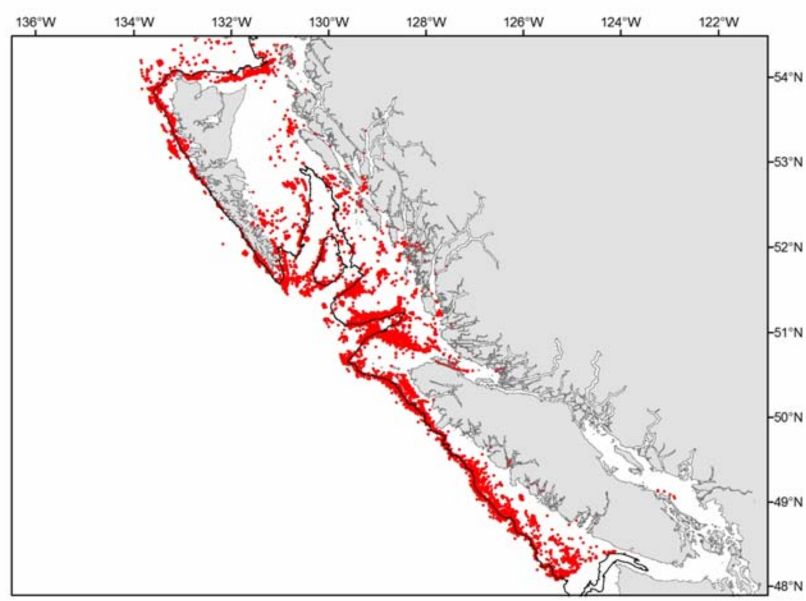

Figure 3. Catch locations of bocaccio in commercial and research catches 2004-2008. The 200 m depth contour is shown by a black line.

An assessment of the coastwide bocaccio stock was conducted using a Bayesian surplus production model that was fitted to six fishery-independent surveys and commercial bottom trawl CPUE (Stanley et al. 2009., DFO 2008). A Bayesian approach was used to explicitly incorporate model and data uncertainty in the assessment results. However, following the presentation of Stanley et al. (2009) at the October 2008 PSARC meeting, a mistake was found in the model calculations. The corrected version provides a more pessimistic view of the current status than that reviewed at PSARC (Table 1 and Table 2). Unless otherwise noted (i.e. Table 1) the following tables and figures indicate the updated results. The previous document, Stanley et al. (2009), will be left unchanged and remains a description of the overall methodology, the inputs (catch, survey estimates and life history parameters) and an exploration of the potential influence of different parameter choices or model configurations. It will however, include a statement that the results were subsequently updated and documented in the present report.

Under the updated reference case, the posterior mean and median estimates of stock biomass in 2008 are 3,022 t and 2,324 t respectively, compared to the original estimates of 4,383 t and 3,292 t (Table 1 and Table 2). Current stock size is low relative to the unfished stock size (*K*) and the mean of the posterior distribution for the point of maximum productivity (B_{MSY}): the posterior mean for B_{2008}/K *is* 8% and for B_{2008}/B_{msy} is 16%. The median values from the posterior distributions are lower at 5.6% and 11% respectively for the same derived parameters. Stock biomass has shown a progressive decline since the 1930s, with the steepest decline occurring between 1985 and 1995 (Figure 4). The impacts on the biomass trend and relative stock status based on alternative model assumptions were explored over 31 sensitivity runs in the assessment presented to PSARC (see Stanley et al. 2009).

Table 1. Original model estimates as reported in Stanley et al. (2009) from posterior distributions estimated by the reference run: the mean, SD, coefficient of variation (standard deviation/ mean), 10th, 50th, and 90th percentiles and mode for key parameters and stock status indicators for B.C. bocaccio. B_{08} and C_{08} are the recruited stock biomass and catch biomass in 2008 (in tonnes), Rep(Y) is the replacement yield in 2008.

	Mean	SD	CV	10%	Median	90%	Mode
K	52720	35538	0.67	19952	43715	95780	23704
r	0.096	0.025	0.26	0.066	0.092	0.129	0.071
MSY	1191	774	0.65	467	999	2137	552
B_{08}	4383	3853	0.88	1248	3292	8682	1545
B_{08}/K	0.115	0.109	0.952	0.030	0.083	0.232	0.037
B_{08}/B_{MSY}	0.229	0.218	0.952	0.059	0.166	0.464	0.074
B_{MSY}	26360	17769	0.674	9976	21857	47890	11852
Rep(Y)	326	211	0.647	128	274	584	152

Table 2. Corrected model estimates from posterior distributions estimated by the reference run: the mean, SD, coefficient of variation (standard deviation/ mean), 10th, 50th, and 90th percentiles and mode for key parameters and stock status indicators for B.C. bocaccio. B_{08} and C_{08} are the recruited stock biomass and catch biomass in 2008 (in tonnes), Rep(Y) is the replacement yield in 2008.

	Mean	SD	CV	10%	Median	90%	Mode
K	54042	35803	0.66	20796	45053	97601	24646
r	0.094	0.024	0.26	0.065	0.091	0.126	0.070
MSY	1203	783	0.65	470	1008	2159	556
B_{08}	3022	2511	0.83	918	2324	5882	1126
B_{08}/K	0.078	0.076	0.973	0.020	0.056	0.158	0.025
B_{08}/B_{MSY}	0.155	0.151	0.973	0.039	0.111	0.317	0.049
B_{MSY}	27021	17901	0.662	10398	22526	48801	12323
Rep(Y)	236	154	0.649	93	198	424	110

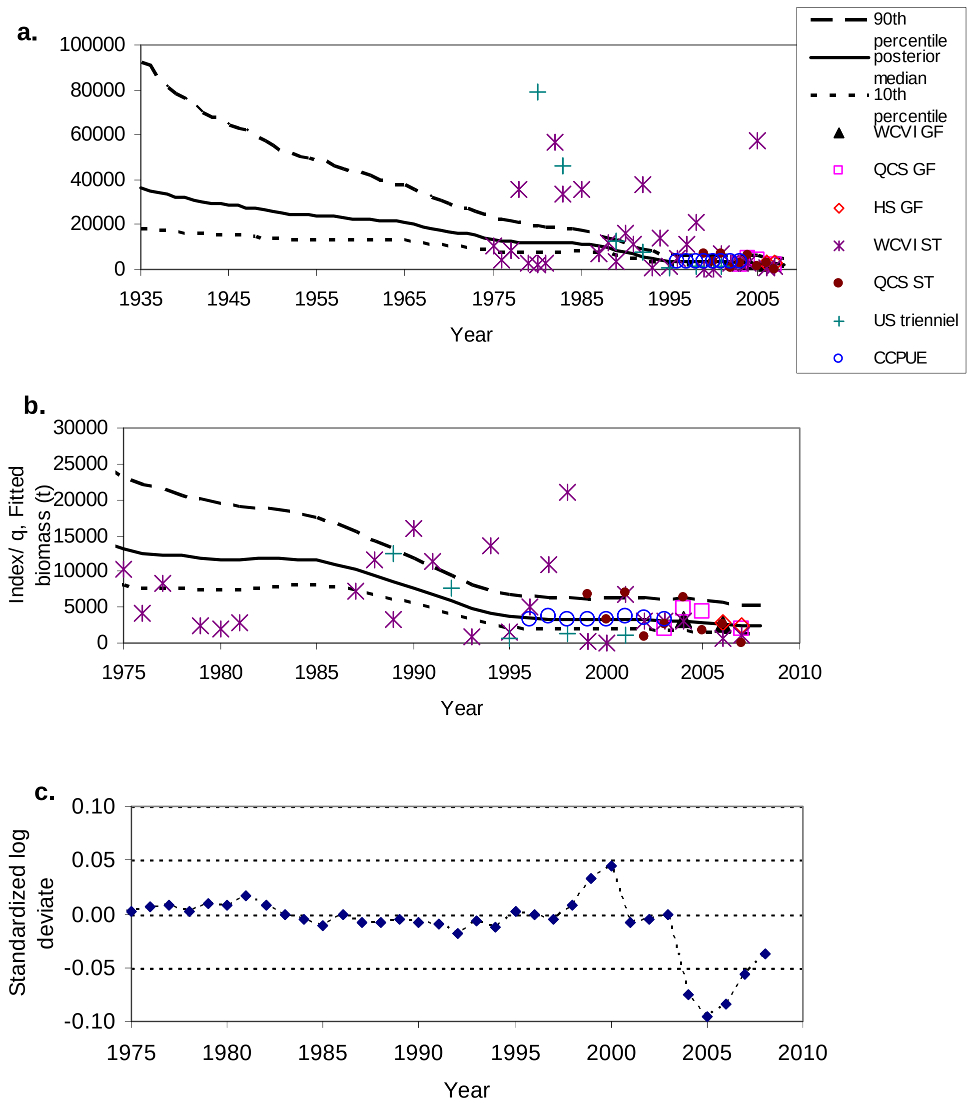

Figure 4. For the reference case, a. posterior median and 80% probability intervals for stock biomass, and the stock trend indices divided by their posterior modal value of constants of proportionality for years 1935-2008, b. the same as a. but with high values not plotted and only for years from 1975 to 2008; and c. log standardized annual deviates in surplus production for years from 1975 to 2006.

2. Evaluate recent species trajectory for abundance, range, and number of populations.

Figure 4b from the reference run indicates that the trend of recent abundance has flattened since 1995, with no evidence of an increase in recent years and possibly a decline. As shown in Figure 3, the range of bocaccio in B.C. continues be widespread along the edge of the continental shelf, with additional scattered observations from enclosed waters and some inlets.

3. Estimate life history parameters

The life history parameters that were used in the stock assessment are summarized in Stanley et al. (2009) and are expressed in the model through a single parameter, *r*, the maximum intrinsic rate of increase. An informed prior based on available life history data including growth, natural mortality rate, maturity-at-age and stock-recruit steepness was developed for this model parameter for use in the reference case. The assessment also explored the effect on the analysis of lower and higher assumptions of stock productivity by shifting the assumption on steepness up and down by 0.1 unit relative to the assumption used in the reference case (Stanley et al. 2009).

4. Describe and quantify the habitat requirements and habitat use patterns

Little is known about the distribution of larval and juvenile stages in B.C. waters, although young bocaccio have been captured in gillnets in sub-tidal depths off the west coast of Vancouver Island (Gillespie et al. 1993). California studies indicate that at the time of parturition, larvae are approximately 4-5 mm in length (Moser 1967). Young of the year reside near the surface for a few months and have been caught up to 480 km from the California coast. Settlement to the littoral and demersal habitat extends from late spring through the summer, where they form schools and are found over bottom depths of 30-120 m. Juveniles are generally captured in depths of 30-120 m, and may be associated with kelp beds (Moser 1967). Fish size appears to increase with depth (Love et al. 1990).

Most of the older juveniles and adult specimens are captured during commercial bottom and midwater trawling over bottom depths of 60-340 m in B.C. waters. The principal fishing locations are on the continental shelf, the edge of the shelf ("break-in-slope") and along the edges of underwater canyons and troughs (Figure 3). Other than the assumption that juveniles aggregate over hard bottom, we are not aware of any spawning or nursery areas. We could not detect any evidence of specific sites for mating or parturition (release of live young) in the available data. In B.C., bocaccio are caught with several other groundfish species including Pacific ocean perch, yellowtail rockfish, and canary rockfish. Their presence in midwater catches and salmon troll catches indicate they can be semi-pelagic (off-bottom) in depth preference.

Like all species in the genus, bocaccio cannot rapidly accommodate the sudden change in pressure as they are brought to the surface. The resulting barotrauma causes death for almost all fish captured during routine commercial fishing. Little is known about their adaptability to other possible changes in their environment.

The barotrauma effects render tagging studies difficult. However, results of two tagging studies that were conducted in California (Hartman 1987, Starr et al. 2001) indicate that bocaccio are mobile during the first few years of life (up to 148 km) but become more sedentary at older ages. Movement appears to decrease significantly after they reach a length of about 47cm (Hartmann 1987). Starr el al. (2001) also showed that bocaccio made rapid vertical movements. Three tagged fish rose vertically to the surface and then returned to depth. A fourth fish dove to 220 m and rose back to 100 m in less than one day. In California, juvenile bocaccio feed on larvae, euphausiids, young rockfish, surfperch, mackerel, and various small inshore fishes. Adult bocaccio prey on other rockfish, sablefish, anchovies, lanternfish, and squids.

5. Population and distribution targets

Since bocaccio appear to be widespread in B.C. waters, this document does not attempt to provide or define a “distribution” target. With respect to relative biomass, 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. Stock status is divided into three zones, Healthy, Cautious, and Critical (Figure 5). 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 consideration of biological, social, and economic factors. The removal reference (RR) 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. In all cases, the expected removal rate for a TAC should not exceed the associated RR in a PA compliant harvest strategy.

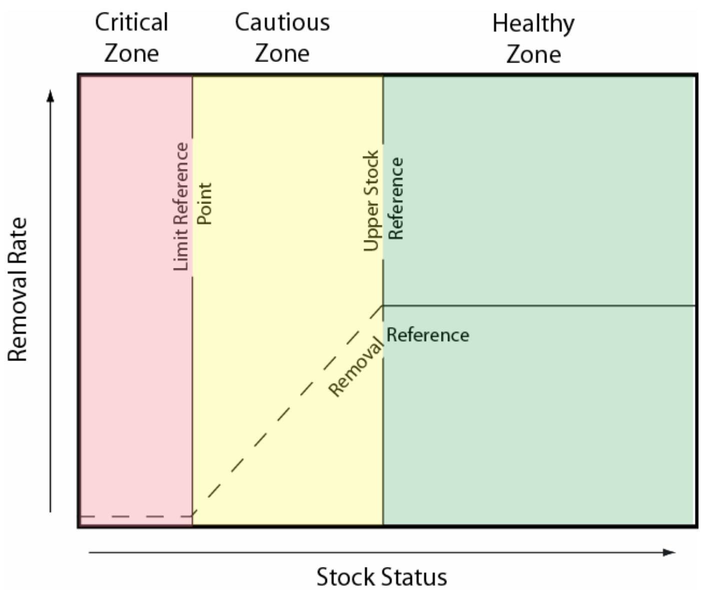

Figure 5. A harvest strategy compliant with the precautionary approach (DFO 2006)

DFO has further circulated a “Fisheries Stewardship and Sustainability Checklist[2]” with suggested proxies for the PA harvest strategy reference points:

> *“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*

[2] A draft of Version 2 of the Checklist is still in the approval process within DFO.

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".*

The posterior mean and median estimates of the current bocaccio stock status (B_{08}/B_{MSY}) are 0.155 and 0.111 respectively (Table 2), indicating that the population of bocaccio in B.C., based on the reference run, is in the critical zone as defined by the PA. Note that the upper 90% bound of this quantity is less than the $0.4B_{msy}$ limit (Table 2).

6. Estimate expected population trajectories

Population forecasts are provided under different constant quota policies (Table 3) and constant exploitation rate policies (constant *F*) (Table 4, Figure 6, Figure 7, and Figure 8) for the Reference case (which uses the best estimate of productivity). The matching constant *F* policies correspond to current year+1 harvests of 0, 50, 100, 150, and 200 t/year. The constant F policy option was added subsequent to the PSARC review in response to industry requests.

The tables indicate expected values and probabilities of the stock reaching target references points over 5-, 20-, and 40-year horizons, with the latter two projections approximating one and two generations. We chose not to model three generations owing to the large uncertainties in projecting over this time frame. The results for the constant quota policy indicates, for example, that while 0 harvest will lead to an 84% chance of the population exceeding the limit reference point in 40 years, harvests of 150 t/y indicate a 47% probability of meeting this target. Figure 6 shows that the model correction has made the constant *F* policy projections considerably less optimistic.

While the Bayesian approach used in this assessment provides a formal mechanism to include uncertainty in model output (including predictions), managers, and stakeholders are advised that not all sources of uncertainty have been addressed and that the true uncertainty is even greater than that presented here. This is because this stock assessment model is relatively simple and there will be unmodelled processes which will add to the overall uncertainty. Even so, there is considerable uncertainty in the relative and absolute estimate of current status presented in the stock assessment results (Stanley et al. 2009). Forecasting adds more uncertainty, as presented in the projection results. But these uncertain projections assume the population will respond to the future physical and biological environment as it did in the past, an assumption which may not hold due to the effects of climate change and/or other external processes.

Table 3. Stock status indicators for bocaccio after 5, 20, and 40 years under constant quota policies in tonnes for the reference case: best estimate of productivity.

Horizon	Policy	$E(B_{fin}/B_{msy})$	$P(B_{fin}>0.4\ B_{msy})$	$P(B_{fin}>0.8B_{msy})$	$P(B_{fin}>B_{cur})$
5 -year	TAC= 0	0.21	0.15	0.03	0.72
	TAC= 50	0.20	0.14	0.03	0.66
	TAC= 100	0.19	0.13	0.02	0.56
	TAC= 150	0.17	0.12	0.02	0.46
	TAC= 200	0.16	0.12	0.02	0.37
	TAC= 250	0.15	0.11	0.02	0.30
	TAC= 300	0.13	0.10	0.02	0.25
20 -year	TAC= 0	0.64	0.55	0.31	0.91
	TAC= 50	0.56	0.49	0.27	0.83
	TAC= 100	0.46	0.42	0.21	0.68
	TAC= 150	0.37	0.33	0.17	0.52
	TAC= 200	0.29	0.27	0.14	0.40
	TAC= 250	0.23	0.22	0.11	0.30
	TAC= 300	0.18	0.19	0.09	0.23
40 -year	TAC= 0	1.26	0.84	0.68	0.97
	TAC= 50	1.09	0.74	0.60	0.88
	TAC= 100	0.86	0.61	0.49	0.71
	TAC= 150	0.64	0.47	0.37	0.52
	TAC= 200	0.48	0.38	0.29	0.38
	TAC= 250	0.35	0.29	0.21	0.28
	TAC= 300	0.26	0.23	0.16	0.21

Table 4. Stock status indicators for BC bocaccio after 5, 20, and 40 years under constant F policies in tonnes for the reference case (best estimate of productivity). "icur" signifies the year 2008.

Horizon	Policy	$E(B_{fin}/B_{msy})$	$P(B_{fin}>0.4\ B_{msy})$	$P(B_{fin}>0.8B_{msy})$	$P(B_{fin}>B_{cur})$
5 -year	F=F(TAC(icur+1)) 0	0.21	0.15	0.03	0.72
	F=F(TAC(icur+1)) 50	0.20	0.14	0.03	0.66
	F=F(TAC(icur+1)) 100	0.19	0.13	0.02	0.56
	F=F(TAC(icur+1)) 150	0.17	0.12	0.02	0.46
	F=F(TAC(icur+1)) 200	0.16	0.11	0.02	0.37
20 -year	F=F(TAC(icur+1)) 0	0.64	0.55	0.31	0.91
	F=F(TAC(icur+1)) 50	0.50	0.45	0.22	0.84
	F=F(TAC(icur+1)) 100	0.39	0.34	0.17	0.69
	F=F(TAC(icur+1)) 150	0.30	0.27	0.12	0.54
	F=F(TAC(icur+1)) 200	0.24	0.23	0.10	0.41
40 -year	F=F(TAC(icur+1)) 0	1.26	0.84	0.68	0.97
	F=F(TAC(icur+1)) 50	0.87	0.69	0.52	0.90
	F=F(TAC(icur+1)) 100	0.60	0.55	0.36	0.75
	F=F(TAC(icur+1)) 150	0.42	0.41	0.25	0.57
	F=F(TAC(icur+1)) 200	0.30	0.32	0.18	0.42

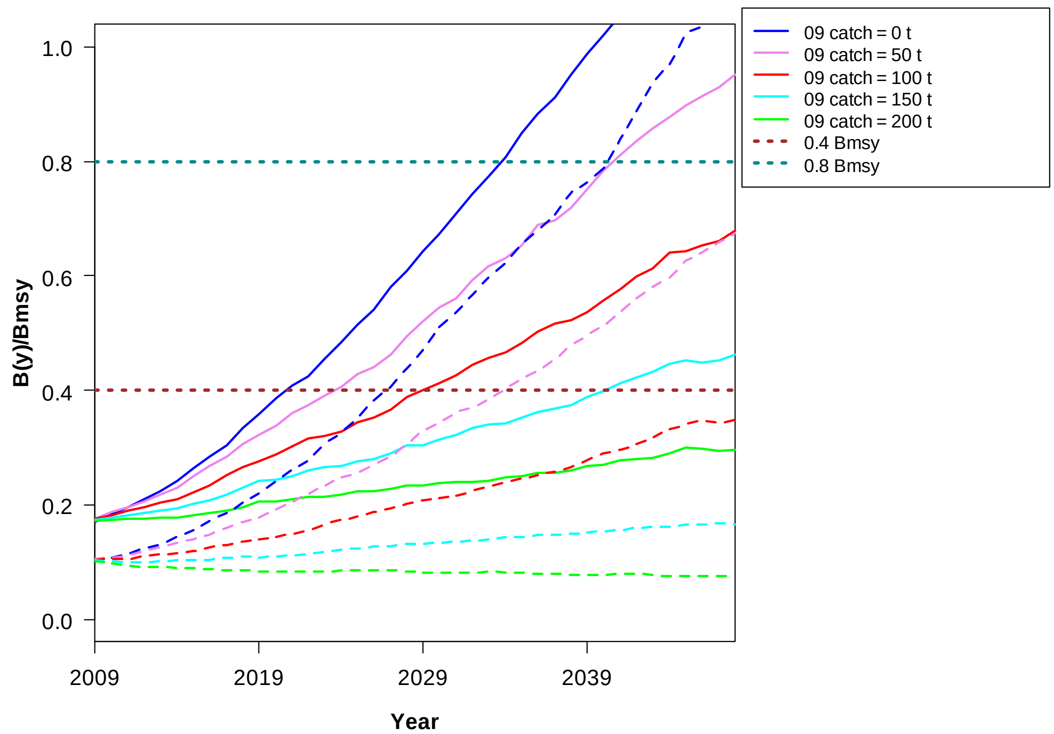

Figure 6. The original and corrected long-term forecasts of median bocaccio relative biomass B_y/B_{msy} under different constant F polices for the reference case (solid and dashed lines indicate Original PSARC and corrected forecast, respectively.

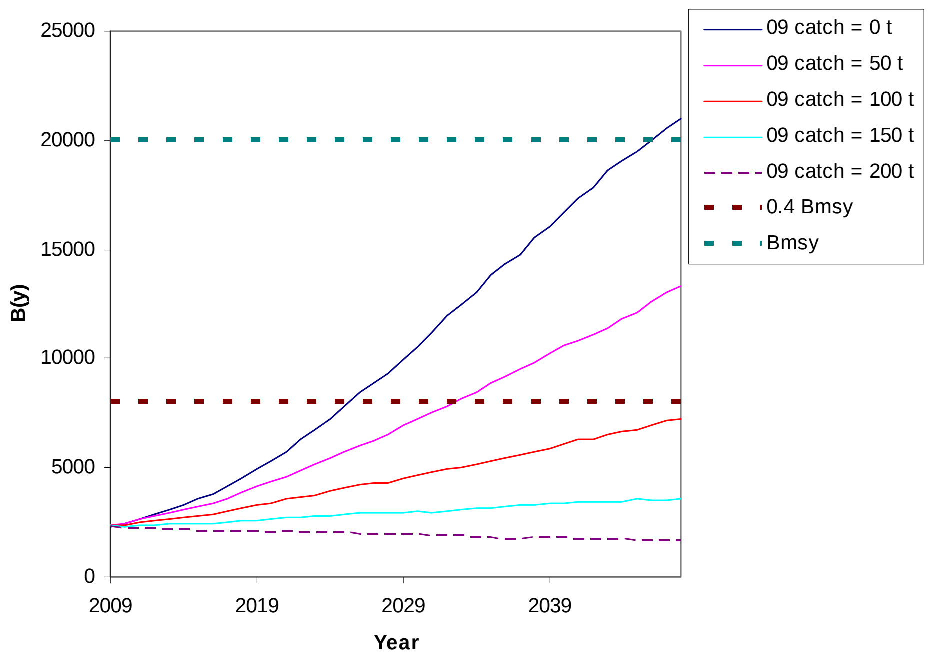

Figure 7. Median estimate of exploitable biomass over 40 years with constant F policy for the reference case.

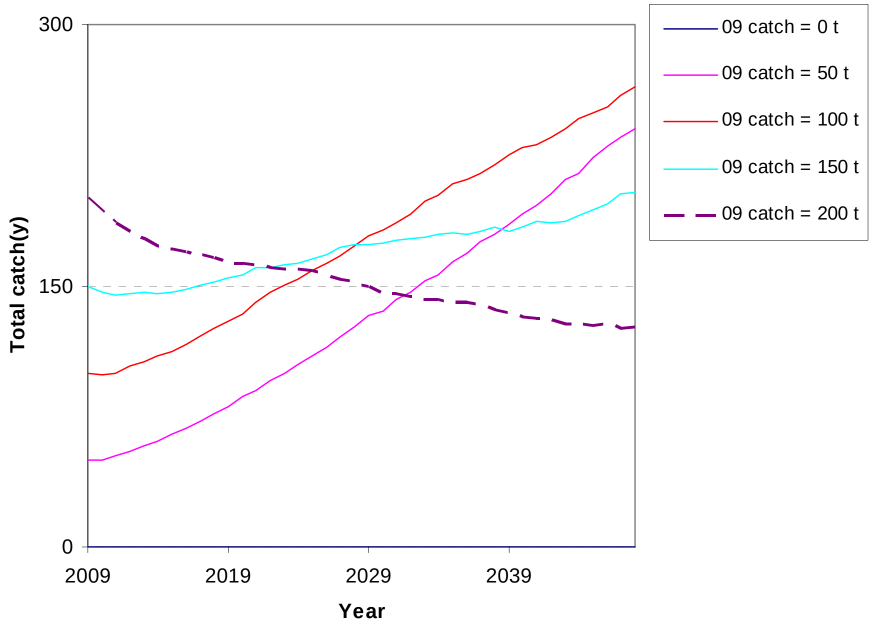

Figure 8. Annual catch of bocaccio under different constant F policies for the reference case.

7. Evaluate residence requirements for the species if any

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].*

Bocaccio tend to be a semi-pelagic ("off-bottom") aggregating species that 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 much broader spatial scale than intended in the above definition.

Love et al. (2002) suggest that large bocaccio are sedentary, and live in caves and crevices. The significant harvests of mature and relatively old individuals by trawl and troll gear indicates they cannot be exclusive cave or crevice-dwelling creatures. Even if some individuals used such locations, it is not readily apparent how existing fisheries or other activities could significantly alter or destroy the locations to the extent that it would represent a significant threat to the population of bocaccio.

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.

In addition to the reference case, Stanley et al. (2009) examined stock status and forecasting under different assumptions of productivity (*r*). A measure of uncertainty in *r* is already included in the informed prior density function constructed from key life history information and productivity assumptions taken from analyses of other rockfish populations. We also examined additional uncertainty in productivity by constructing alternative informed priors for *r* which had arbitrarily lower and higher prior mean values. We believe that these choices bracketed the range of plausible productivity for this population.

As expected, model runs based on the lower productivity prior resulted in more pessimistic estimates of stock status and forecasts (Table 6), with a median 45% probability of exceeding the limit reference point of $0.4B_{msy}$ in 40 years under a constant *F* policy corresponding to a 2009 harvest of 100 t. Conversely, the high productivity scenario resulted in more optimistic estimates, with a median 51% probability of exceeding the limit reference point under a constant *F* policy equivalent to a 2009 harvest of 150 t (Table 8).

Table 5. Status indicators for bocaccio after 5, 20, and 40 years under quota policies with assumption of lower productivity.

Horizon	Policy	$E(B_{fin}/B_{msy})$	$P(B_{fin}>0.4\ B_{msy})$	$P(B_{fin}>0.8B_{msy})$	$P(B_{fin}>B_{cur})$
5 -year	TAC= 0	0.18	0.09	0.02	0.67
	TAC= 50	0.18	0.09	0.01	0.60
	TAC= 100	0.16	0.08	0.01	0.49
	TAC= 150	0.15	0.08	0.01	0.40
	TAC= 200	0.14	0.07	0.01	0.33
	TAC= 250	0.13	0.07	0.01	0.26
20 -year	TAC= 0	0.51	0.42	0.19	0.89
	TAC= 50	0.44	0.36	0.16	0.77
	TAC= 100	0.36	0.30	0.13	0.60
	TAC= 150	0.28	0.22	0.10	0.45
	TAC= 200	0.23	0.17	0.09	0.33
	TAC= 250	0.18	0.14	0.07	0.25
40 -year	TAC= 0	1.06	0.72	0.51	0.96
	TAC= 50	0.87	0.61	0.41	0.83
	TAC= 100	0.67	0.46	0.32	0.63
	TAC= 150	0.49	0.34	0.24	0.45
	TAC= 200	0.35	0.25	0.17	0.31
	TAC= 250	0.26	0.18	0.13	0.23

Table 6. Status indicators for bocaccio after 5, 20, and 40 years under constant F policies with assumption of lower productivity.

Horizon	Policy	$E(B_{fin}/B_{msy})$	$P(B_{fin}>0.4\ B_{msy})$	$P(B_{fin}>0.8B_{msy})$	$P(B_{fin}>B_{cur})$
5 -year	F=F(TAC(icur+1)) 0	0.18	0.11	0.02	0.67
	F=F(TAC(icur+1)) 50	0.18	0.10	0.02	0.60
	F=F(TAC(icur+1)) 100	0.16	0.09	0.02	0.49
	F=F(TAC(icur+1)) 150	0.15	0.09	0.01	0.40
	F=F(TAC(icur+1)) 200	0.14	0.09	0.01	0.33
20 -year	F=F(TAC(icur+1)) 0	0.51	0.46	0.21	0.89
	F=F(TAC(icur+1)) 50	0.40	0.36	0.15	0.78
	F=F(TAC(icur+1)) 100	0.31	0.28	0.11	0.62
	F=F(TAC(icur+1)) 150	0.25	0.21	0.09	0.46
	F=F(TAC(icur+1)) 200	0.20	0.17	0.07	0.35
40 -year	F=F(TAC(icur+1)) 0	1.06	0.77	0.58	0.96
	F=F(TAC(icur+1)) 50	0.71	0.60	0.40	0.86
	F=F(TAC(icur+1)) 100	0.48	0.45	0.26	0.68
	F=F(TAC(icur+1)) 150	0.33	0.33	0.19	0.49
	F=F(TAC(icur+1)) 200	0.24	0.25	0.14	0.34

Table 7. Status indicators for BC bocaccio after 5, 20, and 40 years under quota policies with assumption of higher productivity.

Horizon	Policy	$E(B_{fin}/B_{msy})$	$P(B_{fin}>0.4\ B_{msy})$	$P(B_{fin}>0.8B_{msy})$	$P(B_{fin}>B_{cur})$
5 -year	TAC= 0	0.26	0.19	0.06	0.78
	TAC= 50	0.26	0.18	0.06	0.73
	TAC= 100	0.24	0.17	0.05	0.62
	TAC= 150	0.22	0.15	0.05	0.52
	TAC= 200	0.20	0.14	0.05	0.42
	TAC= 250	0.19	0.13	0.04	0.33
20 -year	TAC= 0	0.88	0.68	0.43	0.97
	TAC= 50	0.78	0.62	0.38	0.90
	TAC= 100	0.64	0.50	0.31	0.75
	TAC= 150	0.53	0.41	0.26	0.60
	TAC= 200	0.42	0.33	0.21	0.46
	TAC= 250	0.34	0.27	0.17	0.34
40 -year	TAC= 0	1.54	0.93	0.78	0.99
	TAC= 50	1.37	0.84	0.70	0.94
	TAC= 100	1.12	0.71	0.59	0.78
	TAC= 150	0.88	0.56	0.47	0.61
	TAC= 200	0.67	0.43	0.35	0.47
	TAC= 250	0.51	0.32	0.27	0.34

Table 8. Status indicators for BC bocaccio after 5, 20, and 40 years under constant F policies with assumption of higher productivity.

Horizon	Policy	E(Bfin/Bmsy)	P(Bfin>0.4 Bmsy)	P(Bfin>0.8Bmsy)	P(Bfin>Bcur)
5 -year	F=F(TAC(icur+1)) 0	0.26	0.19	0.06	0.78
	F=F(TAC(icur+1)) 50	0.26	0.19	0.06	0.73
	F=F(TAC(icur+1)) 100	0.24	0.17	0.06	0.62
	F=F(TAC(icur+1)) 150	0.22	0.16	0.05	0.51
	F=F(TAC(icur+1)) 200	0.21	0.14	0.05	0.42
20 -year	F=F(TAC(icur+1)) 0	0.88	0.71	0.45	0.97
	F=F(TAC(icur+1)) 50	0.69	0.58	0.35	0.91
	F=F(TAC(icur+1)) 100	0.53	0.46	0.26	0.78
	F=F(TAC(icur+1)) 150	0.42	0.38	0.20	0.62
	F=F(TAC(icur+1)) 200	0.33	0.30	0.16	0.48
40 -year	F=F(TAC(icur+1)) 0	1.54	0.95	0.84	0.99
	F=F(TAC(icur+1)) 50	1.11	0.82	0.67	0.96
	F=F(TAC(icur+1)) 100	0.79	0.65	0.49	0.84
	F=F(TAC(icur+1)) 150	0.57	0.51	0.37	0.65
	F=F(TAC(icur+1)) 200	0.42	0.41	0.28	0.50

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

Fishing

Harvests in the commercial groundfish fisheries are assumed to be the major current source of human-induced mortality (Figure 9, see Stanley et al. 2009 for details). Total catch in the 2007/2008 fishing year was 135 t and 17 t in groundfish trawl and HL[3] fisheries, respectively. These catches are incidental while targeting on other species.

All **landings** from the commercial bottom trawl and hook-and-line fisheries are monitored with 100% dockside validation[4]. **At-sea** catch (including discards) in the groundfish trawl fishery (retained and discarded) has been monitored by a 100% coverage at-sea observer program since February 1996. A program that provides 100% at-sea monitoring of all other groundfish sectors (halibut, sablefish, and other commercial groundfish hook and line sectors) was introduced in April 2006. Virtually no sub-market sized juveniles are captured in the commercial or research trawl catches even though they are large enough to be retained by the nets. This probably indicates that the younger stages inhabit shallower or non-trawlable habitats.

Small amounts of bocaccio are possibly caught in First Nations' (FN) and recreational fisheries. While we suggested in Stanley et al. (2009) that these additional amounts are negligible with respect to the overall analysis of current population status, these catches may need to be explicitly considered in the future in the development of a Recovery Strategy. The Recovery Strategy should address the potential for the recreational catches to grow rapidly as 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 the FN and recreational fisheries. It is important to note that verifiable catch

[3] Total catches include 88 t retained and 48 t discarded in the trawl fleet and 4,100 pieces (@4.3 kg) in the HL fleets.

[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.

estimates are not currently available from the FN and recreational fisheries. It should also be noted that fishery-independent research surveys captured approximately 1 t (867 kg) in 2008.

The assessment presented by Stanley et al. (2009) does not include minor catch categories such as FN and recreational. However they are implicitly considered in the stock assessment because the model is fitted to biomass indices that track the effect on the stock of all mortalities, even those that are not quantified. 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. This is because the model projections only include the catch categories that were explicitly modelled (trawl, hook and line, halibut bycatch and salmon troll bycatch).

Catches in U.S. waters from California-Washington may have some impact on the B.C. population of bocaccio; but we have no means of assessing this impact. Observed declines in the U.S. population of bocaccio rockfish have led, in part, to major reductions in trawl effort and the landings of this and other species from the mid-1990s. These actions would also benefit Canadian bocaccio if they were vulnerable to these fisheries. Only the California portion of the US population has been assessed in recent years (MacCall 2003, 2005, 2007). Depending on the model run, current relative depletion is estimated at 10.9-16.3% for the spawning population (MacCall 2007). The assessment indicates some rebuilding since the late 1990s.

Non-fishing sources of mortality

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

Bocaccio are well-known to be particularly “wormy” in comparison with other rockfish. This reputation, which at times has resulted in a lower market value, is largely caused by the high infection rate of the “cod/seal worm” nematode, *Phocanema decipiens*, for which bocaccio is one of the intermediate hosts. Once encysted, the parasite can live for long periods in the fish, and tends to be accumulated over time, causing older fish to carry large numbers of the parasite. The final host is a mammal, usually a seal (Stanley et al. 2001) and it is possible that infection rates may vary inversely with seal abundance. It may also be possible that the natural mortality rate of bocaccio has increased in recent decades due to increased seal populations which have recovered as a result of the implementation of the Marine Mammal Protection Act in the early 1970s.

10. Likelihood that the current quantity and quality of habitat is sufficient

Given that bocaccio appear to be predominantly an off-bottom and aggregating species with areas of highest density (for adults) along the edge of the continental shelf; and that 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.

11. Threats to habitat have reduced habitat quantity and quality

The lack of information on the biology of bocaccio, particularly, for the early life history stages renders it problematic to speculate on habitat issues. 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 long term 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, the quantity of available habitat for bocaccio.

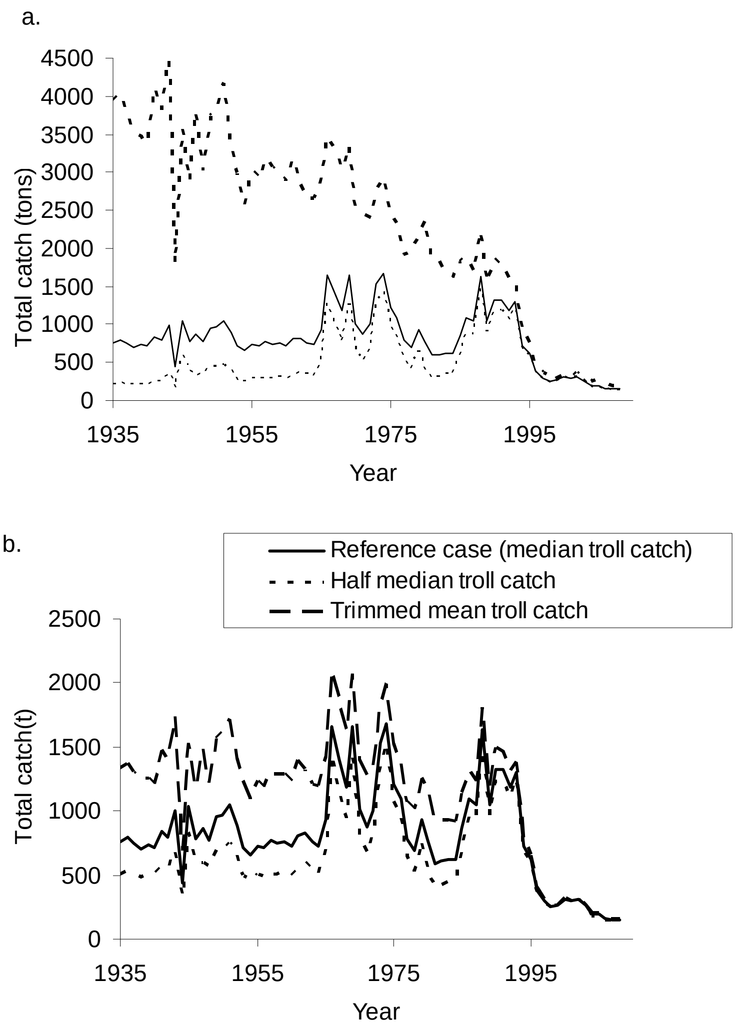

Figure 9. Total bocaccio catch in B.C. waters. a. Reference case median total catch (recorded landings and estimated catches from halibut and troll fisheries combined) with 80% probability intervals; b. Median total catch from the reference case, half median troll catch and trimmed mean troll catch cases.

At a more localized level, it is possible that long term effects of fishing gear (trawl and setline) have had, an impact on bocaccio 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 bocaccio habitat.

Non-fishing coastal development activities in B.C. (for example, aquaculture, and offshore energy development projects) could have negative impacts on bocaccio through habitat perturbation. For example, it is likely that large scale oil-spills would represent a major threat to bocaccio possibly through the impact on the near surface larval and shallower pelagic juvenile habitat.

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.

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

Commercial fishing catch restrictions

Constraining commercial catches appears to be the principal practical means to minimize harm to the B.C. population of bocaccio. These activities are the only known significant source of human-induced mortality. We suggest that the primary means to constrain mortality will be through the management of commercial fisheries, probably by the imposition of catch limits. 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 bocaccio 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 bocaccio to continue fishing other species. Fishers are already aware of most long-term chronic "hot-spots" and other factors which affect catches of bocaccio and they are in constant communication with each other to report instances of where and when bocaccio show up unexpectedly.

If spatial/temporal closures were adopted instead of catch restrictions, then fishers could maintain or exceed current bocaccio catches as they target other species in other areas. Since this species is relatively fast-swimming and semi-pelagic in behaviour, it is presumed to be more wide-ranging than most rockfish. Therefore small area closures such as the current Rockfish Conservation Area (RCA) program are not likely to provide benefit to bocaccio. Altering harvest patterns to reduce to the harvest of mature females might augment the benefits of harvest controls; however, the limited amount of biological sampling to date has not revealed any particular time/space windows where fishing mortality was disproportionately directed at mature females or juveniles.

We suggest that, unless identified by industry during consultation, there is little additional benefit to be gained by adding spatial/temporal effort restrictions to overall catch restrictions. Furthermore, these restrictions may exacerbate the hardship caused by catch reductions by reducing the flexibility of fishers in trying to avoid bocaccio.

13. Inventory of alternatives to the activities that are threats to the species and its habitat

Changes to fishing gear

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 even absent from research trawls that use small-mesh liners. Therefore, trawl mesh size changes (or small fish excluders) will not reduce the already virtually non-existent incidental catch of juvenile bocaccio.

Because adult bocaccio tend to be among the largest of the rockfish captured in bottom trawls, "large-fish" excluders could be considered as a means of reducing incidental catches of bocaccio in bottom trawl catches. However, the relative size differences between bocaccio and other desirable target species are much less than in contexts where fish excluders have been used successfully (e.g., fish excluders in shrimp trawls). Furthermore, bocaccio tend to be smaller than adult female lingcod; thus trawlers would require the capability to switch back and forth between configurations within a trip. 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.

Non-fishery related threat mitigation

As noted above, there are currently no demonstrated non-fishery related threats to bocaccio.

<u>14. Develop and inventory of all reasonable and feasible activities that could increase the productivity or survivorship parameters</u>

We are not aware of any practical means for increasing the productivity of bocaccio. Artificial enhancement has yet to be proven practical in B.C. waters for rockfish species owing to the highly vulnerable larval stages, 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 delayed effects of barotrauma; releasing these dead fish would provide no obvious benefits. Under experimental field conditions, the survival rate 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 (Starr et al. 2001). However, employing these techniques in routine trawling and HL operations would be problematic and, more importantly, bocaccio appear to exhibit the more dramatic symptoms of barotrauma after capture (extended bellies and morbidity) than other species and therefore appear to be among the poorest candidates for this technique.

<u>15. Estimate, to the extent possible, the reduction in mortality rate expected by each of the mitigation measures and the increase in productivity or survivorship associated with each measure above.</u>

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 annual catches for the commercial groundfish industry are shown in Table 3, Table 6 and Table 8.

<u>16. Project expected population trajectory (and uncertainties) over three generations (or other biologically reasonable time), and the time required to reach recovery targets over targeted time frame.</u>

Table 3 to Table 8 provide population projections under different constant harvest and constant *F* policies for the reference case and higher and lower productivity sensitivities. Projections are limited to 40 years, which is about two generations. The uncertainty around the forecasts over three generation projections (60 years) render them too uninformative and speculative. Recovery targets are drawn from DFO policy (DFO 2006). Probabilities of reaching the targets are also shown in the decision table.

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.

We recommend that the reference case projections (Table 3 and Table 4), which are based on the best estimates of the underlying stock productivity, should be used to guide recovery planning. The actual recovery targets (relative biomass, time frame and the likelihood of reaching the biomass target in the timeframe) will be developed through the consultation phase of developing the Recovery Strategy. The decision tables capture the trade-off between the various target options.

CONCLUSIONS

An assessment of B.C. bocaccio was conducted using a Bayesian surplus production model that was fitted to six fishery-independent surveys, commercial bottom trawl CPUE and a catch reconstruction back to the 1930s. The mean and median estimates of 2008 biomass for the reference run are estimated to be 3,022 t and 2,324 t respectively, with large uncertainty. The posterior mean and median estimates of current stock status relative to B_{MSY} (B_{08}/B_{MSY}) for the reference run are 0.155 and 0.111 respectively. The population of bocaccio in B.C., based on the reference run, is likely to be in the critical zone according to the DFO PA, with the upper 90% bound of B_{08}/B_{MSY} lying with the critical zone. Stock biomass has shown a progressive decline since the 1930s, with the steepest decline occurring between 1985 and 1995.

Harvests in the commercial groundfish fisheries are assumed to be the major current source of human-induced mortality. Total catch in the 2007/2008 fishing year was 135 t and 17 t in groundfish trawl and HL fisheries, respectively. These catches are incidental while targeting on other species. 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 First Nations and recreational fisheries are unknown but probably very small at present.

The quantity of physical habitat does not appear to be limiting bocaccio abundance. Current or future coastal activities such as aquaculture, oil and gas exploration, as well as the impacts of climate change, have the potential to affect bocaccio abundance, particularly through impacts on the larval and early juvenile stages. However, there is no evidence available to predict the degree or likelihood of these impacts. There is no information available to suggest that bocaccio have residence requirements, as defined in SARA.

Restricting commercial catches appears to be the most practical means at present to minimize harm to bocaccio in B.C. waters. The means for implementing catch restrictions should be developed in consultation with industry. It is possible that harvests in U.S. waters may have an impact on abundance of bocaccio in B.C. waters. But the degree of overlap between these populations is unknown. 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 populations, it may be beneficial in the future to work towards a harmonized approach in the management of this species.

Population forecasts are provided under constant quota and constant exploitation rate policies (constant *F*). The results for the constant quota policy indicate, for example, that while 0 harvest will lead to an 84% chance of the population exceeding the limit reference point ($0.4B_{MSY}$) in 40 years, harvests of 150 t/y provide only a 47% probability of meeting this target**.** In addition to a reference case, forecasts are provided for both lower and higher productivity scenarios**.** The actual targets for biomass, timeframes and desired probability for reaching the targets, will be determined during Recovery Strategy consultation.

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 and the true uncertainty is even greater. Forecasting adds even more uncertainty. These projections assume the population will respond to the future environment as it did in the past, a strong assumption which may not hold due to 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 if current commercial groundfish catches of about 150 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 in this document suggest that a reduction in harvest from current levels is required to significantly increase the probability of a population increase

Future development of recovery potential advice for bocaccio rockfish should include a simulation study to determine the adequacy of different harvest control rules given, among other unknowns, the combined impact of an uncertain stock assessment and imprecise future information from the survey indices.

SOURCES OF INFORMATION

DFO, 2006. A harvest strategy compliant with a precautionary approach. Can. Sci. Advis. Sec. Sci. Adv. Rep. 2006/023.

DFO, 2007. Revised protocol for conducting recovery potential assessments. Can. Sci. Advis. Sec. Adv. Rep. 2007/039.

DFO, 2008. Proceedings of the PSARC Groundfish Subcommittee Meeting, November 21, 2007. Can. Sci. Advis. Sec. Proc. Ser. 2007/052.

DFO, 2008. Draft. Fisheries Stewardship and Sustainability Checklist 2008/09.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast Fishes of North America. Houghton Mifflin, Boston. 336 p.

Gillespie, G. E., R. D. Stanley, and B. M. Leaman. 1993. Cruise details and biological information from the juvenile rockfish surveys aboard the RV. W.E. Ricker, May 13-25, 1991, and the F/V Island Sun, June 3-11, 1991. Canadian Data Report of Fisheries and Aquatic Sciences 920.

Hartmann, A.R. 1987. Movement of scorpionfishes (Scorpaenidae: *Sebastes* and *Scorpaena*) in the southern California Bight. California Fish and Game Bulletin 73(2): 68-79.

Love, M.S., P. Morris, M. McCrae and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the southern California Bight. NOAA Technical Report NMFS 87: 38 p.

Love et al. Love, M.S., M. Yoklavich, and L. Thorsteinson. 2002. The Rockfishes of the Northeast Pacific. University of California Press. 405 pp.

MacCall, A.D. 2003. Status of bocaccio off California in 2003. *http://www.pcouncil.org/groundfish/gfsafe0803/bocaccio.pdf*

MacCall, A.D. 2005. Status of bocaccio off California in 2005. *http://www.pcouncil.org/groundfish/gfsafe0406/bocaccio2005final.pdf*

MacCall, A.D. 2007. Bocaccio rebuilding analysis for 2007. Draft document obtained from the author: *Alec.MacCall@NOAA.gov*.

MacCall, A.D., S. Ralston, D. Pearson, and E. Williams. 1999. Status of bocaccio off California in 1999 and outlook for the next millennium. Appendix to Status of the Pacific Coast Groundfish fishery through 1999 and recommended acceptable biological catches for 2000. Pacific Fisheries Management Council. Oregon, U.S.A. *http://www.pcouncil.org*

Moser, H.G. 1967. Reproduction and development of *Sebastodes paucispinis* and comparison with other rockfishes off southern California. Copeia 1967: 773-797.

Rutherford, K. Rutherford, K.L. 1999. A brief history of GFCATCH (1954-1995), the groundfish catch and effort database at the Pacific Biological Station. Can. Tech. Rep. Fish. Aquat. Sci. 2299.

Stanley, R.D., K. Rutherford, and N. Olsen. 2001. Preliminary status report on bocaccio (*Sebastes paucispinis*). Can. Sci. Adv. Sec. res. Doc. 2001/148.

Stanley, R.D., M. McAllister, P. Starr, and N. Olsen. 2009. Stock assessment for bocaccio (*Sebastes paucispinis*) in British Columbia waters. Can. Sci. Advis. Sec. Res. Doc. 2009/055.

Starr, R.M., J.N. Heine, J.M. Felton, and G.M. Cailliet. 2002. Movements of bocaccio (*Sebastes paucispinis*) and greenspotted (*S. chlorostictus*) rockfishes in a Monterey submarine canyon: implications for the design of marine reserves. Fish. Bull. 100 (2): 324-337.

Westrheim, S.J. 1975. Reproduction, maturation, and identification of larvae of some *Sebastes* (Scorpaenidae) species in the northeast Pacific Ocean. J. Fish. Res. Board Can. 32: 2399-2411.

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